Circular Economy and Sustainability

Giovanni Lagioia · Annarita Paiano · Vera Amicarelli · Teodoro Gallucci · Carlo Ingrao *Editors*

Innovation, Quality and Sustainability for a Resilient Circular Economy

The Role of Commodity Science, Volume 1

Springer

Circular Economy and Sustainability

This book series aims at exploring the rising field of Circular Economy (CE) which is rapidly gaining interest and merit from scholars, decision makers and practitioners as the global economic model to decouple economic growth and development from the consumption of finite natural resources. This field suggests that global sustainability can be achieved by adopting a set of CE principles and strategies such as design out waste, systems thinking, adoption of nature-based approaches, shift to renewable energy and materials, reclaim, retain, and restore the health of ecosystems, return recovered biological resources to the biosphere, remanufacture products or components, among others.

However, the increasing complexity of sustainability challenges has made traditional engineering, business models, economics and existing social approaches unable to successfully adopt such principles and strategies. In fact, the CE field is often viewed as a simple evolution of the concept of sustainability or as a revisiting of an old discussion on recycling and reuse of waste materials. However, a modern perception of CE at different levels (micro, meso, and macro) indicates that CE is rather a systemic tool to achieve sustainability and a new eco-effective approach of returning and maintaining waste in the production processes by closing the loop of materials. In this frame, CE and sustainability can be seen as a multidimensional concept based on a variety of scientific disciplines (e.g., engineering, economics, environmental sciences, social sciences). Nevertheless, the interconnections and synergies among the scientific disciplines have been rarely investigated in depth.

One significant goal of the book series is to study and highlight the growing theoretical links of CE and sustainability at different scales and levels, to investigate the synergies between the two concepts and to analyze and present its realization through strategies, policies, business models, entrepreneurship, financial instruments and technologies. Thus, the book series provides a new platform for CE and sustainability research and case studies and relevant scientific discussion towards new system-wide solutions.

Specific topics that fall within the scope of the series include, but are not limited to, studies that investigate the systemic, integrated approach of CE and sustainability across different levels and its expression and realization in different disciplines and fields such as business models, economics, consumer services and behaviour, the Internet of Things, product design, sustainable consumption & production, bio-economy, environmental accounting, industrial ecology, industrial symbiosis, resource recovery, ecosystem services, circular water economy, circular cities, nature-based solutions, waste management, renewable energy, circular materials, life cycle assessment, strong sustainability, and environmental education, among others.

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Editors
Giovanni Lagioia
Department of Economics,
Management and Business Law
University of Bari Aldo Moro
Bari, Italy

Annarita Paiano
Department of Economics,
Management and Business Law
University of Bari Aldo Moro
Bari, Italy

Vera Amicarelli
Department of Economics,
Management and Business Law
University of Bari Aldo Moro
Bari, Italy

Teodoro Gallucci
Department of Economics,
Management and Business Law
University of Bari Aldo Moro
Bari, Italy

Carlo Ingrao
Department of Economics,
Management and Business Law
University of Bari Aldo Moro
Bari, Italy

National Congress of Commodity Science
AISME 2022
Bari, Italy
2022/10/27
2022/10/28
https://www.aisme2022.it

ISSN 2731-5509 ISSN 2731-5517 (electronic)
Circular Economy and Sustainability
ISBN 978-3-031-28291-1 ISBN 978-3-031-28292-8 (eBook)
https://doi.org/10.1007/978-3-031-28292-8

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Foreword

The weaknesses of the current economic, social, and environmental scenario, together with the impact of the COVID-19 pandemic that the humankind has faced, are increasingly stimulating an in-depth reflection on the organizational models that today's society is based upon. Those are mainly related to consumers' behaviors, and to the productive models of businesses and organizations, as well as to the functioning of national and supranational socio-political systems.

Therefore, in the process of restoring stability, it is desirable that any form of circular economy (CE) system derives from the implementation of the relevant issues of sustainability, innovation, and quality not only on the scale of production but also on that of use/consumption and disposal. Here comes the Life Cycle Thinking (LCT) perspective that is based upon designing not just products, but also products' life cycles that comply with the goals and targets of sustainable development. Doing so will make it possible to satisfy CE principles and loops, and so extend products' life cycles, and close resource loops through recycling processes. This is a huge challenge that should follow an approach based on exchanging and sharing knowledge, thereby going beyond the multidisciplinary and transversal approach that has always been a classic in commodity science. The latter is aimed at collecting the homogeneous and unitary body of research fields that revolve around the production of material, food, and energy commodities. This includes the study, analysis, and evaluation of both resources and technologies used for their extraction and transformation. It is also expanded to the assessment of the consequent implications on the total quality and use value of the goods and on the external environment with which they interact, including the environmental management and certification systems.

Commodity science can play multiple relevant roles in this regard, as it is highly attached to innovation, eco-design, quality, circular economy, industrial ecology, and sustainability. All of those relevant issues and related complex problems involve a holistic system approach, regulatory aspects, and empirical knowledge, and demand the active participation of all stakeholders involved in the commodity's life cycle, including designers, technicians, practitioners, producers, company managers, and retailers. Therefore, it is recommended that the making of public decisions for promotion of aforementioned issues is supported and informed by scientifically sound quantitative information so as to discern values from facts and to help a fair attribution of responsibility along the entire supply chain and life cycle. Under this perspective, the XXX National Congress of Commodity Science can play multiple key roles, as it created a valuable platform to share and build upon knowledge and skills in a way to strengthen the already existing links among the key actors of the world of academia and research, industry, and politics discussion and study.

Viterbo, Italy Alessandro Ruggieri

Preface

The XXX National Congress of Commodity Science was held in Bari (Italy) on 27th and 28th October 2022; it was promoted by the Italian Academy of Commodity Science (AISME) and was hosted by the Department of Economics, Management and Business Law of University of Bari Aldo Moro. Its aim was to explore the relevant quality, innovation, circularity, and sustainability issues, in an integrated and multidisciplinary approach.

The Congress collected a total of 113 contributions, which can be considered as the sign of the relevance and importance of the research themes it was conceived to address.

The Congress hosted an opening session for institutional greetings, followed by a keynote speech on sustainable innovative energy production systems and an oral section conceived to an overview of the key findings from poster-presented research. In particular, the contributions received were assigned as 21 oral presentations and 92 posters. The congress was then structured into three plenary sections (each per thematic area), chaired by spokes-professors of the Academy, to host the aforementioned oral presentations. The latter were selected in a way to:

– Make sure that the Congress could provide sector operators with methodological tools enabling understanding of the current evolutionary dynamics, particularly in innovations and quality analysis and management
– Contribute to developing new growth models and paradigms towards paths for sustainable development strategies on the micro- and macro-dimension scale in the medium-term time horizon

This year's edition of the Congress was the thirty-first, with the first being held in the early 1960s in Bari,[1] which contributes to making it an event of undoubted historical significance. In Appendix 1, the reader will find all the congress events that have been organised since then. In all of this, it must be said that the commodity

[1] "Convegno sul tema: Progresso tecnologico e miglioramento della qualità", Bari, 12–13 settembre 1962. Atti in: Quaderni di Merceologia (Bari), 1, 1, Bari, Editore Cressati.

science school of Bari is undoubtedly one of the oldest and most prestigious in Italy; it all dates back to the School of Advanced Studies of Commerce that, when founded in 1886, was the fourth in Europe. Over the course of its history spanning more than one hundred and thirty years, that school has contributed to advancing research both on the national and international level. This has been documented by a historical library with volumes dating back to the second half of the 1800s, and a commodity science museum that contains vintage equipment and materials that were used and tested for original research development.

The Congress represented a platform for the exchange of knowledge and skills in all those research development fields which commodity science has always interfaced with, giving its important contributions, including material science, energy, agriculture, engineering, business management, quality management, innovations and social equity. To that end, researchers, practitioners, managers, producers and other stakeholders were positively involved in the Congress. In particular, the Congress managed to trigger a constructive dialogue with the territory and with economic, industrial and political stakeholders on environmental, economic and social issues related to natural resource exploitation and environmental pollution. In doing so, particular attention was paid to the aspects of innovation, quality and sustainability that were assessed by congress participants, with a holistic system perspective, through application of internationally recognised scientifically based methodologies capable of implementing sustainable aims and improving the economic-environmental performances of economic activities, including Material Flow Analysis, Life Cycle Assessment (LCA) and the multi-indicator environmental footprint accounting. This will contribute to the upswing and resilience of companies and societies, despite the undeniable difficulties deriving from the pandemic, the current geopolitical upheavals and the consequent international economic crisis.

An adequate and timely transition towards a green economy could represent an important opportunity for local territories to improve their levels of quality, sustainability and competitiveness in the medium and long term. This puts emphasis on the need for economic operators to comply with the obligations required by the reference legislation in the context of transitioning to sustainable circular forms of the economy; doing so will allow them to assess the possible future implications on their business activities. This can be relevant and useful for all public and private organisations operating in various economic sectors. Furthermore, dissemination of results from the Congress can represent an important knowledge-enhancement opportunity for all those entrepreneurs and producers who intend to undertake initiatives with reduced environmental and socioeconomic impact.

In the light of this, economic operators (i.e., managers, entrepreneurship, business associations, public decision makers) and students were invited to take active part in the Congress for a profitable and mutual exchange of information on the Congress research themes. Furthermore, several business companies have supported this event; their names have been highlighted in a dedicated section in the continuation of the book.

In this context, it is worth highlighting that the Congress objectives and targets fully reflect the purpose recognised by the AISME founders of advancing and promoting commodity science development in the field of scientific and applied research and enhancing the knowledge of the whole commodity science subject and related key features, especially in the sector of public institutions. In doing so, the contributions of commodity scientists will be made increasingly available to producers and consumers as well as to the society as a whole. This can play an essential role in the implementation of technological innovation solutions for creation of production and consumption models that are urgently needed to move towards a society that respects the principles and objectives of sustainable development.

Thanks to the remarkable number of contributions and the numerous opportunities created for debating and sharing ideas, the Congress managed to address key environmental and socioeconomic issues. These can encourage good practices for implementation of circular economy models to best combine profitability with sustainable environmental management and quality of commodities.

The 113 conference papers went through a double-blind review and were put together to form this book titled *Innovation, Quality and Sustainability for a Resilient Circular Economy: The Role of Commodity Science* that is published by Springer Nature as part of the Circular Economy and Sustainability series. Considering the number of papers included and the resulting length of the book, the latter was split into Volume 1 and Volume 2, both comprising papers dealing with the most relevant and up-to-date issues of innovation, quality and sustainability in a wide range of sectors.

Under this perspective, Volume 1 explores the sectors of agriculture, biomass, foods and beverages, consumers' awareness and behaviours, digitalisation and tourism.

Volume 2, instead, investigates the waste management sector and several others related to energy, materials and transports. In addition to this, Volume 2 reviews and builds upon the general important aspects of quality, circular economy and sustainability.

Though it came to a national congress, there has been papers being contributed by authors' teams coming from European countries like Poland and Spain. Such puts emphasis upon the attention and interest that research themes like those addressed by the congress spark on the international level. Furthermore, scanning through the 113 papers, the book editors could see that research development was often taken as the occasion to strengthen ongoing collaborations both at the national and international level, and create new ones.

The collected papers explored the three themes the Congress was centred upon in a multitude of sectors. In this regard, from Fig. 1 there is evidence that "Agriculture, biomass, foods and beverages" was the most investigated one with a total of 37 papers, followed by waste management and a miscellaneous of general facts, with 14 papers each either way. Whereas, as evident from Fig. 2, the majority of the conference papers (61%) investigated circular economy and sustainability-related issues.

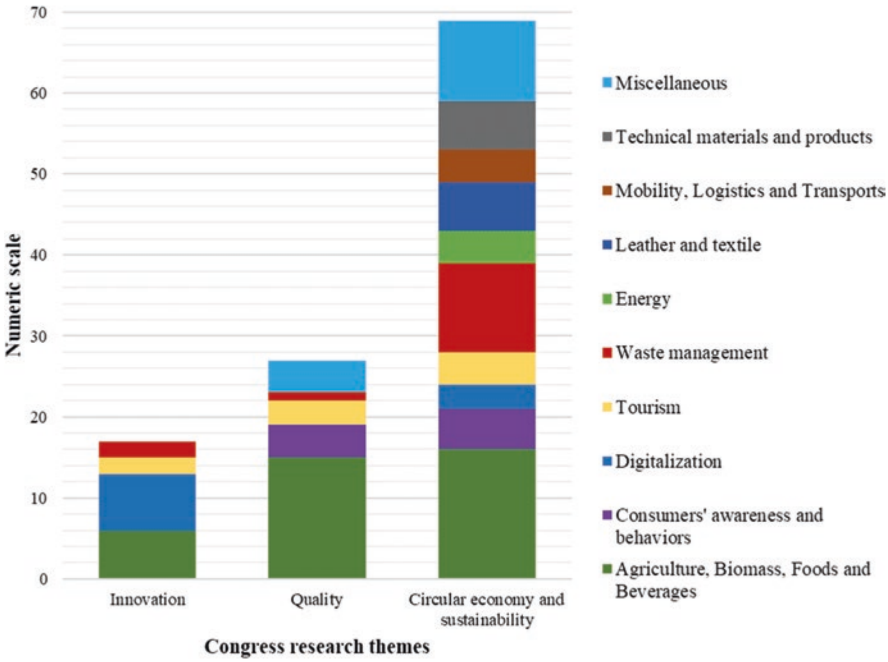

Fig. 1 Number of conference papers per thematic research area and investigated sector

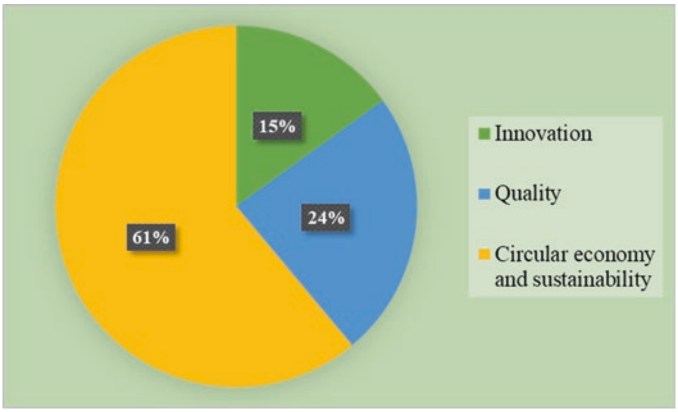

Fig. 2 Percentage distribution of the collected conference papers based upon the thematic area they have addressed

Based upon the number and quality of the contributions, it can be asserted that the Congress attained its main objectives of updating, advancing and promoting interdisciplinary research on innovation, quality, circular economy and sustainability.

The 113-paper collection is expected to make it possible for the Congress to advance knowledge on the subjects of quality of commodities and of ecological transition, with particular attention to the innovations and to the environmental and socioeconomic implications on the production, use and consumption of material and energy commodities that are currently available on the market.

Finally, findings contained in this volume will contribute to guiding public and private decision makers in the identification process of the most appropriate methods and timing in the processes of innovation for commodities' quality enhancement and of transition to a sustainable equitable efficient economy and providing economic operators with in-depth knowledge to deal more effectively and efficiently with the related implications and opportunities.

Bari, Italy

Giovanni Lagioia
Annarita Paiano
Vera Amicarelli
Teodoro Gallucci
Carlo Ingrao

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Acknowledgements

We would like to deeply thank the sponsors for their support to the Congress. It was a real fortune for us to be able to bank upon your generous donors, which contributed to making the Congress possible.

Thanks for supporting us to create a platform for the exchange of knowledge on the relevant issues of innovation, quality, and sustainability, and on the measures to take to accelerate the transition to a sustainable, equitable, circular, post-fossil carbon society.

The Congress was just the beginning of a new joint collaboration journey, as we would be honoured to have the opportunity to work closely with your business in the future!

With gratitude

The Editors

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Part I
Agriculture, Biomass, Foods and Beverages: Innovation

Chapter 1
Key Factors of Digital Agriculture in Competitiveness, Sustainability, and Safety Areas

Francesco Pacchera, Chiara Cagnetti, Mariagrazia Provenzano, Stefano Poponi, and Alessandro Ruggieri

Abstract Digital transformation (DT) is progressively changing the paradigm of agricultural enterprises. The adoption of new digital technologies such as the Internet of Things (IoT), machine learning, cloud, artificial intelligence, and big data aims, at the first moment, to increase productivity and product quality and reduce environmental impacts. Several studies investigate the characteristics and applications of digital technologies in agriculture. However, there are still few works that link economic, safety, and environmental impacts to these drivers of development. Therefore, through a critical review of the literature, this chapter aims to identify factors acting in competitiveness, sustainability, and safety. The articles identified from the literature were selected through a review process using the Scopus database. The search through the keywords "digital agriculture," "high-tech farming," "sustainability," "competitiveness," "economic," and "traceability and safety" returned 128 articles. The results made it possible to identify key factors and describe their influence on the reference areas.

Keywords Digital agriculture · High-tech farming · Sustainability · Safety · Competitiveness

1.1 Introduction

The digital transformation (DT) process progressively increases productivity and improves value creation opportunities along production chains. This transformation has contributed to improving techniques of production and productivity (Dinelli

F. Pacchera (✉) · C. Cagnetti · M. Provenzano · S. Poponi · A. Ruggieri
Department of Economics, Engineering, Society and Business Organization (DEIM), University of Tuscia, Viterbo, Italy
e-mail: francesco.pacchera@unitus.it; chiara.cagnetti@unitus.it; mariagrazia.provenz@unitus.it; poponi@unitus.it; ruggieri@unitus.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_1

et al. 2022) and generating benefits and risks in agricultural enterprises (Xie et al. 2021). It modifies how farmers work, creating social, economic, and environmental impacts (Lioutas et al. 2021). Adopting progressive digital technologies such as big data, robotics, the Internet of Things, or sensors in the production system is trying to improve and make production and livestock more efficient (Birner et al. 2021). Many studies investigate digital technologies' DT and their relative application in agricultural enterprises (Amentae and Gebresenbet 2021). Nevertheless, no studies in the literature systematize the impact of digital agriculture on sustainability, security, and competitiveness.

This chapter aims to identify key factors in digital agriculture in competitiveness, sustainability, and safety. In this regard, the study's research question is the following: How do the key factors of digital agriculture affect the areas of sustainability, competitiveness, and security?

1.2 Methodology

A literature review was conducted using the specific methodology provided by Watson (2002) to answer the research question. The database used to research literature is Scopus, including scientific publications until March 2022. The query used for research is ALL ("digital agriculture" OR "high-tech farming") AND ALL ("sustainability") AND ALL ("competitiveness" OR "economic") AND ALL ("traceability" OR "safety"). The query returned 128 articles, extracted, and organized in an Excel database. The authors selected the papers. A first analysis of the title and abstract allowed for the selection of 49 preliminary articles. An in-depth analysis of the full text made it possible for the authors to identify a total of 37 papers used for this research literature. By doing so, the authors themselves could create a conceptual matrix to summarize the articles identified by the review process. The authors classified items according to the three areas (competitiveness, sustainability, and safety) proposed by Poponi et al. (2022).

1.3 Results and Discussion

The concept of digital agriculture is clearly defined in the literature (Duncan et al. 2022). Bahn et al. (2021) highlighted the benefits of digital agriculture, improving production performance and making agricultural enterprises more efficient and inclusive. Alongside these advantages, the benefits of impact generated in competitiveness, sustainability, and traceability are still uncertain, as outlined in Fig. 1.1. The latter identifies, in fact, for each area, the factors that characterize them.

The factors are derived from a detailed analysis of the literature. The figure identifies those characterizing the study, showing the presence of cross-sectional factors

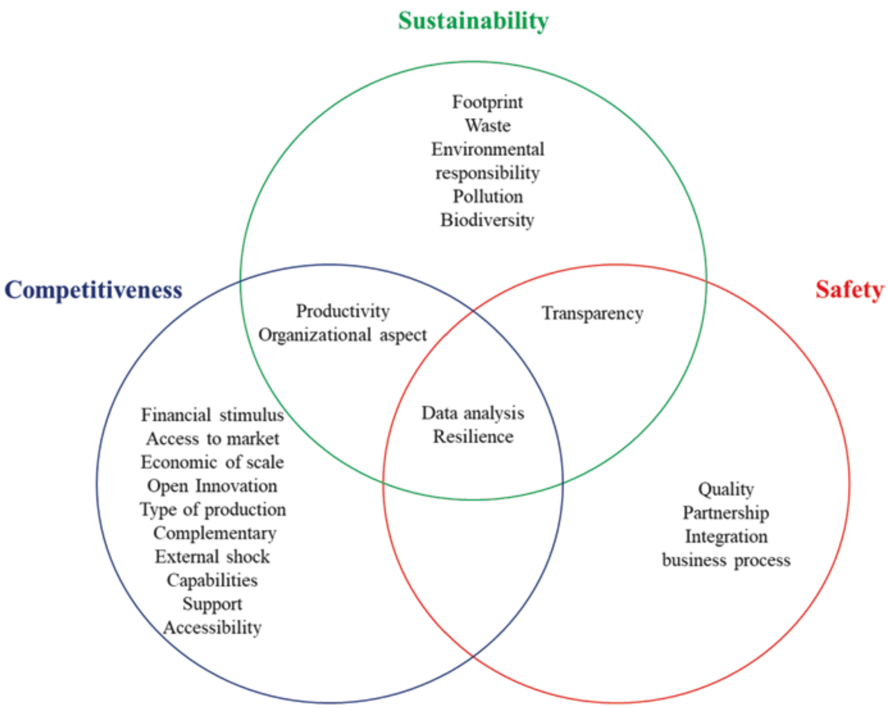

Fig. 1.1 Areas and key factors

(as proposed by Poponi et al. 2022): resilience and data analysis. Each of the three areas of the figure and related findings was addressed in the following subsections.

1.3.1 Competitiveness Area

The competitiveness area includes all factors that impact agricultural enterprises economically. The analysis of the factors identified shows that the use of digital technologies makes it possible to increase profits and improve the quality of production and yields (Bahn et al. 2021; Da Silveira et al. 2021; Friha et al. 2021; Gangwar et al. 2020; Lioutas et al. 2021; Scuderi et al. 2022).

Digital technologies and resource sharing help to improve firm competitiveness (Amentae and Gebresenbet 2021) but, by stimulating digitization in firms, require targeted policies for purchasing and developing facilities, as well as increased training and education of human capital (Bahn et al. 2021; Duncan et al. 2022; Scuderi et al. 2022).

For Da Silveira et al. (2021), companies need to use investments to adopt digital technologies, considering possible limitations. Farmers' adoption of digital technologies is negatively affected by external shocks (such as regulations and industry policies) that create instability (Tan et al. 2021). Many farms find it difficult to adopt digital tools due to a lack of capacity to use such technologies. The complexity of managing and using digital tools leads companies to seek external support. The need to consult experts to support these new technologies is seen as a cost with a negative economic impact rather than an opportunity to increase business performance (Neethirajan and Kemp 2021; Rijswijk et al. 2021). The adoption of digital technologies has a positive economic impact on the resilience of the firm and its production system (Rijswijk et al. 2021). Resilience shows that digital technologies need to be integrated efficiently into firms to avoid the creation of resilient ecosystems (Galaz et al. 2021). Data analytics and economies of scale promote the use of digital technologies on farms. The ability to generate economies of scale in the mechanization and digitization of a production process reduces costs and facilitates the adoption of new technologies for agricultural enterprises. However, economies of scale depend on the size of the farm, its management, and the type of products (Birner et al. 2021).

1.3.2 Sustainability Area

The sustainability area includes all factors that have an impact on the environment. The use of digital technologies reduces input use and enables the creation of a more sustainable and efficient food system (Duff et al. 2022; Jambrak et al. 2021; Remondino and Zanin 2022; Scuderi et al. 2022). Shared data analysis factors and a monitoring system enable increased productivity of the production system (Amentae and Gebresenbet 2021; Bhat and Huang 2021; Da Silveira et al. 2021; Duncan et al. 2022; Garske et al. 2021; Khan et al. 2021; Neethirajan and Kemp 2021; Schnebelin et al. 2021). Digital technologies enable practical and scalable solutions for natural resource conservation (Bhat and Huang 2021), which can increase agrosystems' ecological and economic resilience (Duff et al. 2022; Ozsahin and Ozdes 2022). Several authors (see for e.g. Bahn et al. 2021; Friha et al. 2021) highlight the potential arising from digital technologies to reduce resource use and the ecological footprint, increase biodiversity, and enhance productivity. At the same time, they may generate future threats to sustainability, resource availability, and food security (Lioutas et al. 2021).

1.3.3 Safety Area

The last area identified is safety, which includes agricultural enterprises' traceability and food safety. Digital technologies ensure product traceability by making all information available and offering quality products (Bahn et al. 2021; Finger et al. 2019; Friha et al. 2021; Galaz et al. 2021; Neethirajan and Kemp 2021). Oruma et al. (2021) point out that using digital technologies in agricultural production is a viable option for achieving food security in a country. According to Reisman (2021), data analytics and security are ensured by platforms designed to record, store, and process data on agricultural products at every stage of the relationship between farms and retailers. Furthermore, greater security is achieved by involving all actors in the supply chain (Adamashvili et al. 2021; Collart and Canales 2022). Fundamental is the integration of business processes, where according to Collart and Canales (2022), digital technologies are integrated into the most suitable production processes, depending on the desired results.

1.4 Conclusions and Future Perspectives

Through a critical literature review, the study aims to identify the key factors acting on the economic, security, and sustainability areas in adopting digital tools. The identified factors have different influences in the adoption of digital technologies. Some of them are enabling factors. Others limit the adoption of these technologies by agricultural enterprises. Some factors such as resilience and data analysis can influence all three areas investigated, and for this reason they are defined as cross-sectional. The future research will combine these key factors to create a model to explain their impact on the agricultural enterprises.

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Chapter 2
Precision Agriculture Technologies in the Italian Agricultural Context: A Study on the Rate of Knowledge and Diffusion Among Italian Farmers

Andrea Apicella and Angela Tarabella

Abstract The agriculture of our century is undergoing rapid and continuous changes. The new needs appear to be the improvement of agricultural yield to meet future food needs and the framing of agricultural management with a view to environmental sustainability. In this context, the precision agriculture (PA) paradigm turns out to be decisive in meeting the aforementioned needs. This work aims to identify the awareness rate and adoption drivers of PA among Italian farmers. The research methodology is based on an online survey of a sample of 755 farmers (N = 755) in a period between July and November 2020. A regression analysis was subsequently carried out on the data collected. The results showed that Italian farmers do not have all the information necessary for the development of PA techniques (informed farmers: n = 366; 48.48%), with a diffusion rate of approximately 20% (adopting farmers: n = 155; 20.4%). Considering the research results, it seems necessary to undertake training development paths so that farmers can adequately adopt technologies with an orientation toward sustainability. The present research represents the starting point for future studies aimed at investigating the reason why so many differences emerge in the rate of knowledge and in the models of technological adoption.

Keywords Precision agriculture · Industry 4.0 · Adoption drivers · Sustainability

A. Apicella (✉) · A. Tarabella
Department of Economics and Management, University of Pisa, Pisa, Italy
e-mail: andrea.apicella@unipi.it; angela.tarabella@unipi.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_2

2.1 Introduction

The adoption and development of new technologies have always been among the factors of great interest and have shaped all the most modern agricultural production systems. The mechanization of the various agricultural processes, developed mainly in the last 200 years, has led to work that is far less tiring for humans, with great results in terms of productivity for almost all agricultural crops (Binswanger 1986). The new paradigms of technological implementation in the industry have made Industry 4.0 (a trend of industrial automation that integrates new technologies) pervasive in all sectors: in the agricultural sector, it is identified as "precision agriculture" (PA). In 2019, the International Society of Precision Agriculture (ISPA) adopted a definition that frames the PA as a management tool interconnected with the most modern frontiers of technology, defining it as "*a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines them with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production*."

2.2 Precision Agriculture Diffusion

The growing trend of PA adoption has attracted the attention of academic research (Trivelli et al. 2019) and is an increasingly common paradigm among farmers (Tey and Brindal 2022). Among others, the spread of modern agricultural techniques can be reflected in the evaluation of the PA market. Europe appears to be a relevant context for investigating the adoption and diffusion of modern PA techniques. The Italian PA market is continuously growing; its value reached 450 million euros in 2019, with an increase of 22% compared to 2018 (Osservatorio Smart Agrifood 2020). Although there are no official data on the rate of adoption of PA technologies in Italy, it has been observed that technological innovations spread slowly among Italian farmers (Long et al. 2016), partially in line with their European colleagues (Lowenberg-DeBoer and Erickson 2019).

2.3 Objective and Method

The general objective of this research is to investigate the rates of awareness and adoption of the PA by Italian farmers. In this regard, an online survey was carried out using the snowball sampling method among the largest number of reachable farmers and involving the main Italian trade associations (Confagricoltura, Coldiretti, Confederazione Italiana Agricoltori). For the drafting of the questionnaire, a survey based on mostly closed questions was developed. The questionnaire setup followed general scientific standards for online questionnaires as suggested by Hooker and Zúñiga (2017). Snowball sampling was chosen, considering the large number of Italian farmers and their reluctance to release information (Wayman et al. 2019). The main objective of the survey is to identify the Italian PA adoption models to focus on the major innovation drivers and on the general prerequisites useful to improve knowledge, adoption rate, and future trends.

2.4 Data Collection

The data were collected from the end of July 2020 to the beginning of November of the same year. The online questionnaire was spread through the Google Form platform; its link was initially sent to the regional and provincial sections of the main Italian farmers associations and subsequently distributed via social networks (Facebook groups specifically committed to agriculture) and then directly to farmers. Overall, data from 755 farmers were collected through the questionnaire and used in the analysis. The data were analyzed using the SPSS Statistics 27 software package based on the conceptual framework of factors potentially influencing the adoption of PA. The questionnaire was built in blocks with key questions; in any case, the respondents had access to two minimum blocks of questions with a maximum of five, including blocks regarding knowledge, adoption, willingness to invest, summary, and sociodemographic questions.

2.5 Results and Discussion

Although the total number of interviewees is 755, different groups have different distributions. There are 389 uninformed farmers, those who are unfamiliar with PA, and 366 farmers who claim to know it. Of the latter, 154 companies use at least one of the techniques. On the other hand, 211 respondents had knowledge of PA techniques but did not use any of them.

2.5.1 Regression Analysis on Knowledge of PA

To test whether the likelihood of knowing about PA was predicted by the selected variables, a logistic binary regression with the enter method was performed. All the independent variables were recoded as dummies as indicated before. The dependent variable was knowledge PA coded as a dummy variable (1 = Yes; 0 = No). In the final model (−2LL = 763.561, Nagelkerke R square = 0.240; Hosmer and Lemeshow Test = 0.085), the selected predictors were gender, education, turnover, size, and age, as reported in Table 2.1.

Table 2.1 Results of binary logistic regression on knowledge of PA

Classification table[a]					
Observed			Predicted		
			Knowledge PA		Percentage correct (%)
			No (N)	Yes (N)	
Step 1	Knowledge PA	No	225	102	68.8
		Yes	97	219	69.3
	Mean percentage				69.1

Variables in the equation							
Type of variables		B	S.E.	Wald	df	A	Exp(B)
Step 1[b]	Gender	0.964	0.210	21.027	1	0.000	2.623
	Education	0.895	0.183	23.856	1	0.000	2.446
	Geography	0.150	0.178	0.708	1	0.400	1.161
	Years of activity	−0.236	0.207	1.297	1	0.255	0.790
	Turnover	0.604	0.196	9.450	1	0.002	1.829
	Size	0.901	0.191	22.320	1	0.000	2.462
	Qualification	0.291	0.196	2.204	1	0.138	1.338
	Age	−0.601	0.186	10.424	1	0.001	0.548
	Constant	−1.673	0.300	31.014	1	0.000	0.188

[a]The cut value is 0.500
[b]Variable(s) entered in step 1: Gender, education, geography, years of activity, turnover, size, qualification, age

2.5.2 Regression Analysis on Adoption of PA

To test whether the likelihood of adoption of PA was predicted by the independent variables, a logistic binary regression with the enter method was performed. All the independent variables were recoded as dummies, as indicated in Table 2.2. The dependent variable was the adoption PA coded as a dummy variable (1 = Yes; 0 = No). In the final model (−2LL = 394.754, Nagelkerke R square = 0.142; Hosmer and Lemeshow Test = 0.993), the selected predictors were gender, turnover, and size.

2.6 Conclusions

This chapter aims to detect Italian farmers' rate of knowledge and adoption of modern farming techniques. The results of the analysis show a great relevance of the size of the farm; farmers owning farms with a size above the Italian average in terms of cultivable hectares are more aware of PA technologies and more likely to use them. Gender is also a factor with a strong influence on the knowledge and adoption of PA, with men being more likely to know and adopt PA. Regarding age, the results show that farmers younger than 50 years old are generally more likely to know PA,

Table 2.2 Results of binary logistic regression on adoption of PA

Classification table[a]						
Observed			Predicted			
			Adoption PA		Percentage correct (%)	
			No (N)	Yes (N)		
Step 1	Adoption PA	No	129	54	70.5	
		Yes	58	75	56.4	
	Mean percentage				64.6	
Variables in the equation						
Type of variables		B	S.E.	Wald	df	A	Exp(B)
Step 1[b]	Gender	0.707	0.340	4.329	1	0.037	2.029
	Education	0.067	0.254	0.070	1	0.791	1.069
	Geography	0.104	0.246	0.180	1	0.672	1.110
	Years of activity	0.355	0.290	1.500	1	0.221	1.426
	Turnover	0.885	0.286	9.599	1	0.002	2.422
	Size	0.559	0.272	4.211	1	0.040	1.748
	Qualification	−0.197	0.293	0.454	1	0.501	0.821
	Age	−0.283	0.267	1.128	1	0.288	0.753
	Constant	−1.891	0.482	15.391	1	0.000	0.151

[a]The cut value is 0.500
[b]Variable(s) entered on step 1: Gender, education, geography, years of activity, turnover, size, qualification, age

but there is no specific effect on use. These data can be explained by the fact that younger farmers are on average more educated and more accustomed to the use of new technologies even outside the workplace but, generally, have fewer financial resources and find adoption more difficult. Empirical findings on predictors exerting a positive influence on PA adoption have multiple managerial implications for industry, consulting, and farmers. However, limitations of the research must be mentioned. First, the sample cannot be considered representative of the entire population of Italian farmers, and the use of wording for the first "precision agriculture" key question could be interpreted slightly differently among farmers. The research aims to be a starting point for any future work to better understand the composition of the sample of Italian adopters, as there are no updated census data on the use of technologies. Future research will need to explore more deeply why so many farmers have never heard of PA. Furthermore, for policymakers, there are still very large margins of intervention to spread knowledge and educate farmers to understand the advantages of adopting PA technologies, highlighting their merits in terms of economic profitability for the company, increase in productivity, and environmental sustainability. In this way, the PA will be able to constitute a fundamental element for the development of a more resilient agri-food sector.

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Chapter 3
The Role of Technological Innovation in Agri-food Resilience: A Systematic Literature Review

Biasino Farace and Angela Tarabella

Abstract The agri-food sector is increasingly exposed to multiple internal and external drivers of change, ranging from sudden shocks to long-term stressors, increasing its vulnerability over time. In a world of increasing complexity and future uncertainty, it has become imperative to include contingency as a critical element in sustainable development research. Change, uncertainty, and the adaptive capacity of systems invoke the concept of resilience. There is a growing recognition of how digitalization and so-called 4.0 *disruptive* technologies can contribute to agri-food resilience. This work aims to carry out a systematic literature review combining technological development in the agri-food sector with the concept of resilience. The main objective is to highlight the state of the art on the role of technological innovation and how it sustains the sector by presenting results of a descriptive conceptual nature. The results show that the contribution of technological innovations to agri-food resilience has become a topic of considerable interest, especially in the last 5 years (2018–2022) as a response, above all, to the COVID-19 pandemic crisis. Among the main contributions, digital technologies promote new approaches to production efficiency and decision-making in a logic of increased competitiveness, stability, and sustainability of the agri-food sector in the long term.

Keywords Systematic literature review · Technological innovation · Digitalization · Resilience · Agri-food

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B. Farace (✉) · A. Tarabella
Department of Economics and Management, University of Pisa, Pisa, Italy
e-mail: angela.tarabella@unipi.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_3

3.1 Introduction

The achievement of sustainable and resilient agri-food production and consumption models represents, as never before, a crucial and extraordinarily complex challenge whose solution cannot disregard adequate research on technological innovation. The impacts caused by climate change, overexploitation of natural resources, and aggressive agricultural practices prove to be devastating for the agri-food sector, which depends, among other things, on the livelihoods of an increasing population and the economic, social, and cultural growth of communities around the world (FAO 2020). Even before the COVID-19 outbreak, the agri-food sector in most countries faced many problems of economic instability, social conflict, and food security. The advent of the crisis caused by the pandemic highlighted many others, including fragile production and distribution systems and business models that lack resilience in times of crisis (FAO 2021). Current agri-food systems require profound change, as they still fail to provide basic food for a large portion of the world's population while being responsible for an unsustainable burden on the environment. There is a growing recognition of how digitalization can help make the agri-food sector resilient (Lezoche et al. 2020). Technological innovations in agri-food are crucial to sustaining productivity growth and meeting the growing global demand for food while preserving environmental resources and mitigating climate change (FAO 2017). In the wake of the 4.0 paradigm, sustainable business practices have spread around the world, such as the phenomenon of *smart farming* or *precision agriculture*, which, thanks to the use of so-called *disruptive* technologies, optimize production processes with economic, environmental, and social benefits (Wolfert et al. 2017). The need to include contingencies as critical factors in sustainable development research that embody the concept of resilience (Folke et al. 2010), coupled with more recent developments in digital technologies, opens new research scenarios that need to be elucidated. This systematic literature review (SLR) aims at understanding how digital technologies contribute to agri-food resilience.

3.2 Material and Methods

The study undertook an SLR to provide a comprehensive and thorough understanding of the researched phenomenon (Phillips et al. 2014; Tranfield et al. 2003). Based on Tranfield et al. (2003), this research scheme is divided into three stages characterized by a series of actions that guide the process of conducting the SLR (Fig. 3.1).

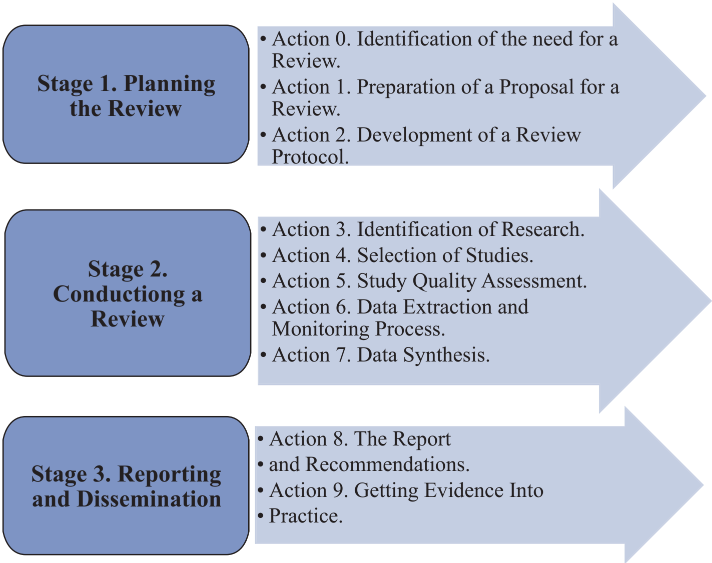

Fig. 3.1 Systematic literature review process. (Source: Own elaboration adapted from Tranfield et al. (2003) and Phillips et al. (2014))

3.2.1 Step 1. Planning the Review

The first research step, preparatory to conducting an SLR, is “Review Planning,” a phase in which researchers clarify the objectives of the research and the inclusion or exclusion criteria in the data collection process (Tranfield et al. 2003). Research sources were limited to specific databases to identify bibliographic streams consistent with research interests, selecting journals with high academic impact (Podsakoff et al. 2005). The Scopus database was considered suitable for data collection (Gavel and Iselid 2008).

3.2.2 Step 2. Conducting the Review

The research was carried out using the search function for “title, abstract, and keywords”; the string used for the SLR after entering the inclusion and exclusion parameters is shown below:

> *(TITLE-ABS-KEY (agri-food) OR TITLE-ABS-KEY (agri*) OR TITLE-ABS-KEY (agro*) AND TITLE-ABS-KEY (technolog*) OR TITLE-ABS-KEY (innovati*) OR TITLE-ABS-KEY (digit*) AND TITLE-ABS-KEY (resilien*)) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))*

Specifically, the final sample of papers identified for the SLR met the following inclusion/exclusion criteria: selection of peer-reviewed scientific articles (books, editorials, reviews, notes, letters, conference proceedings, and nonreferenced publications were excluded from this selection); "*Business*," "*Management*," and "*Accounting*" subject areas; articles written in English; and full-text availability. Therefore, after satisfying the research parameters, the sample of articles was reduced from n = 2005 to n = 22.

3.2.3 Step 3. Reporting and Dissemination: Preliminary Evidence

The "Reporting and Dissemination" process, as suggested by Tranfield et al. (2003) – especially in economic and managerial research – should be a two-stage report oriented to produce a result that informs both the managerial and the theoretical side. By helping to provide insights in both directions, the authors aim to offer a dual outcome of a descriptive and thematic nature (Tranfield et al. 2003).

3.3 Results and Discussion

3.3.1 Descriptive Analysis

Before providing contributions to frame the trend of publications over the years, Table 3.1 shows the list of research articles identified for SLR. Among the most interesting results is the analysis of publications' distribution over the years to understand how interest in the topic has evolved. The results show a particular concentration of studies concerning the role of technological innovation on agri-food

Table 3.1 List of publications selected for the SLR

N°	Author(s)	Year	N°	Author(s)	Year
1	Rengarajan et al	2022	12	Aigbavboa et al	2020
2	Paoloni et al	2022	13	Sharma et al	2020
3	Haile et al	2022	14	Locker et al	2019
4	Galaz et al	2022	15	Aghajanzadeh and Therkelsen	2019
5	Branca et al	2021	16	Riberio and Shapira	2019
6	Cariappa et al	2021	17	Platt et al	2018
7	Anakpo and Mishi	2021	18	Nelson and Phillips	2018
8	Corderio et al	2021	19	Hagman et al	2018
9	Dar et al	2021	20	Mat et al	2018
10	Romão	2020	21	Ely et al	2016
11	Quayson et al	2020	22	De Goede et al	2012

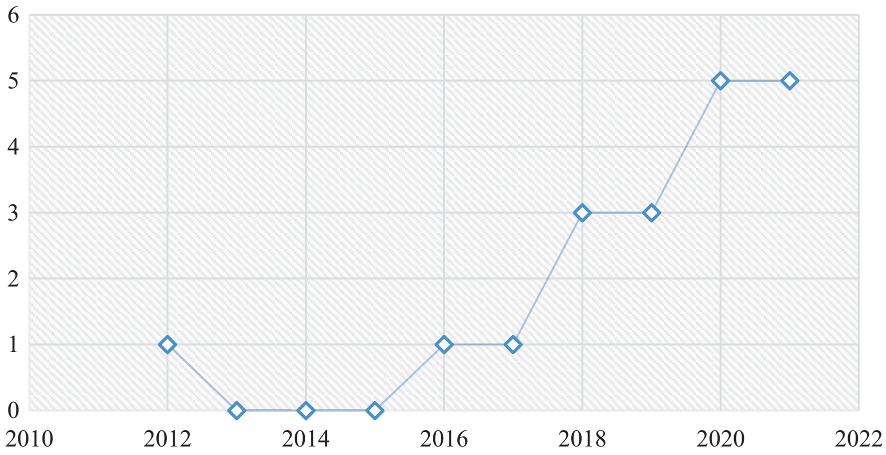

Fig. 3.2 Number of papers per publication year. The graph does not show data for 2022 due to partial scientific production. (Source: Authors' personal elaboration from the analysis of the review sample)

resilience, especially in the last 4 years (2018–2021), which accounted for approximately 85% of the total scientific production on the topic (Fig. 3.2).

3.3.2 Conceptual Analysis

An in-depth analysis of scientific works on technological innovation's role in agri-food resilience shows a deep connection with the critical issues arising from the COVID-19 pandemic (Quayson et al. 2020; Sharma et al. 2020). The relevant literature highlights how recent socioeconomic events, exogenous shocks, climate change, and the issue of food (in)security have highlighted the structural fragilities of the agri-food sector (Branca et al. 2021; Cariappa et al. 2021; Corderio et al. 2021; Dar et al. 2020) while creating the basis for building new opportunities and rethinking new methods of production, distribution, and consumption in a resilient logic (Anakpo and Mishi 2021; Haile et al. 2022). Advances in predictive analytics through various forms of artificial intelligence methods, Internet of Things systems, satellite technologies, growing computing capacity, and developments in robotic industries have paved the way for new approaches to efficiency, productivity, and decision-making (Galaz et al. 2021; Rengarajan et al. 2022). It is argued that in the future, innovation, new technologies, and the creation of relationships between different economic agents could be crucial for the competitiveness, stability, and sustainability of the sector over time (Aigbavboa et al. 2020; De Goede et al. 2012; Paoloni et al. 2022; Romão 2020). Technological innovation, therefore, seems to play a central role in the process that drives policies for transition, energy adaptation, and waste valorization to achieve and contribute to global change toward a sustainable future (Aghajanzadeh and Therkelsen 2019; Ely et al. 2016; Hagman et al. 2018; Locker et al. 2019; Mat et al. 2017; Nelson and Phillips 2018; Platt et al. 2018; Ribeiro and Shapira 2019).

3.4 Conclusions

The agri-food sector today faces multiple challenges. Even before the COVID-19 outbreak, the agri-food sector in most countries faced many problems of economic instability, social conflict, and food security. The advent of the crisis caused by the pandemic has highlighted many more, including the fragility of production and distribution systems and business models that lack resilience in times of crisis. This calls for urgent transformation of the current agri-food sector, and digital innovations can be part of the solution. The so-called fourth industrial revolution considers several sectors, such as agri-food, rapidly transformed by disruptive digital technologies. The SLR highlights that technological innovations can help make the agri-food sector resilient by improving production efficiency and decision-making in a logic of effective management of economic and natural resources. In conclusion, we note that the application of digital technologies is often associated with increased competitiveness, stability, and sustainability of the agri-food sector in the long run.

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Chapter 4
The Agri-food Product's Life Cycle: The Technological Dimension Role from an Open Innovation Perspective

Gianmario Pelleschi, Andrea Apicella, Biasino Farace, and Angela Tarabella

Abstract The literature analysis allowed us to group the main schools of thought on life cycle models into three categories: the marketing dimension (marketing product life cycle), the managerial/engineering dimension (engineering product life cycle), and the technological dimension (technology life cycle). However, the empirical evidence has revealed an overlap of such models, and over time, the technological dimension has taken on an increasingly important role in building successful business models. In particular, the open innovation (OI) concept has found increasing application in the agri-food sector through the construction of models based on specific case studies (OI models). This paper aims to carry out a systematic review of the current literature to underline points of contact and deviations between the most accredited models applied in the agri-food sector to highlight the success variables underlying the application of each model.

Keywords Open innovation · Open innovation model · Food innovation · Agri-food sector · Technology life cycle · Product life cycle

4.1 Introduction

A multidisciplinary approach to the latest life cycle literature allows the main schools of thought to be grouped into three categories: the marketing dimension (Dean 1950; Levitt 1965; Tellis and Crawford 1981), the managerial/engineering dimension (Day 1981; Bennett and Cooper 1984; Westkämper et al. 2001), and the

G. Pelleschi (✉)
School in Economics and Finance, Catholic University of the Sacred Heart, Milan, Italy

A. Apicella · B. Farace · A. Tarabella
Department of Economics and Management, University of Pisa, Pisa, Italy

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_4

technological dimension (Tarde 1903; Rogers 1962; Chesbrough 2003a). The technological dimension is crucial: as stated by Schumpeter (1934), the ability to innovate is fundamental to survive in a competitive environment. According to the original definition, in an open innovation (OI) process, "… *valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well*" (Chesbrough 2003b). In more recent times, the definition has been revisited: "*OI is defined as a distributed innovation process based on purposively managed knowledge flows across organisational boundaries, using pecuniary and nonpecuniary mechanism in line with the organization's business model*" (Chesbrough and Bogers 2014). Thanks to cooperation, companies not only optimize the flow of information but also increase their profits by ensuring a diversification of their resources (Kranenburg et al. 2004; Tarabella 2019). In particular, the food industry is a mature and conservative sector where its profit margins are extremely low, and the R&D failure rate for new products is high (Bigliardi and Galati 2013; Tsimiklis and Makatsoris 2015; Manzini et al. 2016). Furthermore, the food industry has historically given priority to cost minimization, paying less attention to consumers' desires and thus to satisfying their needs (Lienhardt 2004). In fact, many studies have shown that innovation can become an effective tool for mature and traditional consumer-oriented industries (Arcese et al. 2015). This approach has made the food industry unprepared for the dramatic changes that occurred during the twenty-first century, particularly for climate emergencies. The 2030 Agenda for Sustainable Development explains that innovations along with sustainable and safe solutions represent the main challenge for the agri-food sector (Bigliardi and Filippelli 2022). In this respect, the food and drink industry represents the largest manufacturing sector in the European Union. Turning to other food industry challenges, companies face shortened life product cycles, competitive time-to-market race, and cluttered retail shelf space (Bellairs 2010). This implies that digital technology exploitation (e.g., IoT, big data, blockchain, and artificial intelligence) is unavoidable (Saguy 2016). To put it more simply, digital technologies have not only connected the entire world but also changed all sectors, including the agri-food sector (Tarabella et al. 2021). Nevertheless, changing mindsets is difficult since open innovation-oriented small and Medium Enterprises (SMEs) experience several barriers, such as low absorptive capacity (Spithoven et al. 2010), scarce financial resources for research and development (R&D), limited human resources and competences, and small market power (Saguy and Sirotinskaya 2014). Overcoming these internal barriers would allow agri-food companies to develop new open innovation models to exploit digital technologies' potential.

4.2 Materials and Methods

This work aims to carry out a systematic literature review (SLR) of the most accredited open innovation agri-food models. A successful SLR involves three major stages: "planning the Review," "conducting the Review," and "reporting the Review"

(Kitchenham and Charters 2007; Breretona et al. 2007; Xiao and Watson 2019). More precisely, the first stage clarifies objectives, rules regarding the data collection process and, finally, resource database (Tranfield et al. 2003). In this regard, the Scopus database was chosen for collecting data. Second, the "conducting the review" stage involves various steps: searching the literature, screening for inclusion, assessing quality, extracting data, and analyzing and synthesizing data (Xiao and Watson 2019). Thus, the following query has been entered: TITLE-ABS-LEY ("open innovation" and "food" or "agri-food"). Hence, Scopus identified 682 articles. As stated by Xiao and Watson (2019), data extraction is determined after reviewing the title, abstract, and full text. Therefore, a careful reading of the abstract made it possible to identify the literature concerning food open innovation models. However, to identify further models and potential conceptual links, a bibliometric analysis was carried out using the VOSviewer software. Figure 4.1 displays a co-occurrence map for author keywords on the topic of open innovation in food companies.

The goal was to obtain an overview of the present literature to identify additional food open innovation models. The terms "open innovation" and "food" or "agri-food" had to appear in the title, abstract, or keywords. A total of 21,192 terms were observed, and a threshold of 10 occurrences was selected.

Thus, 454 keywords meet the threshold. For each of the 454 terms, the VOSviewer default suggestion to select the 60% most relevant terms has been followed. At the end of the process, VOSviewer created a map related to 272 keywords gathered into four clusters. The blue cluster, located on the left, consists of terms related to production agriculture. The red cluster, placed at the top, covers terms that go beyond the interests of this research. On the other hand, the green cluster is the most interesting one: the most frequent keywords are "open innovation" and "company,"

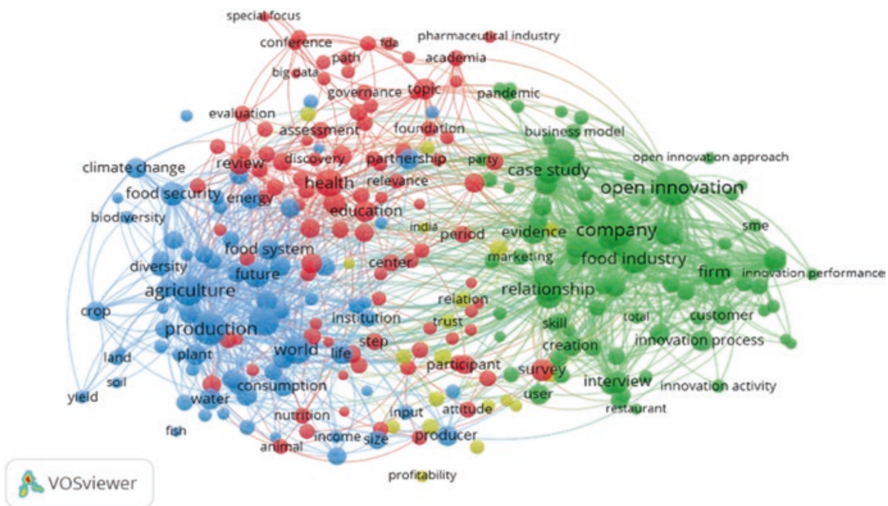

Fig. 4.1 VOSviewer map visualization of the most frequent keywords

located close enough to "case study" and "food industry." It is interesting to note the presence of the SME keyword: this should not be surprising since 99% of European food companies are SMEs. Moreover, the pandemic keyword is observed in the green cluster. Third, the findings are illustrated in Table 4.1, which represents the "reporting the review" stage.

4.3 Literature Review

Table 4.1 provides a summary. Further development of food open innovation models is expected in the coming years. In fact, consumers' needs related to food are spreading enormously: currently, consumers choose customized diets that address their desires to eat low-fat foods or to remove ingredients that affect their allergies or personal beliefs (Cillo et al. 2019).

4.4 Results and Discussions

The food industry is slowly moving toward open innovation models to overcome institutional and socioeconomic changes (Bayona-Saez et al. 2017). Food open innovation models can complement traditional innovation models to strengthen traditional models' weaknesses (Bigliardi et al. 2020). Such a goal is unavoidable since the food sector will soon experience new challenges. However, these challenges could be transformed into opportunities (e.g., exploitation of digital technologies). Moreover, Table 4.1 divides food OI models into two main groups according to their main feature (product innovation and innovation process). Such categorization cannot be considered negligible. For example, companies focused on ingredients should be encouraged to apply food OI models that are product oriented (e.g., OI Cereal Scheme). In this way, it is possible to gain a competitive advantage in a niche market and so to improve export sales. On the other hand, enterprises that base their core business on the process may benefit from food OI models that are process oriented. Considering such advantages, tax incentives are desired: policymakers should plan scenarios that encourage food OI model implementation.

4.5 Conclusions

As shown in Table 4.1, some researchers highlighted that innovation was the only way to escape from the "spiral of death". However, most food companies prefer the cost minimization approach (Juriaanse 2006). Fortunately, in the last decade, open innovation has started to be mainstream in the European food industry: companies such as Cargill, Nestlé, IFF, or Mars have approached open innovation models

Table 4.1 Food OI models: a literature review

Food OI model	Year	Authors	Methodology	Field of application	Features	Results
Connect & Develop	2006	Huston and Sakkab	IT platforms, meetings	P&G	Technology, radical innovation	The C&D model, if seen only as an R&D strategy or as an experiment, is doomed to fail. Hence, it must be guided by the top management.
Share is Winning (SiW)	2009	Traitler and Saguy	Data from R&D, universities, companies involved	Nestlé	Innovation process	Development of the "Innovation Partnerships" strategy and the SiW model.
Food Machinery Framework	2010	Bigliardi et al.	Case study with bibliographic review and questionnaire	Companies involved classified	Radical and incremental product innovations	Each player in the supply chain perceives innovation as a key factor for surviving in current highly competitive markets. Therefore, he actively participates in the OI.
Living Lab	2010	Wolfert et al.	Design-oriented case study	12 large agricultural Dutch farms	Innovation process	Important success factors are incremental growth approaches and service-oriented approaches toward processes rather than software.
Want Find Get Manage (WFGM)	2013	Garcia Martinez	Application of Slowinski's general model (2004)	Mars, Incorporated	Technology	The model increased the collaborative projects successful rate. It happened because the teams respected the following process: defining the necessary resources, finding them outside the company, looking for potential partners to make a deal, managing the consequences of this agreement.

(continued)

Table 4.1 (continued)

Food OI model	Year	Authors	Methodology	Field of application	Features	Results
Controlled OI approach	2013	Lazzarotti and Manzini	Case study with top management interviewed	Lindt & Sprüngli Maitre Chocolatier	Incremental innovation	Model's adoption allows closed companies to exploit the potential advantages of open innovation without radically changing their business model.
Co-creation of value	2014	Garcia Martinez	Case study with interviews	Molson Coors, UK brewing company	Innovation process	Consumer role in co-creation of value is crucial in a product-based industry. Such creation can be achieved through consumers participation as partners or coproducers.
Consumer-centric OI framework	2015	Tsimiklis et al.	Crowdsourcing	Large Spanish yoghurt producer (classified data)	Innovation process	Raw materials, planning skills, and control systems are needed. This can be achieved through the ability to provide forecasts across the supply chain. Simulations and optimization models allow to define initial risks and manage them effectively.
OI Cereal Scheme	2019	Grimsby and Kure	Multi-phase (meetings, reports, interviews, and quantitative data)	Norwegian cereal industry	Product innovation, packaging, and transfer of tacit knowledge	The crispbread case may be an example of successful OI through the export of agriculture-based products from a country with highly subsidized agriculture and a country with the highest labor cost in the world.
Causal loop model of restaurant OI	2020	Yun et al.	Case study with interviews and questionnaires	Four Neapolitan restaurants, one South Korean restaurant, one North Korean restaurant	Innovation process	OI determines the success of small restaurants. Furthermore, if any small restaurant adopts a closed innovation strategy with respect to an ingredient or recipe or service, it should adopt an open innovation strategy to maintain the competitive advantage over the other restaurants in the neighborhood. An OI platform of any ingredient, recipe, or service increases revenue through their sales.

Open social food innovation	2021	Penco et al.	Case study	Fondazione Banco Alimentare Onlus (FBAO)	Innovation process	COVID-19 encouraged the adoption of open social innovation practices to continue to fulfill the social mission and at the same time to create innovative projects.
Food-machinery flexibility model	2022	Hongsaprabhas and Parisot	Case study with interviews	Two Thai food machinery SMEs	Outbound (e.g., insourcing R&D) and inbound (e.g., customer involvement) practices	The model is divided into six sub-patterns with different and unique characteristics. The results of these patterns demonstrate the flexibility of food machinery companies in applying one logical OI or another. In fact, companies do not only practice inbound OI or outbound OI but a mix of them. This agility in adopting various OI logics and practices helps the food machinery company to develop new core competencies along with its production technology.

(Bigliardi and Galati 2013). Nevertheless, such improvement is still slow. This issue has already been evoked in the literature: currently, few studies on the food open innovation approach have been developed (De Medeiros et al. 2016; Cillo et al. 2019; Sadat and Nasrat 2020). On the whole, the diffusion of theoretical food open innovation models is still limited. Currently, economic actors live in the open innovation era, so organizational culture must embrace an open mindset. Therefore, national policies should foster innovation-oriented entrepreneurial skills along with incentives to facilitate food OI model implementation. In conclusion, this research carried out with Scopus can be improved through the integration of additional databases, and it may represent a starting point for future research that will promote companies' growth rate.

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Chapter 5
Innovation in the Food Sector: Development Prospects for Synthetic Meat Production

Vito Tommaso, Roberto Leonardo Rana, and Caterina Tricase

Abstract Currently, the production of meat appears to be unsustainable due to its environmental impact and because it causes natural resource depletion. Furthermore, in the next few years, the situation will worsen due to the increase in the human population and the lifestyle change of some nations, such as China or India. Moreover, according to scientists, conventional meat production would be insufficient to satisfy the growing demand for this food. To solve these problems, an innovative technology has recently been developed that can produce meat in the laboratory. Thus, the first synthetic meat production started in 2016. To date, there are different methodologies that try to overcome some problems linked to the poor quality and high cost of this new food. In light of these premises, the present study aims to present an overview of synthetic meat production techniques, analysing the advantages and disadvantages that meat production can entail. The results showed that synthetic meat could contribute to reducing environmental pollution and natural resource depletion as well as feed the growing world population. However, some technological problems should be resolved, such as its taste not always appreciated by consumers and the huge energy consumption that its production needs.

Keywords Synthetic meat · Cultured meat · Tissue engineering · Innovation

5.1 Introduction

Hunger is one of the major plagues that afflict the human population. Although in recent decades the United Nations (UN) has started several initiatives to reduce this problem by 2020, the percentage of world hunger has increased by approximately 9.9%. This result has not allowed achieving the goal Zero Hunger within 2030 by

V. Tommaso (✉) · R. L. Rana · C. Tricase
Department of Economy, University of Study of Foggia, Foggia, Italy
e-mail: vito.tommaso@unifg.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_5

the UN (FAO 2021). Despite this, meat consumption is expected to double in 2050 due to population growth and increased income in some countries, such as China or India (FAO 2021; Bai et al. 2020). Therefore, conventional meat production would be insufficient to produce enough meat to supply the global demand for meat. Moreover, conventional meat production contributes to the release of high quantities of greenhouse gases (principally carbon dioxide, methane, and nitrous oxide) and the consumption of natural resources (i.e. water, soil, etc.) and destroys natural ecosystems (i.e. rainforests) (FAO 2021). To answer these future challenges, synthetic meat (or in vitro/cultured meat) production has been proposed, an innovative technology that could represent a valid alternative to conventional meat production. Furthermore, in vitro meat also seems to contribute to solving environmental problems and natural resource depletion. In this context, this study aims to present an overview of synthetic meat production techniques, analysing the advantages and disadvantages that their production can entail. This study could also provide useful information for improving the challenges that this innovation implies and for policymakers who intend to know the main elements that have to be taken into account to support the use of this novel food.

5.2 Materials and Methods

This study was carried out through literature research using specific keywords (i.e. "technique" AND "synthetic meat" or "in vitro meat," "cultured meat" AND "innovation") and the most important databases on this topic (i.e. Scopus and PubMed). Consequently, thanks to the selected studies, pros and cons have been analysed from a technical, economic, and environmental point of view. The authors underline that this work represents a preliminary study, which will be followed by systematic research considering a specific methodology.

5.3 Current Techniques for Producing Synthetic Meat

Synthetic meat has the same characteristics as an animal meat product but was developed artificially starting from living cells. Originally, research on in vitro meat production was initiated in the late 1990s by the National Aeronautics and Space Administration (NASA) for space travel (Kumar et al. 2021) using fish cells (muscle tissue from *Carassius auratus*). Since then, research on cultured meat has increased. Thus, in 2003, Mark Post, in his laboratory at Maastricht University (Netherlands), cultured the first in vitro meat beef. Subsequently, revolutionary progress was recorded in 2012 (Post 2012) when the first in vitro meat–based burger was prepared and presented in an exhibition at the Riverside Studios of London. However, synthetic meat was not yet ready for commercial purposes since its production was very expensive due to (a) the high costs of culture media, (b) the absence of commercial infrastructures, and (c) the early stage of research. Indeed, the initial price of a cell-cultured burger (composed of 200 g of meat) obtained with this technology was approximately $330,000. A few years later, the introduction of new technologies reduced the price of cell-cultured meat, reaching $9.00/9.50 per burger (Kantono et al. 2022). Currently, in vitro meat production is spreading worldwide, and this obviously affects some economic aspects. It is estimated that there is an increasingly aggressive trend in the creation of start-ups in this sector. Due to the improvement of these technologies in the last decade, according to Kumar et al. (2021), there are approximately 32 start-ups/companies producing cultured meat on an industrial scale. These companies are continuously searching for better technological inventions by focusing their research and development (R&D) on cultured beef (25%), poultry (22%), pork (19%), seafood (19%), and exotic meat (15%). Moreover, 40% of these companies are based in North America, 31% in Asia, and 25% in Europe. The estimated global market for synthetic cell-based meat will amount to approximately $214 and $593 million by 2025 and 2032, respectively (Mateti and Laha 2022). Furthermore, according to research, the low cost of synthetic meat will probably allow an increasing consumption from 0% to 10% up to 2030 and approximately 35% to 2040. On the other hand, the conventional meat supply will drop by 33% from 2020 to 2040 (Gerhardt et al. 2020). Although these trends will have positive effects, such as decreasing the environmental impact and reducing the use of natural resources, they could cause economic problems for farmers who profit from conventional meat production. Synthetic meat technology has improved in the last three decades. The first technology consisted of the monoculture of satellite cells,[1] which, when fused, produce structural muscle cell fibres. In the second step, the muscle fibres were physically stretched, allowing their development in the proper direction (Boonen et al. 2010; Post 2012). However, this typology of meat lacks bone scaffolds and fat cells, and consequently, its taste is not similar to that of conventional meat. Moreover, the absence of specific multiple stimuli led to a cell culture without a complex structural organization. Therefore, this synthetic meat had a much lower protein source than conventional meat.[2] In contrast, differentiating and fusing, thanks to appropriate stimuli, these mature cells produced enough protein sources, improving the nutritional properties of meat. Another type of technology uses different cells, such as stem cells and induced pluripotent stem cells.[3] Several stem cells have been identified for producing in vitro meat culture. In recent decades, technology developed for their isolation, identification, cultivation, and engineering has made it possible to take a large step forward in the production of synthetic meat. In fact, until then, cells usually grew in

[1] Satellite cells, also known as myosatellite cells, are small multipotent cells. These muscle stem cells are found in mature muscle. Satellite cells are precursors to skeletal muscle cells, able to proliferate giving other satellite cells or differentiated skeletal muscle cells.

[2] Generally, 100 g conventional meat has around 20 g proteins.

[3] Stem cells differ from other cells in their uniqueness. In fact, being pluripotent, they can differentiate into different cell types. Stem cells can remain in a rather undifferentiated state for a significant number of cellular passages during culture.

two-dimensional (2D) form because there was no structural interaction between the cells (there was only contact interaction), and the cultured meat had a low quality compared to conventional meat.[4] It is believed that the 2D culture system is less reliable than the 3D co-culture system in vitro since the latter closely mimics cell physiology in vivo. Indeed, the 3D co-culture system allows interactions between different cell types, producing meat with good taste and quality (Boonen et al. 2010). Since 2013, the co-culture of myoblasts and fibroblasts has been believed to be one of the main techniques for synthetic meat production. Indeed, co-culture of these two specific cell lines has established the analysis of fat regulation and deposition of muscle (made by myoblasts) in a 3D structure (made by fibroblasts). As a relevant result, several biochemical markers related to muscle/fat formation and regulation have been studied in myoblast and fibroblast co-culture (Zhang et al. 2010). One of the newest technologies for cultured meat production uses fibro-adipogenic progenitor cells (FAPs).[5] According to Dohmen et al. (2022), FAPs have a high potential to produce fat and a significant potential to proliferate in vitro. Consequently, they could potentially be used for a better scalable cultured meat production process. From the hydrogel culture of FAPs, a 3D-structured meat (thanks to the hydrogel that acts as a scaffold) can be produced, obtaining a product that accurately mimics traditional beef fat in terms of lipid profile and taste. Thus, this technology represents the most commonly used technology for the commercial production of cultured beef, especially because it is high in fat (Dohmen et al. 2022).

5.4 Advantages and Challenges

This section analyses the advantages and challenges of synthetic meat production. One of the best advantages is that in vitro meat production, compared to meat produced by conventional methods, is characterized by reducing energy consumption up to 40%, land use by 99%, water consumption by 90%, and greenhouse gas emissions (GHGs) by 90% (Tuomisto and Teixeira De Mattos 2011; Kumar et al. 2021; Mateti and Laha 2022; Dohmen et al. 2022). Another advantage is that synthetic meat production could also prevent the contamination of meat by bacteria and pathogens such as *Salmonella* spp., *Campylobacter* spp., and *Clostridium perfringens,* which cause dangerous diseases to consumers (Scallan et al. 2011). For instance, avian and swine influenza viruses often spread when intensive livestock farming is adopted (Borkenhagen et al. 2019). Therefore, synthetic meat products can ensure safety for consumers. In addition, replacing conventional meat with synthetic meat could improve the quality of health and reduce/prevent diseases due to

[4] It is recalled that conventional meat has a complex network, a highly ordered and three-dimensional (3D) structure.

[5] FAPs are also multipotent cells, present in bovine muscle. These cells are transcriptionally and immunophenotypically different from the satellite cells seen above. FAPs have a higher adipogenic potential than satellite cells, which have a higher myogenic potential.

the consumption of red meat. In fact, the known composition of synthetic meat and the protocols for its production can reduce the intake of fats and cholesterol and therefore reduce atherosclerosis and thrombosis events. The biochemical composition of in vitro meat, such as the increase in polyunsaturated fatty acids, can also lead to dietary and healthier products (Capper 2011). However, in vitro meat production involves some disadvantages specifically because its production system is still in the early stage. One problem is linked to its taste. Rosenfeld and Tomiyama (2022), in fact, state that many people find synthetic meat too disgusting to eat. In this study, it was estimated that 35% of meat-eaters and 55% of vegetarians felt too disgusted to eat this new food. Working on the feeling and perception of synthetic meat as similar to conventional meat can improve consumer acceptance of cultured meat in the coming years, allowing the consumption of meat by vegetarians and avoiding the ethical problems that lead to this choice of life. A fundamental point regarding synthetic meat production is the ethical and legal aspects. In fact, as a disadvantage, producers could try to sell cultured meat as conventional meat to still have a profit but thus deceive the consumer. Furthermore, cultured meat producers could produce meat of species other than those declared or for which they are authorized, also trying to produce meat of protected animal species, thus expanding the illegal meat market. Even more concerning is the possible use of human cells, which could even lead to cannibalism. Unfortunately, the regulatory frameworks are currently unclear and under development (Mateti and Laha 2022). Furthermore, although the production of synthetic meat leads to a reduction in greenhouse gas emissions, use of land and water, and realization of pollutants, its industrial production has the disadvantage of significant energy consumption. Indeed, its production system requires much more energy (18–25 GJ/t) than the conventional system (4.5 GJ/t) (Tuomisto and Teixeira De Mattos 2011; Alexander et al. 2017; Hong et al. 2021). By switching to renewable energy sources, fewer GHGs would be emitted, and the positive effects on the environment due to the only reduction in intensive farming would not be eliminated. A further controversial point in the replacement, albeit partial, of conventional meat with cultured meat is the reduction of obtainable by-products (wool, leather, bone objects, hormones, etc.) deriving from farms. This can be considered a further disadvantage from an economic point of view, but on the other hand, the production of synthetic meat produces a much lower quantity of waste than that produced by slaughtering to obtain conventional meat (carcasses, sewage, and nonedible waste), resulting in waste disposal problems (Kumar et al. 2021).

5.5 Conclusions

In conclusion, considering all these aspects, synthetic meat could be a possible solution in the coming years to most of the problems due to environmental pollution by large meat production and intensive livestock farming companies, even if it would cause economic damage. It would also make a huge contribution to world meat needs, especially in developing countries.

However, as a young technology still evolving, its development in research must be accompanied by a parallel growth of regulations and laws. Only in this way, we can avoid all the possible frauds and illegalities that could sink this new market sector, and its development in safety would lead to greater acceptance by the consumer and its ever-increasing global diffusion.

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Chapter 6
Valorization Strategies of Technological and Therapeutic Properties of Orange Byproducts

Paola Campana, Raffaella Preti, and Anna Maria Tarola

Abstract Orange byproducts are generated from the production of citrus juice and consist of approximately 45–60% of the fruit. It has been estimated that global orange juice production can generate between 0.8 and 1 million tons of byproducts each year. This waste represents for producers not only an underutilized commodity but also a source of environmental pollution and a heavy cost for its disposal. The most common processes implemented to improve their management are their use as fertilizers or animal feed, as well as other minor uses. Recently, many alternatives have been proposed to add value to these residues. Most of them aim to exploit the higher dietary fibre, phenolic and antioxidant values contained in the peel of orange and pomace compared with the fruit and the presence of characteristic beneficial compounds present only in the peel, such as limonoids, alkaloids, pectin, and essential oils. Starting from this evidence, valuable molecules generated from orange waste can be used in the food, cosmetic, or pharma industries. Other interesting applications reported in the literature involve the production of bioethanol, enzymes, adsorbent materials, food packaging, paper, and fabric. The purpose of this chapter is to examine a variety of different novel products derived from this waste as a key strategy for the application of the circular economy in the orange juice processing industries.

Keywords Technological innovation · Environmental pollution · Circular economy

P. Campana (✉) · R. Preti · A. M. Tarola
Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: paola.campana@uniroma1.it; raffaella.preti@uniroma1.it; annamaria.tarola@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_6

6.1 Introduction

Approximately 24% of world production of citrus is in the Mediterranean countries of Spain, Italy, Greece, Egypt, Turkey, and Morocco, with Brazil (24%) being a major individual citrus-producing country. Fruit and vegetables are the most responsible for food waste in all supply chain stages, i.e. approximately 45%, and approximately 21.7% of this food waste is generated at the processing and manufacturing stages (Alves de Castro et al. 2020). In particular, global sweet orange (*Citrus sinensis*) juice production is estimated to generate between 0.8 and 1 million tons of byproducts or waste each year and represents one of the largest sources of food waste worldwide (Ravindran and Jaiswal 2016). The byproducts from orange processing account for over half the weight of the incoming raw material: approximately 45% is accounted for by the peel, 6% by the pulp, and 3.5% by the citrus molasses. This waste can represent a serious environmental problem with an important impact on agri-food industries and the population, as it may cause phytotoxicity phenomena, contamination of water bodies, deterioration of drinking water quality, death of sensitive marine organisms, and inhibition of seed germination (Castro-Muñoz et al. 2022). When a fruit is processed, parts such as the core, peel, pips, and kernel are discarded, even if these byproducts contain a large number of valuable components that can represent a resource and not a waste. The most common uses to recover this waste are as animal feed or as fertilizer, or they are disposed of in landfills or incinerated. Previous studies have reported higher dietary fibre values from the peel of orange and pomace and higher levels of phenolic compounds and antioxidant capacity compared with the fruit (Liu et al. 2021).

The aim of this chapter is to examine several applications to valorize the compounds hidden in orange byproducts, such as food additives, functional foods, nutraceuticals, cosmetics, pharmaceuticals, and biopackaging.

6.2 Antioxidant Compounds

Phytochemical and nutritional assessments show that citrus peels contain a variety of functional compounds, including flavonoids, limonoids, essential oils, and pectin, which could be used for medicinal purposes. Citrus byproducts are a major source of phenolic compounds, and the peel is reported to possess the highest amounts of polyphenols compared to other edible parts of the fruit, with a total phenol content in the peel of 736 mg/kg GAE (Rafiq et al. 2018). Flavonoids are the most abundant, with more than 60 types of flavonoids isolated and identified. They include naringin, hesperidin, eriocitrin, narirutin, rutin, tangeretin hesperidin, naringenin, narirutin, and neohesperidin and have different biological activities, such as antioxidant, anticancer, antiviral, cardiovascular, and anti-inflammatory beneficial properties. Such characteristics have attracted attention, and peel has been proposed to be used as a functional ingredient in cosmetics, nutraceuticals, and functional foods in their raw material for additive processes. These perspectives are of particular interest considering that the global market of functional food ingredients is estimated to be USD 98 billion in 2021, and it is expected to grow to USD 137 billion by 2026 (Castro-Muñoz et al. 2022). Limonoids are a series of natural tetracyclic triterpenoid compounds that have been demonstrated to exert many biological activities in vitro, including antioxidant, antibacterial, antiangiogenic, and anti-inflammatory effects. In general, conventional extraction of bioactive compounds from agri-food waste and byproducts is carried out in three consecutive steps: (1) pretreatment, (2) extraction, and (3) purification and conservation (Fierascu et al. 2019). For the extraction of citrus flavonoids, organic solvent extraction is the most widely used because of its ease of use and efficiency. The antioxidant capacity of orange peel extract has been proven by in vitro chemical assays, such as ferric reducing antioxidant power (FRAP), oxygen radical absorbance capacity (ORAC), and 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Liew et al. 2018), and in vivo in animal models (Chen et al. 2013). The antioxidant capacity was demonstrated to be related to the flavonoid content, and in fact, different orange varieties had different capacities.

6.3 Dietary Fibre

Regular consumption of dietary fibre is recommended for the prevention of gastrointestinal and cardiovascular diseases, diabetes, hypercholesterolemia, and obesity. The effectiveness of citrus peel in lowering plasma liver cholesterol, serum triglyceride levels, serum total cholesterol, liver total lipids, and liver cholesterol has been proven by many epidemiological studies. The peel fibre derived from orange fruit is involved in the improvement in intestinal function and health. Peel, pulp, and peel fibre from *Citrus hystrix* and *Citrus maxima* (red and white varieties) could be used as potential dietary fibre sources in the enrichment of foods because of their high physicochemical properties. Citrus fibre, which possesses bioactive functions due to the presence of polyphenol-like components, can be used as an effective inhibitor of lipid oxidation in meat products, thereby improving their oxidative stability and prolonging their shelf life (Rafiq et al. 2018).

6.4 Essential Oils

Essential oils, volatile oils extracted from the citric fruit peel, have several applications in the pharmaceutical and food industries. Additionally, these oils can contain compounds with biological activity, such as limonoids and their glucosides that possess insecticidal activity, such as neem oil, and have been proven to cause the inhibition of cancerous tumours induced in rats, mice, and hamsters. Essential oils from orange peel have shown good antimicrobial activity against yeasts, fungi, and bacteria, and limonene and γ-terpinene, as the major components in citrus peel essential oils, have a wide spectrum of biological activities, such as antimicrobial, antioxidant, and anticancer properties (Gavahian et al. 2019). Because of their peculiar aromas and low costs, citrus essential oils can be used in perfumes, food, and pharmaceuticals. Recently, the incorporation of citrus essential oils into edible films has received innovative attention because of their antibacterial and antioxidant activities in the control of *Listeria monocytogenes* (Mahato et al. 2019) and for improving the physicochemical properties of edible films, such as moisture content and solubility. The traditional methods of extracting essential oil are cold pressing and steam distillation. Cold pressing is the standard method for extracting essential oil from citrus peels and mainly uses strong pressure to squeeze the citrus peels so that the oil cells burst and the essential oil flows out (Gavahian et al. 2019).

6.5 Biofuels

Various studies have investigated the application of citrus peel waste as a promising feedstock for biofuel production due to its rich composition of organic compounds (Fazzino et al. 2021). In contrast, it is not suitable for any co-digestion in biogas production since orange peels contain D-limonene, an antibacterial agent (Mahato et al. 2019).

A ton of solid orange byproducts can yield up to 600 kg of bio-oil. Citrus processing waste can be used to produce ethanol, limonene, and other coproducts. Enzymatic hydrolysis can be applied to the organic waste to maximize the monomeric sugar content, and then sugars can be converted into ethanol by fermentation. If enzymatic hydrolysis is followed by saccharification and fermentation processes, the ethanol yields can reach 94%. The lignin content in citrus peel can serve as a promising alternative to lignocellulosic biomass to also produce biofuels (Liu et al. 2021).

6.6 Livestock Feed

Citrus byproducts are utilized as a low-cost nutritional supplement to the diets of cattle, as they are suitable for inclusion in ruminant diets because of the ability of ruminants to ferment high-fibre feeds in the rumen and present fewer negative effects on rumen fermentation than starch-rich feeds.

The citrus byproducts also showed the ability to inhibit the growth of both *Escherichia coli* and Salmonella within mixed ruminal microorganism fluid media. Citrus byproducts commonly used as high-energy ruminant feed are fresh citrus pulp, citrus silage, dried citrus pulp, citrus meal and fines, citrus molasses, citrus peel liquor, and citrus-activated sludge. They are often used as supplements to support the growth and lactation of cattle due to their composition of soluble carbohydrates and readily digestible fibre. Citrus pectin is easily and extensively degraded, producing acetic acid, which is less likely than lactic acid to cause a pH drop and result in acidosis (Alnaimy et al. 2017).

6.7 Pectin

Citrus peels are rich in pectin (for dry weight basis: orange (*C. sinensis*), 28%; grapefruit (*C. paradisi*), and 23%; mandarin (*C. resticulata*), 19%). Citrus pectin has been investigated intensively due to its beneficial effects on human health. Its main effects are on intestinal inflammation and on the reduction of the incidence of heart disease and blood cholesterol levels.

The traditional methods of extraction are acid, alkaline, and enzyme extraction, but microwave assisting, subcritical water, and ultrasound-assisted extractions have also been investigated to reduce time and solvents (John et al. 2017).

6.8 Food Packaging

The incorporation of orange peel in food by extracts, powder, or complex encapsulation technology to exploit its natural antioxidant capacity has been investigated to improve storage qualities. Another way to use this byproduct is its incorporation in edible films or the use of orange essential oils in nonedible, biodegradable, and compostable polymers. Orange waste presents the essential constituents of bio-based plastic, i.e. pectin and cellulosic fibres that can provide the required strength and ensure biodegradability. Recently, there have been encouraging studies in this field with promising biofilms produced entirely from orange waste that can replace conventional plastic with an eco-friendly material (Jayachandra et al. 2022).

6.9 Sustainable Fabrics

The high cellulose content of orange byproducts has also been applied to the production of a novel cellulosic fibre to be employed in the fashion industry for the production of sustainable fabrics. Orange Fibre is an Italian company established in Sicily that has patented and produces sustainable fabrics from citrus fruit byproducts coming from the local orange processing industry. Its products are used in the fashion luxury sector by important brands such as Ferragamo and Marinella, which are interested in disseminating the circular economy positive and innovative values. Orange Fibre's goal is to produce 60 tons of fabrics from citrus waste per year.

6.10 Conclusions

Applying various extraction and purification techniques and analytical methods, it is possible to recover important components from citrus waste and further transform them into a wide range of added value products for the food, feed, pharmaceutical, and even fashion industries (Fig. 6.1).

These sustainable applications can also improve the economics of citrus fruit processing and cotemporally reduce its environmental impacts. Orange peel is a rich source of bioactive compounds that can be used as inexpensive food additives to provide beneficial effects to human health but also to enhance flavour, increase water and oil retention, and extend shelf life. The applications in the food industry also involve food packaging with bioplastic based on pectin and cellulose derived from orange waste. From an environmental point of view, the use of this residue reduces microbiological contamination and environmental pollution and can be used as the raw material to produce mineral bio-oil and bioethanol without the use of natural resources. Promisingly, recent studies point out how emerging technologies can successfully extract any compound type from pomace with superior yield and purity, process time reduction, and no effect on bioactivity of the molecules in comparison with conventional techniques, with a positive impact on the economic feasibility of the valorization of the biowastes, which has been far the most deterrent aspect for their use.

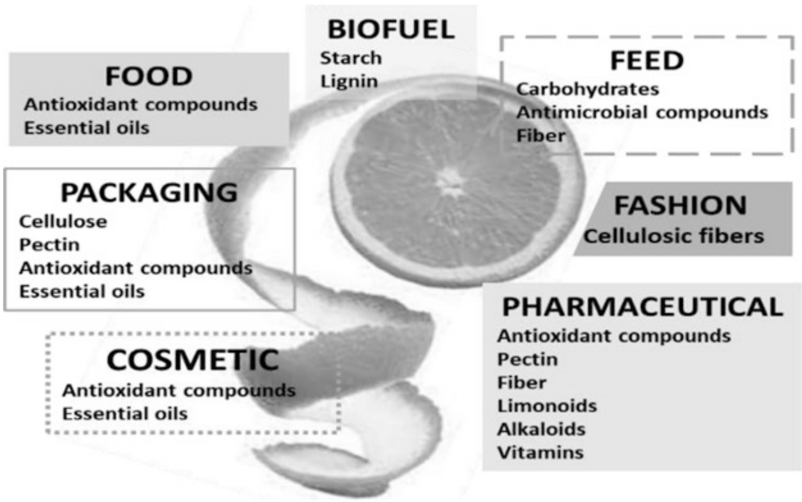

Fig. 6.1 Application areas of citrus processing byproducts, with relative key compounds

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Part II
Agriculture, Biomass, Foods and Beverages: Circular Economy and Sustainability

Chapter 7
Circular Economy in the Agri-food Industry. How Social Media Can Create Engagement?

Benedetta Esposito and Ornella Malandrino

Abstract The need to redesign production and consumption models to achieve sustainable development is widely recognized. In this context, the circular economy (CE) model, based on reduction, reuse, and recycling activities, has emerged as a powerful framework to succeed in this global trial. Scholars have highlighted that the engagement of the whole supply chain is essential to successfully shift from the traditional linear economic framework to the CE model, especially in the agri-food (AF) sector. Accordingly, stakeholder engagement plays a crucial role in this process. Recently, scientific literature has demonstrated that companies could use social media (SM) as a disclosure instrument to generate engagement between companies and their stakeholders. Starting from this background, this research aims to explore stakeholders' perceptions regarding the disclosure of CE practices and performance in the agri-food (AF) sector through SM.

Keywords Circular economy · Stakeholder engagement · AF sector · Social media

7.1 Introduction

The COVID-19 pandemic has intensified the social and environmental crisis on which our ecosystem relies. Accordingly, the urgency to change the actual production and consumption models based on the take-make-dispose paradigm has emerged. To do so, a transition towards a more sustainable paradigm is needed. In this scenario, the circular economy (CE) paradigm based on reduction, reuse, and recycling practices (3R) has been garnered as a successful approach to restrain the negative impacts of the current crisis (Merli et al. 2018). Scholars have demonstrated that the whole supply chain (SC) is called for this paradigm shift, since all

B. Esposito (✉) · O. Malandrino
Department of Management and Innovation Systems, University of Salerno, Fisciano, Italy
e-mail: besposito@unisa.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_7

SC actors must cooperate to successfully implement a circular production and consumption business model (Esposito et al. 2020). From this perspective, stakeholder engagement is acquiring a growing relevance to achieving this global goal. Indeed, if one of the SC actors does not share and implement the same circular principles in its operations, all the SC effort in being circular would become vain (Gupta et al. 2019). Consequently, public institutions, companies, associations, and citizens are called to act coordinately to stimulate the achievement of sustainable goals by adopting CE models (Stahel et al. 2016). Therefore, organizations adopting CE business models pay particular attention to communicating information about their CE strategies, policies, and practices to enhance stakeholders' awareness of sustainability issues and stimulate their collaboration in reaching companies' objectives. To do so, companies are using social media (SM) to engage with an extensive symposium of stakeholders (Pizzi et al. 2021).

Starting from this background, this chapter aims to investigate the perception of CE disclosure practices via SM in the agri-food (AF) industry. A content analysis of the Twitter posts published by three Italian AF industries from the beginning of COVID-19 has been performed following a coding framework developed in light of the CE paradigm. Furthermore, the communication direction and the balance level have been analysed.

7.2 Literature Review

Over the past few years, the CE notion has been extensively investigated, resulting in the elaboration of multiple concepts in light of several streams of research. Accordingly, the CE concept has been seen by some scholars as an "umbrella concept" for its characteristic of encompassing all the approaches previously mentioned to reach sustainable development (Blomsma and Brennan 2017). Several scholars have confirmed and demonstrated this proactive approach towards the engagement of all stakeholders in activating virtuous strategies for waste and loss reduction (e.g. Barnabè and Nazir 2022). Accordingly, companies, associations, and governments are called to provide comprehensive and reliable information on CE practices and policies (European Commission 2020). Accordingly, sharing sustainable and circular-related information is pivotal in building successful circular strategies (Esposito et al. 2021a). In this scenario, customers are also more engaged in environmental and sustainability issues. As a result, CE information disclosure is becoming essential to involve the last stage of SCs, the consumption stage, in changing their consumption models inspired by the 3R paradigm. Accordingly, industries are called to disclose CE information for two reasons. On the one hand, firms can obtain a competitive advantage by enhancing their corporate image. On the other hand, their stakeholders could be involved in their CE practices (Kazancoglu et al. 2021). Regarding the importance of this issue, academics have started inquiring about the function of CE strategy and practice disclosures (i.e. Jakhar et al. 2019; Unal et al. 2019; Scarpellini et al. 2020). To the best of the authors' knowledge, no scientific articles have examined CE disclosure to reach stakeholder engagement. Aiming to fill this gap, this study is developed using two theoretical backgrounds based on stakeholder (Carroll 2021; Freeman 1984) and legitimacy theories (Suchman 1995). In the AF sector, industries are asked to meet stakeholders' demand for accountability. The adoption of SM strategies to communicate sustainable actions can support the AF sector in enhancing stakeholder engagement by establishing a bidirectional dialogue between companies and SM users (Bellucci and Manetti 2017). Scholars have defined SM as supporting dialogic instruments for information pooling and sharing to grasp stakeholders' expectations (Bebbington et al. 2007). Hence, SM is incrementally becoming vital for CE transition since the compelling need to involve all SC actors in this paradigm shift (Esposito et al. 2021a). Furthermore, SM helps obtain stakeholder collaboration and bring legitimacy to become increasingly competitive. Starting from this background, this research aims to explore how AF firms engage with their stakeholders.

7.3 Methodology

This research aims to investigate the CE disclosure and the stakeholder engagement level of CE posts published by three AF companies on Twitter, defined as a proper social network for building engagement (Boons et al. 2017). Three large Italian companies have been chosen from the "AIDA Breau van Dijk International" database per capital market using the ATECO (ATtività ECOnomiche code) codes "10-food processing industries" and "11-beverage companies" in the Campania region. The dimension criterion has been chosen since the company's size affects its attitude towards circular and environmental investments (Giannarakis et al. 2020). Accordingly, larger companies can be considered more willing to disclose CE practices. All tweets published by each company from the ninth of March 2020 until the extraction data on the tenth of June 2022 were extracted, purified, and analysed using data mining techniques, since our research purpose was to explore the engagement level from Twitter's accounts on CE in the agri-food sector (AFS) during the pandemic and post-pandemic period. However, our analysis does not include Tweets published after the tenth of June 2022 and, as a consequence, shows only a partial view of the 2022 trend. Data mining was performed using the NVivo software. More specifically, the open-source extension "NCapture" drawing on the application programming interface (API) has been adopted to easily access Twitter's accounts (Reyes-Menendez et al. 2018). The data analysis was structured into three phases: (1) dictionary-based content analysis with NVivo, (2) manual content analysis, and (3) results integration. The authors have developed a coding framework presented in Table 7.1 to perform content analysis.

Moreover, to strengthen the analysis and investigate the type of content in terms of informing or interacting nature (Schroder 2021), two independent researchers carried out a manual content analysis through an empirically grounded approach. In detail, the coders classified the tweets as "informing" if they communicated an

Table 7.1 Circular economy glossary reclassified according to the 4R paradigm

Categories	Words
Reduce	Carbon footprint reduction; environmental impact reduction; raw materials reduction; waste reduction; emissions reduction
Reuse	Alternate materials; disassembly; durability; maintain; redistribute; refurbish; remanufacture; repair; reuse; upcycling; waste diversion
Recycle	Anaerobic digestion; compostable; composting; end-of-life; radio frequency identification; recyclability; waste conversion; water conservation
Redesign	Dematerialization; design; raw material conversion
General	Circular economy; biodiversity; closed loop; finite materials; green financing; regenerative production; renewable energy; renewable materials; renewable source; reverse logistics; sharing; virgin materials

Source: Barnabè and Nazir (2020) and "Glossary of Circular Economy"

action, an initiative, a goal, or a policy. Quite the opposite, the posts that show engagement with stakeholders have been classified as "interacting." Furthermore, this research has investigated the stakeholder engagement level, investigating the posts' communication direction. The tweets that enable a comment by an account were classified as "two-way communication"; alternatively, the posts were categorized as "one-way communication" (Schroder 2021). Furthermore, Krippendorff's alpha index (α) was calculated to prevent subjective interpretation and evaluate the intercoder reliability. The coefficient, computed on the first 25% of posts, equals 0.87. This value can be considered adequate since it is within the range of 1.00 (equivalent) and 0.00 (entirely different) (Krippendorff 1980).

7.4 Results and Discussion

The descriptive statistics of the total tweets published by the three companies from March 2020 to May 2022 are presented in the following section. The results show that 39.33% of the extracted tweets can be categorized as CE content concerning all tweets. Nevertheless, according to Esposito et al. (2020), our findings show that non-CE messages have a lower level of stakeholder engagement than CE messages. The retweet values are low since the highest portion of Twitter users is likely to interact with the content through the feedback mechanism, i.e. through likes. Regarding the classification of Tweets per company, Company C shows the highest number of likes and retweets for the CE messages (i.e. 119; 32), while considering the total messages published, Company A shows the highest number of likes (i.e. 178). Company B shows the lowest level of engagement and agreement with only five retweets compared to the 278 posts examined. The communication trend from the pandemic until data extraction shows that each company represents a progressive development trend in CE communication. The spread of COVID-19 has led to a growing interest in sustainability and CE-related issues. Furthermore, our results suggest an increasing awareness of AF industries and institutions of the need to be proactive in overcoming the crisis, allowing the disclosure of sustainability and CE performance to conquer legitimacy from stakeholders and engage with them in the restart of the whole AF SC. The CE tweets have been classified according to the 4R analytical framework developed. The descriptive statistics of each CE side (reduce, reuse, recycle, redesign, and general) indicate that the CE disclosure of the AF companies examined has been mainly focused on the “recycling” dimension both for Company A (i.e. 37.5%) and Company B (i.e. 25.67), while the “reduce” dimension is the most disclosed by Company B (i.e. 36.84). In contrast, the reuse and redesign dimensions are generally less disclosed. Company A does not disclose reuse messages, while Company B does not provide redesign content in their tweets. Company C, instead, equally unveils each dimension, focusing on reducing and recycling practices. Our findings are in line with other research on CE disclosure (e.g. Barnabè and Nazir 2020, 2022), according to which the interest in recycling practices is antecedent concerning the spread of CE models and – in turn – there has been a greater awareness among stakeholders. Since recycling practices are more straightforward than reducing, reusing, and redesigning, disclosing these issues is easier for companies, non-profit organizations, and policymakers. With regard to the engagement level, the highest content that has generated engagement among users are the recycling posts for each Company A and B (i.e. 50% for Company A; 46.98% for Company B). Company C instead shows the highest percentage of likes for the reduced posts (i.e. 32.43%). However, a low rate of retweets has been retrieved from the analysis in general for each company. Regarding the direction and balanced nature of the published posts from 2020 to 2022, the lowest percentage of CE messages is classified as one-way communication (i.e. 17.90%), while 82.09% provides two-way communication content. The communication balance shows that an interacting nature characterizes 57.02% of the CE posts published by the companies, while 45.56% have a communicating nature.

7.5 Conclusions

In conclusion, the preliminary findings presented have outlined that SM have the potential to communicate and disclose to a whole forum of stakeholders CE-related information, such as practices, initiatives, and performances. Moreover, SM could also be useful tools to stimulate a dialogue with stakeholders and society. This engagement can support AF companies in raising awareness among social network users of the need to be part of the CE transition to allow ecosystem survival. In fact, stakeholder dialogue is a pivotal topic that enables AF managers to encompass stakeholders’ expectations in their strategies. This study can be helpful for both scholars and AF managers who can count on our findings to explore and adopt SM to disclose their commitment towards CE to enhance the stakeholder engagement level, stimulating the digital debate. In the end, institutions can establish frameworks and guidelines for CE reporting through SM at the European and international levels. This study also provides some theoretical implications. Although the literature on stakeholder engagement and CE disclosure is still poor, SM can be considered one of the most helpful tools for creating a dialogue between AF companies and their stakeholders. Accordingly, scholars can explore this research window in depth to provide practical recommendations and proposals to AF managers to establish engaging disclosure strategies. Moreover, scholars can explore CE disclosure via SM according to different theoretical perspectives. Nevertheless, this research has some limitations. First, it is limited to a defined period. Consequently, future research could employ different instruments to extract and analyse data, following other analytical frameworks. Furthermore, academics can investigate the use of other SM, such as Instagram, Facebook, and LinkedIn, or perform the analysis on a higher company sample in different geographic areas.

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Chapter 8
Circular Urban Food Policies: The "Food in the Circular City" Model Promoted by the City of Prato

Leonardo Borsacchi, Gabriele Feligioni, and Patrizia Pinelli

Abstract Urban food policies are highly relevant among the governance policies of a city. By putting food at the centre of a system of relations at a territorial level, it is possible to create an integrated system. Modern urban food policies also incorporate the principles of sustainability and the circular economy.

This chapter presents the "'Food in the Circular City" model, developed within the framework of the "Prato Circular City" strategy, promoted by the Municipality of Prato to accelerate the city's circular transition. This model aims to achieve a balance between supply and demand for agricultural products for the city, which does not necessarily have to achieve self-sufficiency but rather an integrated and harmonized system of relations between city and countryside that optimizes production to meet real needs in terms of quality and quantity. The affirmation of a circular urban agri-food system and of this integrated vision of food production and consumption also requires access to scientific knowledge, technologies, incentives, and financial facilities available to all interested parties. The aim of the "Food in the Circular City" model is the creation of a short and multifunctional supply chain, constituting an overall design for the enhancement of Prato's agri-food offer.

Keywords Circular economy · Urban agriculture · Urban food policies

L. Borsacchi (✉) · G. Feligioni
ARCO (Action Research for CO-Development) – PIN, University of Florence, Prato, Italy
e-mail: leonardo.borsacchi@pin.unifi.it; gabriele.feligioni@arcolab.org

P. Pinelli
Department of Statistics, Computer Science, Applications "Giuseppe Parenti" (DiSIA), University of Florence, Florence, Italy
e-mail: patrizia.pinelli@unifi.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_8

8.1 Introduction

Cities, over the centuries, have taken on different structures and functions. Thus, a city can be considered an ecosystem depending on other territories both to acquire resources needed (i.e. energy, water, etc.) and to dispose of what it has not fully metabolized (Caroli and Magarini 2015). Regarding the production processes, according to the circular economy principles, the products must be designed and optimized to facilitate disassembly, reuse, and recycling; sharing must be promoted; and negative externalities must be identified and eliminated, such as air, water, and soil pollution (Giorgi et al. 2017).

Regarding food, cities have left their original function of production to peripheral areas. Currently, population growth at the urban level requires the adoption of new policies that favour sustainable solutions for food production. Urban agriculture poses itself as a solution, offering different options that can be adapted to all contexts and models and offering various advantages in productive, environmental, economic, and social terms. In recent years, the issue of creating food-based systems has become increasingly central (Steel 2020) to counteract the increasing number of people moving to cities and to make these places food sustainable, aiming for a green transition. This is at the heart of the European Green New Deal (European Commission 2021a) and the so-called "Farm to Fork" (European Commission 2021b) strategies. The adoption of a circular economy approach in cities should necessarily involve administrators, productive activities, associations, and citizens. It is desirable that this sharing of intentions translates into concrete actions to promote innovation, regeneration, and cohesion as the accelerating factors of the transition into a circular city model (Borsacchi and Pinelli 2019).

Various examples of food policies already in place include the Milan Food Policy, as a shared vision of the city's future relationship with food, which includes key actions to harmonize the various projects the administration is pursuing on the topic of food (Comune di Milano 2020), or the newly launched Rome Food Policy (Minotti et al. 2022). In addition, virtuous and sustainable models of urban agriculture have been taking shape within cities for years, combining food issues with environmental and social aspects, i.e. in Paris (Paris.it 2020), Berlin, and Turin (Orti generali 2022). In recent years, the municipality of Prato has decided to develop an urban agri-food model, putting food at the centre of a system based on sustainability, circularity, and high social impact policies. This chapter describes the results of the development of the urban agri-food model of the City of Prato, finally called "Food in the Circular City."

8.2 Material and Methods

To develop its urban agri-food model, the municipality of Prato decided to use, at the methodological level, the "Prato Circular City" (PCC) platform (Prato Circular City 2020), which through a participatory process with qualified stakeholders aims to outline policies and actions for the city's circular transition. In 2020, with the launch of PCC, to accelerate the circular transition at the urban level, the city administration of Prato included sustainable urban agriculture as one of its four priority topics for discussion. The authors have facilitated the process by coordinating the meetings of the PCC. Structured as a living lab, PCC operates to overcome the barriers that slow down the transition to the circular economy. For this reason, PCC focuses on better regulation, better funding, and better knowledge. Living labs work on specific topics to formulate a hypothesis for an action plan (Borsacchi et al. 2021).

On the topic of sustainable urban agriculture, the working group involved the Municipality of Prato, associations of producers, agri-food operators, distributors, and the university to discuss food policies, urban agriculture, and food waste reduction. On these issues, the priority was to define policies and to encourage the overcoming of obstacles to promote the consumption of food from short supply chain circuits and contribute to the local urban and peri-urban economy of the area.

8.3 Results and Discussions

Within the territory of the province of Prato, although the predominant economic sector is textiles, there is also widespread agricultural production, which we can observe in the areas north and south of the province, especially in Val di Bisenzio and the Montalbano biodistrict. According to official data provided by the municipality of Prato, the number of active farms in the province is 418, including 162 in Prato and 83 in the municipalities of Val di Bisenzio. The agricultural area is 3600 hectares, a quarter of which is devoted to organic farming. Since 2009, short supply chain market initiatives (e.g. Terra di Prato market) have been widespread in the area, with positive spin-offs for local agricultural producers and the promotion of healthy eating styles based on seasonality and typicality. At the same time, collective brands of agricultural producers with good local recognition are active in the area (e.g. "*Gran Prato*" in addition to the "*Terra di Prato*"). The role played in the past by the Province of Prato in promoting food specialties of the territory has been gradually scaled down due to the depowering of the provinces in Italy. The municipalities of the Province of Prato have therefore launched paths of valorization, often linked to the enhancement of the territory in terms of tourism.

Starting from the weak points of Prato's urban and peri-urban agri-food sector, which emerged during the living labs, barriers and possible solutions have been outlined. Table 8.1 summarizes the proposed action plan.

Currently, there is a substantial lack of data on agri-food production in the area, which prevents the definition of strategic and systemic policies, in terms of both planning and real needs. Information derived from periodic censuses or data collection carried out by individual associations does not solve the problem. On the front of better regulations, the possibility of relating with policymakers through aggregated forms and business networks could help strengthen the demands presented and favour their acceptance. In fact, agricultural producers expressed the need to have in public procurements a duration of more than 3 years for the supply of

Table 8.1 Problems and possible solution for the creation of the circular and integrated system

Problems encountered	Barrier	Action proposed
Short-term public procurement for the food supply in public canteens. Promotion of short supply chains	Better regulation	Public procurement with a duration of more than 3 years to encourage local producers to convert to organic production
At the local level, more attention to policies for the textile sector	Better knowledge and better funding	Valorization of agri-food sector and creation of specific policies to enhance collaboration and awareness
Fragmenting farmland	Better knowledge and better funding	Mapping of uncultivated land and the need of funds for land acquisitions
Poor generation turnover	Better knowledge and better funding	Approaching young people through the promotion of sustainable, circular agriculture and using digital tools.
Agricultural fields run by Chinese	Better knowledge	The growing phenomenon to be better known, including in relation to agricultural practices applied
Water scarcity and the possibility of reuse of treated wastewater for agricultural purposes	Better knowledge	Awareness raising
Creation of urban gardens	Better knowledge	Active citizenship activities and promotion of healthy and sustainable lifestyles

agricultural products to school canteens, especially in the case of supplying organic products. They also highlight, for example, the need to be able to obtain long-term concessions, preferably 10 years, for the organization and management of public spaces used as markets. Moreover, on the better financing front, aggregate forms of enterprises can identify suitable financing opportunities on more relevant calls and provide support for network enterprises in preparing individual financing applications.

Starting from the proposed action plan, stakeholders decided to focus on three specific actions to push the circular transition in the agri-food sector at the local level:

1. Reuse of treated wastewater for agricultural purposes: In Prato, the presence of the urban and industrial wastewater treatment plant (i.e. Gestione Impianti Depurazione Acque S.p.A. (GIDA)), together with recent European legislation on the reuse of treated wastewater, can place the city as a prime location for the study and subsequent use of this water source for irrigation of arable land. The working group aims to bring together agricultural operators, businesses, associations, and water treatment plants to define the feasibility and methods of creating an integrated water system that aims, from a circular economy perspective, to reuse treated wastewater, generating a reduction in the use of water from groundwater or surface water bodies.
2. Short supply chain: The working group intends to promote with targeted actions the concept of proximity inherent in the essence of the "short supply chain" system, thus fitting within the European "Farm to Fork" strategy. This may also

fit within recovery and redevelopment projects, with a view to the circular economy of peri-urban areas.

3. Development of urban gardens: The working group intends to address raising awareness among citizens about the possibilities of horticultural production, moving from good cultivation practices to promote healthy food lifestyles related to the seasonality and typicality of produce.

Moving from the findings of living labs of PCC, the “Food in the Circular City” model was developed. This model aims to create a harmonized integrated system of relationships between city and countryside that optimizes production to the real needs in quality and quantity through the enhancement of networks between food operators along the chain.

Figure 8.1 shows the “Food in the Circular City model.” Based on circular economy principles, the model starts from urban and peri-urban vegetable gardens (which should be private, social, or hydroponic). The use of treated wastewater and

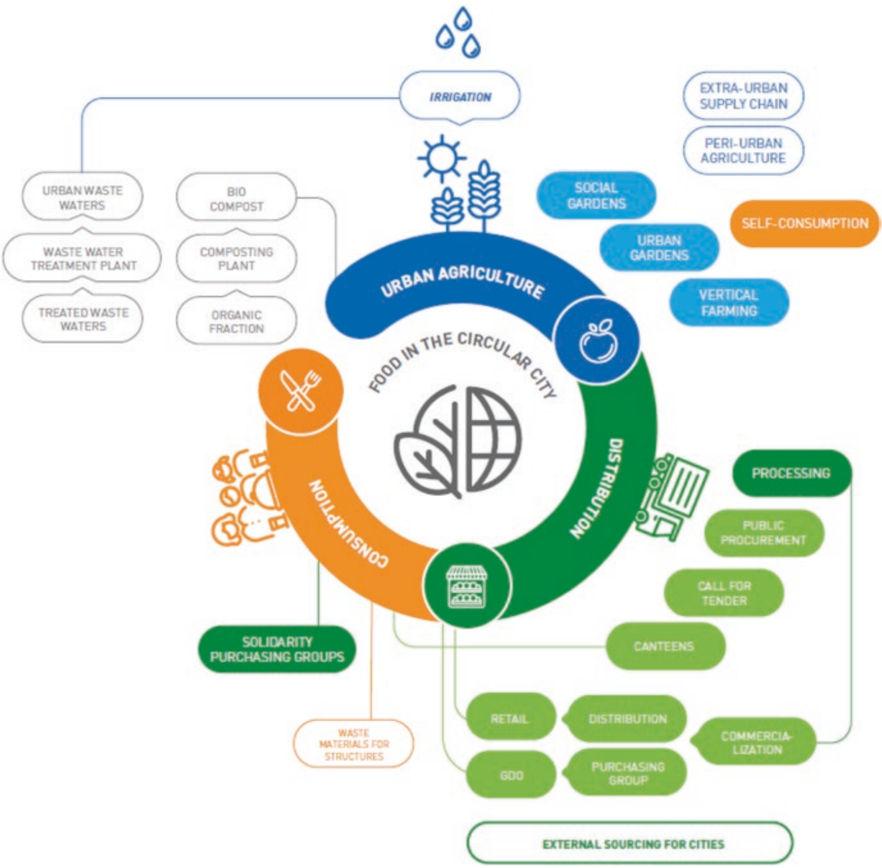

Fig. 8.1 “Food in the Circular City”. (Source: Authors (English version from the original Italian version included in “Next Generation Prato” (2022)))

biocompost (from the collection and composting of organic fractions) could be considered a good circular practice. Agri-food production (i.e. fruits and vegetables) can reach consumers through three possible routes: (i) self-consumption; (ii) sales through solidarity purchasing groups (SPGs); and (iii) processing: From this stage, they move towards marketing within the large-scale retail trade or retail sales, or they can be included in supply specifications and public procurement. Following these three routes, the products will be consumed, resulting in waste, which, as mentioned earlier, will be collected and taken to the composting plant from which the compost used in the production of fruit and vegetables can be obtained.

8.4 Conclusions and Future Perspectives

The "Food in the Circular City" model aims to achieve a balance between the supply and demand of agricultural products for the city of Prato. Establishing a circular urban agricultural system and this integrated vision of food production and consumption also requires access to scientific knowledge, technologies, incentives, and financial facilities available to all stakeholders. For this, adequate resources will be needed to promote the enhancement of networks between agricultural producers, processing and marketing companies, catering, and tourist accommodation with the aim of creating short and typical supply chains in an overall design of enhancing Prato's agri-food supply. In the continuation of the activities of the Prato Circular City, listening, collaboration, and full involvement with the various stakeholders will be essential to achieve the objectives set.

Disclaimer Prato Circular City is a strategy of the Municipality of Prato promoted by the Councillorship for Economic Development, Innovation and Digital Agenda and the Councillorship for Urban Planning, Environment and Circular Economy, with the support of the local Europe Desk office. The technical–scientific coordination is carried out by the Circular Innovation and Sustainable Commodities Unit of ARCO – PIN University of Florence. The views expressed herein are those of the authors and therefore do not necessarily reflect the official opinion of the Municipality of Prato.

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Chapter 9
S-LCA Applied in a Research Project and Social Conditionality of the New Common Agriculture Policy 2023–2027

Alfredo Ernesto Di Noia, Giuseppe Martino Nicoletti, Giulio Mario Cappelletti, and Carlo Russo

Abstract We contributed to the research project titled 'Innovations in Organic Farming to Improve the Sustainability of Apulian Farms for Cereals and Industrial Crops'. We aimed to define a new agroecological model based on the crop rotation of some of the main Apulian herbaceous crops (industrial tomatoes, durum wheat, and legumes). We also aimed to improve the competitiveness of organic crops through experimentation with pilot farms to measure sustainability. In 2021, the reform of the Common Agriculture Policy (CAP) 2023–2027 introduced a new mechanism of 'social conditionality', (SC), relating to the conditions of workers, to which obtaining income support is linked. The application of social conditionality (SC) on a voluntary basis is expected to occur from 2023 to 2025 and then becomes mandatory. The social life cycle assessment (S-LCA) methodology was used in the project to assess social sustainability. The chapter aims to define the S-LCA methodology to be implemented in the project, which includes the requirements of the SC of the new CAP 2023–2027, for the health and safety subcategory and for the new employment relationship subcategory.

Keywords Social sustainability · S-LCA · Organic farming · LCA · Social conditionality · Common Agriculture Policy 2023–2027

9.1 Introduction

We contributed to the research project titled 'Innovations in Organic Farming to Improve the Sustainability of Apulian Farms for Cereals and Industrial Crops'. We aimed to define a new agroecological model based on the crop rotation of some of

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A. E. Di Noia (✉) · G. M. Nicoletti · G. M. Cappelletti · C. Russo
Department of Economics, Management and Territory, University of Foggia, Foggia, Italy
e-mail: alfredo.dinoia@unifg.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_9

the main Apulian herbaceous crops (industrial tomatoes, durum wheat, and legumes). We studied solutions and innovations to improve the competitiveness of organic crops through experimentation using pilot farms to achieve increased productivity and sustainability. In 2021, the reform of the Common Agriculture Policy (CAP) 2023–2027 introduced a new mechanism of 'social conditionality' (SC), relating to the conditions of workers, for whom obtaining income support is linked. The social life cycle assessment (S-LCA) methodology was used in the project to assess social sustainability. It provided for the LCA approach (ISO 2021) and aimed to achieve the objectives of the 2030 Agenda. The chapter aims to define the S-LCA methodology to be implemented in the project, including the social conditionality (SC) requirements of the CAP 2023–2027. We analyse the adoption of S-LCA in the context of workers (as stakeholders) for the health and safety subcategory and for the new employment relationship subcategory according to United Nations Environment Programme guidelines updated in 2020 (Benoît Norris et al. 2020).

9.2 New CAP and Social Conditionality

The reform of CAP 2023–2027, Regulation (European Union, EU) 2021/2115, establishes rules on support for strategic plans to be drawn up by member states. Article 14 introduces the SC by which farmers and other beneficiaries receive direct or annual payments (OJEU 2021). The payments are subject to an administrative penalty if they do not comply with the requirements related to respect for certain fundamental principles according to applicable working and employment conditions or employer obligations arising from the legal acts (in Annex IV). The main reason for the introduction of SC lies in the widespread recognition of abuses observed on farms employing a large workforce, especially seasonal workers. Among the socioeconomic impacts of the CAP, employment is one of the most important factors. Indeed, employment has been the only consistently relevant topic in studies carried out since 2005 (Lillemets et al. 2022). Finally, we note that the application of SC on a voluntary basis is expected to occur from 2023 to 2025 and then become mandatory. In addition, the European Commission will examine the functioning and scope of this mechanism by 2027 (OJEU 2021).

9.3 Material and Methods

In applying the S-LCA methodology according to ISO 14040:2021 (ISO 2021), we used the guidelines of the United Nations Environmental Programme updated in 2020 (Benoît Norris et al. 2020) and the related methodological sheet updated in

2021 (Traverso et al. 2021). Attention has been given to the context of the workers as stakeholders in the health and safety impact subcategory and for the new employment relationship in relation to the two areas of social conditionality:

Health and safety by Directive 89/391/EEC (OJEC 1989) to encourage improvements in the safety and health of workers and Directive 2009/104/EC (OJEU 2009) on the minimum safety and health requirements for the use of work equipment by workers (Tables 9.1 and 9.2) and Employment by Directive 2019/1152 (OJEU 2019) on transparent and predictable working conditions (Table 9.3).

We employed the S-LCA methodology for the evaluation of the social sustainability of the agroecological model experimented within the research project. Its system boundaries extend from the '*gate of the firm to the gate of the product collection center, and any byproducts*', according to the circular economy.

Subsequently, we identified the social performance indicators based on the reference documents (Benoît Norris et al. 2020; Traverso et al. 2021; Harmens et al. 2022) and the European legislation referred to by the SC (Tables 9.1 and 9.3). We used the indicators to realize the impact assessment in the scale reference (not covered in this chapter).

Therefore, we considered the indicators in both the phase of formulating the questions of the S-LCA Questionnaire to be administered to the owner and workers of the pilot farms of the project and the verification phase of the related documents made available.

Finally, we associated these questions with the respective articles of the European Directives considered for the SC of the CAP.

Table 9.1 Measures to encourage improvements in the safety and health of workers at work (Directive 89/391/EEC) objectives of SC, CAP 2023–2027

Art.	Directive 89/391/EEC
5	General provision defining employer's duty to ensure workers' safety and health
6	General obligation of employers to take measures necessary to protect safety and health, including prevention of risks and provision of information and training
7	Protective and preventive services: Worker/s to be designated for health and safety activities or competent external service to be engaged
8	Employer to take measures for first aid, firefighting, and evacuation of workers
9	Obligations of employers regarding assessment of risks, protective measures, and equipment, as recording and reporting of occupational accidents
10	Provision of information to workers on safety and health risks and protective and preventive measures
11	Consultation and participation of workers in discussions on all questions relating to safety and health at work
12	Employer to ensure workers receive adequate safety and health training

Source: Personal elaboration from OJEU (1989)

Table 9.2 Minimum safety and health requirements for use of work equipment by workers (Directive 2009/104/EC) objectives of SC, CAP 2023–2027

Art.	Directive 2009/104/EC
3	General obligations to ensure that work equipment is suitable for work to be carried out by workers without impairment to their safety or health
4	Rules concerning work equipment: Equipment must comply with the directive and established minimum requirements and must be adequately maintained
5	Inspection of work equipment: Equipment to be inspected with periodic inspections by competent persons
6	Work equipment involving specific risks to be restricted to persons tasked with using it and all repairs, modifications, and maintenance to be performed by designated workers
7	Ergonomics and occupational health shall be taken fully into account by the employer
8	Workers to receive adequate information and, where appropriate, written instructions on the use of work equipment
9	Workers to receive adequate training, including training on any risks

Source: Personal elaboration OJEU (2009)

Table 9.3 Transparent and predictable working conditions (Directive 2019/1152) objectives of SC, CAP 2023–2027

Art.	Directive 2019/1152
3	Employment conditions to be provided in writing ('employment contract')
4	Assurance that agricultural employment is subject to an employment contract
5	Employment contract to be provided within first 7 days of working
6	Changes to the employment relationship to be provided in the form of a document
8	Probationary period as defined in national law or practice
10	Conditions regarding minimum predictability of work
13	Mandatory training provided to worker free of cost, count as working time

Source: Personal elaboration OJEU (2009)

9.4 Results and Discussions

Tables 9.4, 9.5 and 9.6 show the questions of the S-LCA Questionnaire associated with the respective articles of the European Directives relating to SC (Tables 9.1, 9.2 and 9.3). This association will make it possible to assess the level of social sustainability and compliance of the firm with the SC simultaneously to reduce the possibility of losing the benefits of the CAP.

According to Laurent and Nguyen (2022), the growing complexity of farm labour organization generates needs for new types of advice, including those required to meet the requirements of SC. In this sense, the S-LCA methodology (Benoît Norris et al. 2020) can represent one of those possible new types of advice. Farmers need management systems to avoid losing the benefits of the CAP, which

Table 9.4 List of questions on the S-LCA Questionnaire (Health and Safety subcategory) that satisfy the SC of the CAP 2023–2027 to meet Directive 89/391/CEE (OJEC 1989)

Questions relating to the Health and Safety subcategory in the S-LCA Questionnaire	Article of the directive
1. Is there a documented workplace health and safety policy on the farm? If the answer is affirmative, indicate how the policy is communicated to ensure workers are adequately informed of the policy and the measures adopted relating to the occupational health and safety risks.	6–9 – 10
2. Are the general measures necessary for the protection of safety in the workplace adequate? If the answer is affirmative, indicate the main ones (information, training, equipment, procedures, etc.).	5–6 – 10 – 12
3. Have preventive measures and emergency procedures for accidents and/or injuries been adopted? If the answer is affirmative, indicate the main ones (information, training, equipment, procedures for first aid, firefighting, and evacuation of workers, etc.).	6–8 – 9 – 10 – 12
4. Have employees been appointed for the responsibilities connected with activities relating to health and safety in the workplace or have competent external services been used? 5. Has the employer appointed a ‘person in charge’ who must supervise compliance with company provisions on health and safety at work and who is obliged to intervene and suspend the activity of workers who do not comply with the provisions, even in the case of deficiencies in the means and work equipment and in any dangerous condition detected during surveillance? 6. Has the employer/manager adequately informed (tracing this activity) the person in charge of these new supervisory obligations and the methods of communicating violations? 7. Does the person in charge of reporting this supervisory activity in written form also have to prove their effectiveness of action? 8. Has the employer registered all the tasks and activities for which training is mandatory with the relevant workers to be trained for the correct and safe use of equipment, machines, systems, substances, and devices, including personal protection? 9. Has the employer identified the experienced people who need to deliver the training? 10. Has a training calendar been drawn up with a relative register (paper or electronic, etc.) to track the training interventions?	7
11. Does the employer offer any documents and/or training programs on the risks of injury for workers? 12. How often (month, year, etc.) are documents and/or training programs on the risks of accidents for workers created end/or updated? 13. Does the employer have any recordings (documents, audio, video, etc.) of the latest accident prevention training program?	6–12
14. Is there a provision for consultation of workers and their participation in discussions on all issues relating to safety and health protection in the workplace?	11

over the years has increasingly represented the (real) profitability of agricultural activity (in southern Italy, approximately 50%) (Frascarelli et al. 2021).

9.5 Conclusions and Future Perspectives

The use of S-LCA for the measurement of social sustainability in the research project makes it possible to monitor compliance with European legislation of the SC. Therefore, the S-LCA in the voluntary testing phase of the SC could provide

Table 9.5 List of questions on the S-LCA Questionnaire (Health and Safety subcategory) that satisfy SC of the CAP 2023–2027 to meet Directive 2009/104/EC (OJEU 2009)

Questions relating to the Health and Safety subcategory in the S-LCA Questionnaire	Article of the directive
1. Is there a documented workplace health and safety policy on the farm? If the answer is affirmative, indicate how the policy is communicated to ensure workers are adequately informed of the policy and the measures adopted relating to the occupational health and safety risks.	8
3. Have preventive measures and emergency procedures been adopted for accidents and/or injuries? If the answer is affirmative, indicate the main ones (information, training, equipment, procedures for first aid, firefighting, evacuation of workers, etc.)	8–9
11. Does the employer offer any documents and/or training programs on the risks of accidents for workers? 12. How often (month, year, etc.) are documents and/or training programs on accident risks for workers created/updated? 13. Does the employer have any recordings (documents, audio, video, etc.) of the latest training program on accident prevention?	9
15. Is the equipment adequate for the work that workers have to carry out without compromising their health and safety in the workplace?	3
16. Is work equipment properly maintained?	4
17. Do any measures provide for the verification and/or calibration of work equipment after installation and periodic checks by competent personnel?	5
18. Is the use of work equipment that presents a specific risk reserved only for assigned workers? 19. Of such specific risky equipment, are all repairs, conversions, and maintenance performed only by designated workers?	6
20. Are there specific indications on ergonomics and health in the workplace?	7

Table 9.6 List of questions on the S-LCA Questionnaire subcategory ‘Employment relationship’ that satisfy SC of the CAP 2023–2027 to meet Directive 2019/1152 (OJEU 2019)

Questions relating to the ‘Employment relationship’ subcategory in the S-LCA Questionnaire	Article of the directive
21. Does a written contract define the relationship between the employer and workers (with rights/duties and responsibilities of each)?	3–4
22. Do the workers receive a copy of the signed employment contract?	3–4
22.1. If the answer is affirmative, do the workers receive the signed employment contract within 7 days?	5
23. Is there a written amendment, possibly recorded in a register of contracts?	6
24. If the employment legislation provides for a trial period, is it carried out?	8
25. Are there conditions of minimum predictability of the work?	10
26. If the labor legislation provides for compulsory training, is it provided?	13

valid support to prevent and promptly manage any lack of compliance. In this sense, the S-LCA methodology according to the achievement of the SC could be useful for all EU member states. The S-LCA Questionnaire’s items are currently being administered. Future research will concern the empirical verification of the usefulness of the S-LCA methodology for the purposes of the SC.

Acknowledgements This research was supported by the Apulia Region (SOFT Project number 94250035584 – under the Puglia 'PSR 2014–2020', submeasure 16.2).

Authors' Contributions A.E. Di Noia carried out the bibliography and the collection and processing of the data. G.M Cappelletti and A.E Di Noia carried out the application of the methodology, and G.M. Nicoletti and C. Russo reviewed the chapter.

Appendices

Appendix A

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Chapter 10
The S-LCA Applied in a Research Project: "Smallholders Including Farmers" Impact Subcategory

Alfredo Ernesto Di Noia, Giuseppe Martino Nicoletti, Giulio Mario Cappelletti, and Carlo Russo

Abstract To overcome the difficulties of the market and some supply chains' organic production being more efficient and competitive, we contributed to the research project "Innovations in organic agriculture to improve the sustainability of Apulian farms for cereals and industrial crops." We aimed to define an agroecological model based on crop rotation of the main Apulian herbaceous crops: industrial tomatoes, durum wheat, and legumes. We used this model to measure organic crop sustainability. We assessed social sustainability using the social life cycle assessment (S-LCA) methodology, which envisages the LCA approach. After the first United Nation Environment Program (UNEP) / Society of Environmental Toxicology and Chemistry (SETAC) guidelines were published in 2009, they were updated in 2020. Furthermore, these guidelines were integrated with methodological sheets in 2013 and 2021. However, these approaches do not include reference scales with specific indicators to assess every subcategory's impact. We aimed to define the application of the S-LCA methodology to evaluate the new impact subcategory "Smallholders including farmers" (stakeholder "Workers"), introduced in the new 2020 guidelines. We also aimed to elaborate on the relative reference scale to be adopted in the impact assessment.

Keywords Social sustainability · S-LCA · Innovation · Organic farming · Life cycle assessment · Subcategory impact

A. E. Di Noia (✉) · G. M. Nicoletti · G. M. Cappelletti · C. Russo
Department of Economics, Management and Territory, University of Foggia, Foggia, Italy
e-mail: carlo.russo@unifg.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_10

10.1 Introduction

To overcome the difficulties of the market, some supply chains' organic production is more efficient and competitive, and we contributed to the research project "Innovations in organic agriculture to improve the sustainability of Apulian farms for cereals and industrial crops." We aimed to define an agroecological model, characterized using solutions/innovations, based on the rotation of the main Apulian herbaceous crops: industrial tomatoes, durum wheat, and legumes. This model is being tested in pilot farms to measure productivity gains and assess organic crop sustainability. We assessed social sustainability using the social life cycle assessment (S-LCA) methodology, which provides for the life cycle assessment (LCA) approach according to ISO 14040: 2021 (ISO 2021) and aims to achieve multiple objectives of the sustainable development goals (SDGs) of Agenda 2030. However, the implementation of the S-LCA approach for approximately 20 years has not answered critical questions regarding methods, frameworks, paradigms, and indicators (Huertas-Valdivia et al. 2020). If we use the S-LCA methodology according to UNEP (2020) and UNEP (2021), in a context of limited diffusion in the business system, we do not have available a specific reference scale to assess each subcategory's impact. We aimed to define the application of the S-LCA methodology in the evaluation of the new subcategory "Smallholders including farmers" (stakeholder "Workers"), introduced in the 2020 guidelines (UNEP 2020). We also aimed to elaborate the relative reference scale to be adopted in the impact assessment.

10.2 Review of the Literature

The first guidelines for the adoption of S-LCA methodology were published in 2009 (UNEP/SETAC 2009). The 2020 update (UNEP 2020) proposed methodological solutions based on the experience gained. Furthermore, these guidelines were integrated with methodological sheets in 2013 (UNEP/SETAC 2013), which were updated in 2021 (UNEP 2021). The new guidelines introduced a new subcategory of impact: "Smallholders including farmers" (stakeholder "Workers"). Furthermore, these guidelines proposed the "Reference Scale Approach" (also known as Type I or Reference Scale S-LCIA) for the assessment of social performance (UNEP 2020). The evaluation of the results is associated with the quality of the data collected, which is not the subject of this study. Many of the useful indications and a scale reference for this evaluation are available in other suitable practice manuals for social-value assessment (Harmens et al. 2022). Finally, despite the scientific community's growing interest (Arcese et al. 2018; Di Cesare et al. 2018; Huertas-Valdivia et al. 2020; Mattioda et al. 2015; Petti et al. 2018a; Traverso et al. 2020), significant implementations of the S-LCA methodology in relation to food issues remain uncommon (UNEP 2020).

10.3 Material and Methods

The selection of the S-LCA methodology to measure the social sustainability of the new agroecological model of the research project aligned with the 2020 Guidelines (UNEP 2020) and related Methodological Sheet 2021 (UNEP 2021) as well as the assessment path of ISO (UNI EN) 14040 (ISO 2021). Therefore, the goal and scope of the S-LCA study was the evaluation of the social sustainability of the model tested in the SOFT project. The system boundaries are defined as the "gate of the farm to the gate of the product collection centre, and any byproducts," according to the circular economy. The paper aims to adopt the S-LCA methodology relating to the new subcategory "Smallholders including farmers" (stakeholder "Workers") in the research project. The Subcategory Assessment Method (Sanchez Ramirez et al. 2014) was taken into consideration, as it was already used to produce tomatoes (Petti et al. 2018b) and was the subject of the experiments in the research project. Subsequently, we proceeded to select the inventory indicators to identify the "small farmers" based on the characteristics envisaged by the reference documents and by European and Italian legislation because there is no shared definition (UNEP 2021). These indicators were the subject of the questions of the S-LCA questionnaire to be administered to the pilot farms (owner and workers) of the research project and in the verification of the related documents made available. Finally, based on the inventory indicators, we developed a reference scale aligned to UNEP (2020).

10.4 Results and Discussions

Regarding the definition of "Smallholders including farmers" (stakeholder "Workers"), we considered the following characteristics important: size, socioeconomic aspects, and the endowment of resources. This definition also includes farming companies, partnerships, and privately owned sole proprietorships that have fewer employees and/or lower annual revenues than a full-sized firm or company (UNEP 2021). In particular, the inventory indicators taken into consideration are size, direct and/or family work contribution, level of CAP support, inclusiveness, productivity, access to services, commercial relations, type of farmer, and actions/interventions, including organic ones for data acquisition to calculate the indicators. The size indicator adopted is more than 2 ha (with a focus on income crops) (UNEP 2021). Furthermore, in the preliminary phase, we assumed a size of less than 5 ha for two reasons:

- Small farmers scheme for European Union (EU) CAP support (OJEU 2013).
- New legislation on organic farming; this dimensional level allows for group organic certification (OJEU 2018).

The latter reason becomes strategic for the purposes of the research project because the lead partner is represented by an organization of producers in the specific sector that represents over 60 organic farms. Another indicator that we considered for the definition of small business is direct and/or family work, which comprises at least one third of the total workforce needed. We borrowed this indicator from the figure of the "small agricultural entrepreneur" in the Italian legislation (art. 2135 Italian Civil Code). In addition, for the definition of small business, we considered the "number of employees" indicator of approximately two employees based on sector statistics (herbaceous crops) (Tarangioli and Pupo D'andrea 2021). In addition, for the definition of "small agricultural enterprise," we assumed a maximum EU support payment in the CAP of 1250 €/ha (OJEU 2013).

Finally, we considered some inventory indicators from Seville et al. (2016) and UNEP (2021) concerning inclusivity, productivity, access to services, commercial relations, next-generation farmers, and actions/interventions that increase awareness of indicators and company results in the supply chain (Table 10.1).

We used the inventory indicators to adopt the "reference scale approach," which allowed for the development of a reference scale as an ordinal scale that contains five levels, each of which corresponds to a performance reference point (PRP) (UNEP 2021) (Harmens et al. 2022). We checked the PRPs between −2 (extreme noncompliance) and +2 level (ideal performance), where level 0 (compliance with local laws and/or international standards) represents the minimum level of acceptability of the evaluation of the inventory related to the "Smallholders including farmers" subcategory (Table 10.1).

Table 10.1 Inventory indicators identified for the subcategory "smallholders including farmers" of the workers stakeholder

PRP	Scale-level definition	Inventory indicators
+2	The farm has prioritized efforts to improve the results of indicators relating to smallholder issues in its organization and across the entire value chain, including customers, and can demonstrate its approach's success.	Evidence of priority given to actions/interventions aimed at improving the results of the indicators measured in your organization and related successes. Evidence of priority given to actions/interventions aimed at improving the results of the indicators measured in the entire value chain, including customers, and related successes.
+1	The farm has a management system and raises awareness of indicators relating to the issues of small farmers within its organization, its subcontractors, and its first-level suppliers.	Actions/interventions that raise awareness of the indicators measured within the organization, also among its subcontractors and its first-level suppliers.

(continued)

Table 10.1 (continued)

PRP	Scale-level definition	Inventory indicators
0	Availability of a management system related to small farmers issues in which it is reported that family work is at least one third of the total work, the maximum CAP support payment is 1250 €/ha for small farmers, ownership of <5 ha, <1.9 employees, in which the inclusivity indicators are positive, the availability of data relating to the indicators of productivity, service access indicators, trade relationship indicators, and next-generation farmer/owner indicators.	Size indicators: >2 ha (income crops) and <5 ha. Inclusion indicators: Participation in a farmers' organization, ownership of the farm/business, direct work contribution and/or the family providing at least one third of the total workforce needed, the maximum CAP support not exceeding 1250 €/ha. Productivity indicators: Proof of crop yield, proof of production per year. Indicators of access to services: Evidence of access to services (e.g. inputs such as fertilizers and seeds), access to credit and capital at affordable prices, use of credit (in a given year), and access to agronomic assistance. Trade relationship indicators: Membership in or access to a farmers' organization, evidence of the quality of the relationship with the main buyer, traceability, and understanding of quality standards and price premiums (if any). Next-generation farmer/owner indicators: Level of education completed by the household members, age of the company's/firm's manager or of the person who generally makes the decisions, family unit (age, training, management of sales money, and credit receipt), and participation in cooperatives or an organized group of farmers.
−1	Lack of data related to any of the indicators related to small farmers, but the company has committed to solving this problem with a corrective action plan with a clearly defined timeline.	Evidence of lack of indicator data on smallholder issues. Evidence of the presence of a management mechanism that allows for the definition of measures/actions/interventions to collect missing data within a defined period.
−2	Lack of data relating to any of the indicators relating to small farmers, and the company has not committed to solving this problem with a corrective action plan with a clearly defined timeline.	Evidence of the lack of indicator data on smallholder issues.

Sources: Adapted from OJEU (2013, 2018), Seville et al. (2016), Tarangioli and Pupo D'andrea (2021), and UNEP (2021)

10.5 Conclusions and Future Perspectives

The identification of inventory indicators and the formulation of the related reference scale represent a concrete attempt to account for the lack of a shared and internationally accepted definition of "Smallholders including farmers" through experimentation in the research project. However, this definition represents a challenge in this subcategory to make the evaluation consistent in the implementation of multiple cases. Furthermore, bearing in mind that the collection of and access to data can be difficult, the results of the application in the research project can constitute a best practice for expanding the implementation to other farms associated with the lead partner. The results can constitute a specific database about social topics for organic agriculture and for the Apulian territory, an area where the social risks associated with agricultural work are high.

Acknowledgements This research was supported by the Apulia Region (SOFT Project number 94250035584 – under the Puglia 'PSR 2014-2020', submeasure 16.2).

Authors' Contributions A.E. Di Noia carried out the bibliography and the collection and processing of the data. G. Cappelletti and A.E. Di Noia carried out the application of the methodology, G.M. Nicoletti and C. Russo reviewed the paper.

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Chapter 11
The Potential of Soil Carbon Sequestration: International and National Soil Carbon Projects

Alessia Acampora, Luca Ruini, Olimpia Martucci, and Maria Claudia Lucchetti

Abstract However, less importance has been given to the management of SOC than to the carbon in living soil cover because of the faster recycling of the latter. Soil can be a source or sink of carbon, depending on its management. Globally, agriculture, forestry, and land use changes account for ca. 21% of the global emissions, with strong regional differences regarding regions and source sectors. The question is whether it is possible to manage soil so that agricultural practices and land use in general become carbon sinks instead of sources. Scientific evidence indicates that increases in SOC are associated with better soil fertility and biodiversity and more resilience against erosion, droughts, and floods, in addition to other positive effects directly related to several sustainable development goals (SDGs). This chapter explores different soil carbon projects, carried out both internationally and nationally, to exploit the enormous potential of soil in mitigating climate change.

Keywords Soil · Soil carbon projects · Soil carbon sequestration · Carbon neutrality · Net zero

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A. Acampora (✉) · O. Martucci · M. C. Lucchetti
Department of Business Economics, Roma Tre University, Rome, Italy
e-mail: alessia.acampora@uniroma3.it; olimpia.martucci@uniroma3.it; mariaclaudia.lucchetti@uniroma3.it

L. Ruini
Global Supply Chain, People Safety, Environment & Energy Vice President, Barilla G. e R. Fratelli S.p.A, Parma, Italy
e-mail: luca.ruini@barilla.com

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_11

11.1 Introduction

Agriculture has great potential in the fight against climate change because it is the only sector that has the capacity to remove Greenhouse gases (also known as GHGs) safely and cost-effectively from the atmosphere without reducing productivity. In particular, improved agricultural practices can help mitigate climate change by reducing emissions and by storing carbon in plant biomass and soils. Moreover, the sequestration of carbon in soils and vegetation can be used to offset greenhouse gas emissions generated by another sector (Acampora et al. 2020). Specifically, in the Organisation for Economic Co-operation and Development (OECD) (2019) report, the global technical mitigation potential of the agricultural sector in 2030 has been estimated to be 5500–6000 $MtCO_2$ eq year^{-1} (Smith 2012), demonstrating that it is technically feasible for agriculture to become close to carbon neutral, relying on supply-side mitigation (low carbon farm practices and practices to remove CO_2 from the atmosphere) measures alone, although this depends on optimistic assumptions about the potential of soil carbon sequestration (SCS). The mean global potential for soil carbon sequestration in agricultural soils is 1.5 $GtCO_2$ year^{-1} and 2.6 $GtCO_2$ year^{-1}, at carbon prices of USD 20/tCO_2eq and USD 100/tCO_2eq, respectively (Smith 2016; Smith et al. 2007). Moreover, in the 2019 IPCC report on climate change and land, soil carbon sequestration in croplands and grasslands was listed as one of the options with the largest potential for carbon dioxide removal (0.4–8.6 CO_2eq year^{-1}) together with afforestation/reforestation (0.5–10.1 CO_2eq year^{-1}) and bioenergy with carbon capture and storage (BECCS) (0.4–11.3 CO_2eq year^{-1}) (Shukla et al. 2020). Different soil carbon projects have been developed over the years to exploit the enormous potential of soil in mitigating climate change (DEHSt 2018). This chapter first presents the main international soil carbon sequestration projects and then presents the case study of Barilla S.p.A.

11.2 Methods

This research explores the role of soil carbon sequestration in light of the decarbonization strategy of countries and companies. As sequestering carbon in the soil could contribute to climate mitigation goals, it is critical to develop soil carbon projects that could boost the uptake of the measures. Through a literature review and the analysis of several case studies, this chapter analyses best practices at international and national levels. Then, the Barilla company was identified as a solid foundation to develop a case study on the topic. Observational research and content analysis of communication materials, reports, and website incentives were used to develop the case study analysis.

11.3 Results

11.3.1 International Carbon Soil Sequestration Projects

LABEL BAS CARBON – The French Label Bas Carbone (French Carbon Standard) is a framework for voluntary carbon reduction project that was adopted by the French Government in November 2018. It provides a transparent framework for guaranteeing the integrity of carbon reduction projects. Environmental integrity is ensured through the utilization of standardized methodologies in line with the overarching rules set in the regulation (Directorate-General for Climate Action – European Commission 2019). Companies, public organizations, or individuals who wish to compensate for their emissions can voluntarily acquire the emission reductions determined thanks to these methodologies to offset their emissions. Individuals or sectors can propose methodologies that the regulator must approve. These methodologies set guidelines for how to do the following: establish eligibility criteria; calculate baseline scenario and demonstrate additionality of the project; demonstrate environmental integrity (i.e. co-benefits), requirements on identifying and managing non-permanence risks; and calculate emission reductions relative to baseline, and measurement, reporting and verification (MRV) requirements and methods (Gabriella Cevallos et al. 2019). Only projects that are additional will be approved (i.e. the carbon credits would shift the net present value of the project from negative to positive, and the project would not otherwise occur without credits). To date, it includes approved methodologies for forestry (afforestation, coppicing, and restoration) and for agriculture. Agricultural methodologies have been approved for cattle and field crops (CARBON AGRI), sustainable management of hedges, and plantation of orchards.

CARBON AGRI and CAP2'ER® – CARBON AGRI provides a method for project developers (i.e. person/organization/company) to account for emissions reductions on cattle (beef and dairy) or field crop farms in France thanks to actions that mitigate GHG or increase carbon storage. These validated emissions reductions can then be traded for payment from an external party voluntarily offsetting their emissions. The method includes six types of actions: herd management and feeding, animal manure management, crop and grassland management, consumption of fertilizers and energy, and carbon storage (in total 40 low carbon practices). It quantifies both reductions on farms and associated upstream emissions, applying life cycle assessment. Emission change is calculated using the national tool CAP2'ER®, a whole farm calculator.

The mitigation potential of carbon sequestration in agricultural soils is large and has consequently been the focus of recent international attention, such as the '4 per 1000' initiative launched at the 21st Conference of the Parties (COP 21) (4 per 1000 Initiative: Soils for Food Security and Climate 2017). The 4 per 1000 initiative is an international, voluntary collaboration to increase soil organic carbon (SOC) stocks by 0.4% annually, enough to halt the increase in the CO_2 concentration in the atmosphere related to human activities (Minasny et al. 2017; Soussana et al. 2019).

The initiative aims to reduce deforestation and encourage agroecological practices that increase the quantity of organic matter in soils and meet the 4 per 1000 target per year (French ministry for agriculture and food 2015).

11.3.2 The Barilla S.p.A. Case Study: Soil Health as a New Business Model

Currently, many actions have been undertaken by global food companies toward agri-food sustainability involving third parties beyond raw materials suppliers and their customers. Barilla is one of these firms, and it reframes its strategy, including sustainability inside the 'Good for You Good for the Planet' vision, putting it as an essential milestone to engage people on sustainable development goals challenges.

The company has internalized sustainability concepts, where environmental objectives are expressed as explicit targets for each raw material used in food production. Currently, Barilla employees are focused on improving raw material sustainability performance by engaging in new relationships with upstream value chain actors, mainly raw materials producers, farmers' cooperatives, mills, and processors, and looking at these interactions as a potential source of new information and data useful to monitor tool and strategy efficiency.

11.3.2.1 The DIVERFARMING Project

Barilla has tested a sustainable agriculture practice by establishing horizontal agreements between three of its main input suppliers: Co.Pro.B. for sugar beet, Cereal Docks for oilseeds, and Casalasco Farmers' Cooperative for tomato. Today, these horizontal agreements are bilateral, which means that the Barilla Group has a specific agreement with each of the suppliers, but thanks to the research activities in the H2020 DIVERFARMING project, new approaches are being tested to define multilateral agreements.

In the DIVERFARMING project, a first multiyear and multicrop agreement was set up and evaluated by field experiments on three farms in the Po Valley. In all farms, the cropping systems are planned to supply raw material to agroindustry requests (Durum wheat and Tomato), which in turn sets the quality requirements for acceptance and provides farmers with technical advisory. Keeping in mind both the sustainable intensification and agroecology principles, the case studies were co-designed with the active engagement of the farmers and agronomist and researchers with a view to the sustainability of the overall farming system. Looking at the first 2 years of the experiment, researchers can affirm that co-defined and multidimensional diversification options mitigated the effect of climatic and market instability on the farm gross margin compared to current crop management in the area, and a positive impact was recorded for soil biodiversity, organic carbon content, and GHG emissions reduction.

To pull farmers in this new technical-managerial path, it is necessary to increase the relationships between farmers and farmers as well as between farmers and other value chain actors and advisors. Thanks to the Barilla Sustainable Farming project, for the first time, while still putting the farmer at the centre, a new logic of 'cooperating to compete' is adopted by offering concrete business opportunities in a 'win–win' situation for all parties to reduce the agricultural impact and contribute to spreading a new thinking regarding sustainability.

11.3.2.2 The ICAFRUD Project

The pilot project Impronta CArbonica della coltivazione di FRUmento Duro (ICAFRUD) – the Carbon Footprint of the cultivation of durum wheat – edited by the Policy and Bioeconomy Research Center of the Council for agricultural research and analysis of agricultural economics(CREA-PB) in collaboration with Barilla, Horta, Lyfe Cycle Engineering and CCPB – has allowed us to evaluate the results achieved by the cereal growers who have adopted the 'Decalogue for the sustainable cultivation of quality durum wheat', using an advanced decision support system regarding different cultivation techniques (GranoDuro.net® developed by Horta). The carbon footprint of durum wheat has been developed within an approach based on the life cycle analysis tool. This project has a dual purpose: (1) to demonstrate that sustainable production protocols lead to lower emissions and greater environmental benefit and (2) accounting for any carbon credits generated as part of the development of sustainable durum wheat cultivation.

11.4 Conclusions

Soils store large quantities of carbon as soil organic carbon (SOC). This has tremendous potential in the fight against climate change, as stabilization mechanisms in organic matter store carbon over decades to millennia. Indeed, soil carbon sequestration and related soil carbon projects have gained popular and political attention as a possible net-negative emissions technology and as a decarbonization strategy in the agricultural sector. While the benefits of soil carbon are well known, the adoption of soil-enhancing agricultural practices remains slow and surrounded by widespread scepticism. Major uncertainties are related to how long carbon can be stored in the soil, how much carbon can be sequestered by different practices, and how to effectively measure and track the carbon that is sequestered. Indeed, for these projects to become an important mitigation strategy, a credible, cost-effective, and consistent MRV system is essential for building trust and confidence in the results (and eventually carbon credits) generated.

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Chapter 12
Eco-innovation and Digitalization of Agri-food Companies Towards the Circular Economy: A Pilot Project for the Evaluation of the Impacts and Circularity Indicators for the Agri-food Chain

Alessia Acampora and Maria Claudia Lucchetti

Abstract The circular economy (CE) aims to close the material cycle with a reduction in resource consumption and emissions released into the environment through the concept of productive metabolism. Indeed, the circular economy could provide tools to improve and optimize sustainability within the food system. The sector could therefore benefit from the development of strategies to promote a more circular approach to its operations. The application of the circular economy and the reduce, reuse, and recycle (3R) approach in the agri-food sector is essential to transform society and make production systems and communities more circular. This chapter aims to present a pilot project to analyse the behaviour of Italian companies in the agri-food sector to develop a model that focuses on eco-innovation, digitalization, and ecological transition. This chapter presents the main goals and steps of the pilot project. This chapter presents the main goals and steps of the pilot project. The project goal is to analyse how the principles of the circular economy and climate neutrality can be applied in the agri-food sector through the creation of models for assessing the circularity and sustainability of businesses. To this end, it is planned to carry out an in-depth analysis of the literature that will allow the definition of a reference framework for circular agri-food supply chains and specific circularity KPIs applicable to the entire agri-food sector. Starting from the identification of the main environmental impacts of the sector, this project explores which circularity practices can be implemented. Furthermore, the indicators to measure circular practices in the sector will be identified, tested, and validated through a pilot phase with selected stakeholders.

A. Acampora (✉) · M. C. Lucchetti
Department of Business Studies, Roma Tre University, Rome, Italy
e-mail: alessia.acampora@uniroma3.it; mariaclaudia.lucchetti@uniroma3.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_12

Keywords Circular economy · Agri-food · Sustainable agriculture · Sustainability indicators

12.1 Introduction

In recent years, climate change and resource consumption have been at the centre of the media and politics scene. Achieving a climate-neutral circular economy is currently one of the primary objectives of all national and international policies. In November 2018, the European Union published its long-term strategic vision for a climate-neutral economy by 2050 with the communication "A clean planet for all – A long-term strategic European vision for a prosperous, modern, competitive and climate neutral" (28/11/2018 – COM (2018) 773) (European Commission 2018). With this communication, the European Union presented its vision to achieve zero net greenhouse gas emissions by 2050. The European vision for a climate-neutral Europe is, however, also strongly based on the achievement of a circular economy as a key factor for this sustainable transition (Directorate-General for Climate Action – European Commission 2019). In a historical moment also characterized by the pandemic emergency, the ecosystem must be understood not only as a planet but also as an economy and more generally as a container of social well-being. This is especially true for the agri-food sector. The agri-food sector is, in fact, responsible for both an excessive use of natural resources and various environmental damages (Shukla et al. 2020). This research project is placed in a national and international economic–social context in which the concept of global sustainability can become not only a necessary component for the survival of companies but also an increasingly competitive variable for the creation of value within production chains (Poponi et al. 2021). Agriculture contributes between 21% and 37% of GHG (Greenhouse Gases) emissions (food waste is responsible for 8% of these emissions) and over 58% of nitrogen emissions (300 times more harmful than CO_2). This sector is also one of the main drivers of biodiversity loss, as it uses approximately one third of the planet's earth for food production and accounts for 70% of freshwater withdrawals (Shukla et al. 2019). The impact of agribusiness also entails enormous social costs. It has been estimated, in fact, that by 2050, with a population close to 10 billion, food production would increase by 70%. Furthermore, 1.3 billion tons of food are wasted every year, and 820 million people go hungry. Ultimately, the effects of climate change will hit developing countries hard, where large numbers of people are employed in agriculture, as land productivity will decline (Shukla et al. 2019). Agriculture is, at the same time, the main cause and the main victim of the ongoing environmental crisis (Acampora et al. 2020). Agricultural practices, in fact, produce significant volumes of GHG emissions, the main cause of climate change. However, this sector suffers the most negative impacts of climate change in terms of reduced productivity and higher risks related to food security. At the same time, agriculture has great potential in the fight against climate change. In addition to reducing GHG emissions, through the introduction of sustainable agricultural practices, agriculture is the only sector that has the ability to remove GHG from the atmosphere safely and economically without reducing productivity (Skøt et al. 2016). For this reason, significant efforts have been made to introduce sustainability practices and indicators in the agri-food industry (Merli et al. 2018a). In particular, the sector could benefit from the development of strategies to promote a more circular approach to its operations (Ellen MacArthur Foundation 2019; Jurgilevich et al. 2016). The application of the circular economy (CE) and the 3R approach (reduce, reuse, and recycle) in the agri-food sector is essential to transform society and make production systems and communities more circular (Poponi et al. 2019, 2021).

The circular economy was, in fact, recently introduced as a pillar to guide all production and consumption activities and to simultaneously promote economic gains and reduce environmental impacts (Merli et al. 2018b). The European Union defines CE as "*an economy in which the value of products, materials and resources is maintained in the economy for as long as possible and the generation of waste minimized*" (Rizos et al. 2016). While many industries are redefining their operating principles considering this approach, the potential of CE in the agri-food chain is still largely unexplored. By adopting a circular approach, the sector could identify paths that combine the improvement of environmental performance with that of the reuse of secondary raw materials, which could arrive as inputs to the production process, also generating economic benefits (Ghisellini and Ulgiati 2020; Tunn et al. 2019). The first step in this direction is the identification of potential areas for implementation of the CE in the agri-food sector, together with the development of specific indicators that could measure the circular potential of the industry. Today, both the implementation of circular principles and a system of circularity indicators in the agri-food sector are still missing (Acampora et al. 2017). A fundamental part of the corporate sustainability strategy is the identification of indicators to measure performance. Indeed, to promote CE, it is necessary to measure the effectiveness of the strategies introduced at the national, regional, or local level. Therefore, it becomes essential to introduce monitoring and evaluation tools as indicators to measure and quantify this progress (Geng et al. 2012; Su et al. 2013). Despite the growing interest of scholars and professionals, research on indicators and methodologies to measure the level of application of CE strategies is still in its initial phase, particularly at the micro level (Elia et al. 2016); therefore, more efforts to establish a set of reliable indicators are needed. Some authors point out that using only one set of indicators at the micro level may fail to capture the full development of CE in different enterprises (Banait 2016). To avoid this, each firm should set firm-specific indicators based on its existing characteristics, conditions, and problems (Su et al. 2013).

In this context, eco-innovation and the digitalization of agri-food businesses will play a fundamental role (Muscio and Sisto 2020). In fact, the numerous innovations available, which allow for an increase in real-time information on the systems and professional skills of the subjects involved, represent an enabling factor for the development of circular agriculture. The components of Agriculture 4.0, sustainable from an environmental, social, and economic point of view, are fuelled by the development of new Information and communications technology (ICT) solutions, technological innovation in sensors, optical instruments, and robotics. In addition, advances in know-how and research on production systems and agri-food processing, all focused on cloud computing, will drive the ecological transition in the sector.

12.2 Material and Methods

This project aims to analyse the behaviour of Italian companies in the agri-food sector for the development of a model that focuses on eco-innovation, digitalization, and ecological transition. The application of the principles of circular economy and climate neutrality will be analysed through the creation of models for assessing the circularity and sustainability of businesses. The main aim is to create a scientifically robust, tested, and validated reference model that can become a point of reference in the ecological transition process of companies in the sector. To this end, an in-depth analysis of the literature will be carried out, which will allow the definition of a reference framework and specific circularity key performance indicators (KPIs) applicable to the entire agri-food sector. Starting from the identification of the main environmental impacts of the sector, this project explores which circularity practices can be implemented. Furthermore, the indicators to measure circular practices in the sector will be identified, tested, and validated through a pilot phase with selected stakeholders.

12.3 Results and Discussions

This is a multi-stakeholder research project in which companies from the agri-food chain take part, with the scientific contribution of the researchers of the Roma Tre University Business Studies Department and the cross-industry vision of Enel X (the global business line of the Enel group that offers services for innovation, the energy transition, and the circular economy).

The main actors involved in the project are Italian companies in the agri-food sector that are willing to start or consolidate virtuous paths of sustainability and circular economy, enhancing technical, managerial, and scientific skills, with the aim of contributing to the transition to new business models.

The aim of the research project is to analyse the behaviour of Italian companies in the agri-food chain to develop a model of sustainability that focuses on eco-innovation, digitalization, and ecological transition. Finally, through the creation of models for assessing the circularity and sustainability of businesses, it analyses the level of application of the principles of circular economy and climate neutrality.

This research project is divided into the following phases:

- Planning and implementation of a continuous research activity aimed at mapping the scenarios and their evolution (next 5/10 years) of the agri-food sector, with specific attention to the main macrotrends and the effects on the national and international context.

- Carrying out activities of the dissemination of research results through conferences, workshops and digital initiatives, publication of papers and reports.
- Design and implementation of targeted training activities on research topics aimed at the development of talents and the transformation of technical skills, also following the expected generational change in the medium term. Participation in European calls on circularity.
- Establishment of a platform for listening and multi-stakeholder engagement capable of involving the main operators of the food chain and of intercepting and analysing the most significant trends underway in the sector, both internationally and nationally.

In detail, the following activities are planned:

- Analysis of the state of the art, through a systematic literature review of scientific literature and grey literature and the construction of a database of national and international projects related to the topic. Furthermore, an exploratory analysis based on a case study analysis of successful companies and related circularity indicators and impact assessment models in the agri-food sector will be developed.
- Development of the conceptual model and identification of industry-specific circularity KPIs in the food sector, processed based on aggregated and anonymous data and development of the monitoring model. These KPIs can be used by partner companies to improve their circularity performance.
- Preparation of an annual report on the macrotrends of the sector and the ability of companies to apply the principles of eco-innovation and the circular economy along the entire supply chain, with concrete proposals for a real "circular" turning point, having as its object a chapter dedicated to the methodology for identifying the circularity KPIs.
- Data analysis to study the food sector in terms of innovation, digitalization, and circularity, identify the gaps, and suggest a path for improvement to companies in the sector.
- Coordination of engagement, training, and research activities for the annual report and development of any partnerships and institutional sponsorships.

12.4 Conclusions

The results of this research project are a benefit not only for the scientific community but also for operators in the sector who will benefit from them for the purpose of the effective ecological transition of the sector based on a more structured strategy guided by scientific references. Understanding the dynamics of the agri-food sector in terms of ecological transition and circular economy can provide useful policy indications to increase the innovation potential and undertake training and communication actions aimed at entrepreneurs to improve their ability to design and implement effective innovative processes. It can also provide important elements for identifying priority areas of intervention towards which direct financial resources can be directed. This is because the research project aims to study the implementation of models for evaluating circularity and adherence to the principles of ecological transition, which are embedded in the reality of farms in the agricultural supply chain. Moreover, through careful data collection and the subsequent creation of specific reports, companies will be provided with sustainability information useful for the decision-making process. The long-term aim is to introduce the principles of the green revolution, the ecological transition, and the circular economy into the corporate strategies and sustainability assessments of companies in the sector, which are already very active. Through technological innovation and the digitization of business processes in environmental sustainability, the aim is to propose increasingly sustainable products and foods on the market, in line with international competition. Furthermore, the agri-food sector represents both a productive and scientific excellence that, however, still presents both structural and system deficiencies, but thanks to the new methodologies, including the one proposed in this project, it can also be a driving force for the development of related sectors, such as tourism, bioeconomy, and, more generally, green economy.

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Chapter 13
Application of the DNSH Principle to the Restoration and Enhancement of a Historical Garden: The Project "Well-Being and Spirituality: Orto-giardino Laudato Sì"

Leonardo Borsacchi and Gabriele Feligioni

Abstract The application of the "Do No Significant Harm" (DNSH) principle, as foreseen by the Italian Recovery and Resilience Plan (PNRR in Italian), intends to demonstrate that a project intervention does not cause significant harm to the environment and can produce positive impacts. This chapter describes the results of a preliminary analysis of environmental aspects and impacts, in accordance with the DNSH, related to the restoration and reforestation of the historic garden of Villa San Leonardo al Palco in Prato. Alongside the care and restoration of the villa, which already hosts events, conferences, and retreats, the project "Well-being and spirituality: *Orto-giardino Laudato Sì*" will enhance the garden and preserve biodiversity, with benefits for citizens and tourists. One of the main objectives is the adoption and development of ecosystem functions in the garden, with direct and positive environmental effects. The principles of both circularity and sustainable agriculture inspire the creation of a bioactive garden to cultivate local biodiversity for self-consumption, with the possibility of enhancing sustainable food models, health, and well-being. The garden will become an ecological, economic, and social laboratory capable of strengthening and spreading scientific, technical, botanical, and environmental knowledge.

Keywords Urban gardens · Circular economy · Environmental impacts · Well-being

L. Borsacchi (✉) · G. Feligioni
ARCO (Action Research for CO-Development) – PIN, University of Florence, Prato, Italy
e-mail: leonardo.borsacchi@pin.unifi.it; gabriele.feligioni@arcolab.org

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_13

13.1 Introduction

According to European Union (EU) Regulation 241/2021, all measures in recovery and resilience plans must comply with the principle of "Do No Significant Harm" (DNSH) to environmental objectives and impacts (European Commission 2021). This requirement translates into an assessment of the project intervention and the evaluation of compliance with DNSH. The Italian National Recovery and Resilience Plan (the so-called PNRR in Italian) also includes the DNSH principle and asks for its application in new project interventions (Italia Domani 2021).

In 2022, the Italian government launched a call, within the framework of the PNRR, with the aim of funding the restoration and enhancement of historic parks and gardens (i.e. *Misura 2 "Rigenerazione di piccoli siti culturali, patrimonio culturale, religioso e rurale" Investimento 2.3: "Programmi per valorizzare l'identità dei luoghi: parchi e giardini storici" la Missione 1 – Digitalizzazione, innovazione, competitività e cultura, Componente 3 – Cultura 4.0 - M1C3).* Promoting this financial line, the main objectives for the Italian government are to increase the touristic and cultural appeal of historic gardens (public and not public) by i) modernizing the material and immaterial infrastructure of historical and artistic heritage, ii) improving cultural usability and tourist accessibility through digital investments and investments aimed at removing physical and cognitive barriers to heritage, iii) renewing and modernizing the tourism offer through upgrading accommodation facilities and strengthening strategic tourism infrastructures and services, and iv) supporting the recovery of the cultural and creative tourism industry.

In response to the above-mentioned call, the Diocese of Prato decided to submit a project proposal for the restoration and modernization of the historic garden of the monastery of San Leonardo al Palco in Prato. The main aim of the project, called "Well-being and spirituality: *Orto-giardino Laudato Sì*," is to promote space fully harmonic with nature and living beings, an ecological, economic, and social laboratory aimed at identifying the optimal dimensions of a sustainable, resilient, and autonomous living space. Although the monastery and its garden are owned by the Diocese of Prato, the project proposal fits perfectly into the sustainable development and circular economy framework already implemented by the City of Prato. Thus, the intervention of planting trees in the garden is in line with the city's forestation plan (i.e. Prato Urban Jungle) (Comune di Prato n.d.-c); the circular economy principles inspiring the intervention (i.e. circular urban gardens) agree with the so-called Prato Circular City (Comune di Prato n.d.-a) local strategy. Moreover, the project is also outlined in the "Next Generation Prato" document published by the Municipality of Prato in July 2021 in response to priority interventions on PNRR (Comune di Prato n.d.-b). By applying the DNSH principle, an assessment was made regarding the consistency of the proposed intervention in relation to the PNRR measures. In July 2022, the project "Well-being and spirituality: *Orto-giardino Laudato Sì*" was judged eligible for funding.

13.2 Materials and Methods

The DNSH principle is based on what is specified in the taxonomy system of environmentally sustainable activities indicated in Article 17 of Regulation EU 2020/852, adopted to promote private sector investment in green and sustainable projects and to help realize the objectives of the Green Deal. In fact, there is currently no unambiguous methodology for assessing DNSH in Italy, even though a guideline was issued in early 2022 (Italia Domani 2021). The main references are checklists prepared at the European level; even for their compilation, no standardized instructions are provided (e.g. on how to measure specific requirements or any reference methods). For this work, to carry out the assessment, the methodology included on-site visits, semistructured interviews, and a desk review of existing documents about planned structural interventions. The requirements included in the checklists "Afforestation – Table 19" and "Cultivation of perennial and non-perennial crops – Table 20" have been considered as references.

13.3 Results and Discussions

The project targets the courtyard of the Villa within the perimeter walls (area of 15,000 m^2). It is substantially flat, characterized by the presence of numerous plant varieties, trees, and an Italian-style garden. It also contains 350 olive trees and a water source. A hydraulic system compensates for the water levels originating from the spring by a system of cascade basins.

The interventions included in the project proposal are listed in Table 13.1.

Figure 13.1 summarizes the interventions and their interconnections by applying virtuous practices of the circular economy and environmental and climate protection.

The self-assessment was conducted using the DNSH self-assessment form for Measure 2 (Table 13.2) and by checklists "Afforestation" and "Cultivation of perennial and non-perennial crops." The purpose of the datasheets is to provide a summary of operational and regulatory information that identifies DNSH constraints.

The initial situation with 350 mature olive trees plays a significant role with a CO_2 absorption in 1 year of approximately 3500 kg (Palese et al. 2013). The intervention includes the planting of more than 1000 plant species, which together will bring an estimated CO_2 absorption balance to 9500 kg/year.

The selection of crops will be added to those already present, bringing the soil coverage to almost all of it, thus well above the minimum 75% needed. Observing Fig. 13.2, the area covered by the project will already be covered almost in its entirety by green areas, in particular a garden (approximately 4200 m^2), an olive grove (approximately 8000 m^2), and woodland (approximately 800 m^2). An additional green area dedicated to a vegetable garden will also be created. The garden

Table 13.1 Major interventions proposed

(a) Plant component and garden design	Introduction of new plant elements respecting and consistent with the historical landscape and soil characteristics of the site Creation and recovery of bioactive orchards Creation of suitable habitats and arrangements to attract insects Inclusion of hives and swarms of bees that will perform pollination and gene exchange between plants
(b) Architectural and sculptural component	Restoration of stone walls and "Belvedere" Resurfacing of the forecourt and the drainage of rainwater
(c) Plant component	Restoration and upgrading of hydraulic systems of historical interest and the restoration of tanks with phyto-purification functions) Implementation of energy-efficient lighting systems Installation of photovoltaic panels
(d) Safety and accessibility	Installation of a video surveillance system Installation of an access ramp Construction of a pedestrian boulevard Installation of charging systems for electric mobility
(e) Valorization and communication	Inclusion of the garden within cultural itineraries in the area Participation in participatory local development initiatives Involvement of voluntary associations and citizens in maintenance, management, enhancement, and communication activities

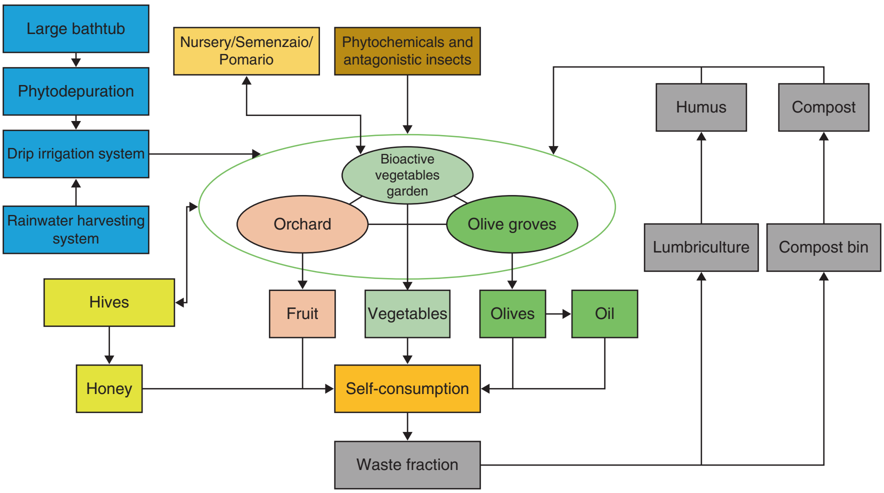

Fig. 13.1 Circular system of the intervention

management method (bioactive garden) will have a productive function intended for self-consumption and high social impact purposes. Finally, in the garden area, medicinal and aromatic plants will be planted, as well as flower strips, respecting the historical design of the Renaissance Garden (Nanni 2010). The analysis of physical climatic risks can be traced back to phenomena that are now particularly frequent and habitual due to climate change. The use of the motors is compensated by

Table 13.2 DNSH self-assessment form for Measure 2

Environmental objectives	Questions	Yes/No	Substantive justification if NO has been selected
1. Climate change mitigation	Is the measure expected to lead to significant GHG emissions?	No	
2. Climate change adaptation	Is the measure expected to lead to an increased adverse impact of the current climate and the expected future climate, on the measure itself or on people, nature, or assets?	No	
3. The sustainable use and protection of water	Is the measure expected to be detrimental: (i) to the good status or the good ecological potential of bodies of water, […]?		
4. The circular economy, including waste prevention and recycling	Is the measure expected to: (i) lead to a significant increase in the generation, incineration, or disposal of waste, […]; or (ii) lead to significant inefficiencies in the direct or indirect use of any natural resource at any stage of its life cycle which are not minimized by adequate measures; […]?	No	Given its nature, the investment has no foreseeable impact on this environmental objective, considering both direct and primary indirect effects. However, parks and gardens produce a huge number of cubic meters of bulk green waste annually from tree and shrub removal, pruning, weed removal, and lawn mowing throughout the park.
5. Pollution prevention and control to air, water, or land	Is the measure expected to lead to a significant increase in the emissions of pollutants into air, water, or land?	No	Treatments against parasites, pathogens, and pests must preferably be carried out by recurring to coltural criteria, and other biological control or chemical substances of low or zero toxicity to humans, on wild fauna and flora.
6. The protection and restoration of biodiversity and ecosystems	Is the measure expected to be: (i) significantly detrimental to the good condition and resilience of ecosystems; […]?	No	To manage the soil pollutants, it is planned to create guidelines for the correct management of agronomic activities and the collection and disposal of agricultural waste.

Fig. 13.2 Green areas Villa del Palco

Table 13.3 Factors that absorb and produce CO_2 emissions

Factors that absorb or reduce CO_2 emissions	Factors producing CO_2 emissions
Introduction of new plant elements (trees, shrubs and hedges, and grasses) Rehabilitation of pomaria and orchards Introduction of bioactive vegetable garden. Use of compost bins Creation of suitable habitats to attract insects Insertion of hives and swarms of bees Introduction of phytodepurative plants Installation of photovoltaic panels Energy-efficient electrical renovation Charging systems for electrical mobility	Use of motors for irrigation pumps Use of tractor for garden maintenance and landscaping Conveyance of construction waste because of improvements to the architectural component Use of electrical equipment (video surveillance, accessibility) in case of energy needs that are not guaranteed by photovoltaic panels

the increased absorption of CO_2 due to the inclusion of the new greenery. In addition, there is already a rainwater collection system that conveys rainwater to a cistern located inside the villa. Table 13.3 summarizes the interventions by dividing them into those that contribute to the absorption/reduction of CO_2 and those that produce it.

A drip irrigation system is planned for the irrigation of gardens and vegetable gardens, which will contribute to the efficient management of water resources. Inside the perimeter wall of the garden, it is planned to introduce phytodepurative plants in the existing water tank. The construction of a compost heap and an area for mowing is intended to generate a closed cycle in which the residues and byproducts of production and mowing can return as organic fertilizers. To promote the circular economy, it is planned to create guidelines for the correct management of the different material flows.

13.4 Conclusions and Future Perspectives

Even though a unique and standardized method is not yet in place, by the application of the DNSH principle, it is possible to carry out assessments to demonstrate that the proposed intervention would not generate excessive impacts on the environment. The project *"Orto-giardino Laudato sì"* (funded by PNRR)is intended to be a balanced model of landscaping areas, with the possibility of enhancing sustainable food models and promoting well-being and health. At the local level, the project fits into the policies of the Municipality of Prato in terms of circular economy, development of urban and peri-urban agricultural systems, and forestry.

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Regulation EU 2020/852. Taxonomy regulation

Chapter 14
The Adoption of Information Systems for the Analysis of the Life Cycle of Hazelnuts

Carlo Amendola and Marco Savastano

Abstract Attention to the different phases of the life cycle of agri-food products by producers and consumers is an aspect that is growing at the same speed with which the agricultural sector is introducing innovations brought by digital transformation, evolving into agri-tech.

Therefore, it becomes necessary to evaluate the sustainability of the entire agri-food chain to understand where and how to intervene to improve its efficiency and quality. This work, through a case study relating to an Italian agricultural company operating in the hazelnut sector, aims to analyse the impacts of the life cycle of this product considering the path from the raw material to the final treatment before the hazelnuts are delivered to the transformation company. The final goal is to assess the potential critical issues concerning hazelnut production, with a view to improving the efficiency of the life cycle stages using innovative information systems set up ad hoc. As a result, our findings describe a best practice of a system able to support the company in the management of its data, which can be updated directly in-house, continuously and in a coordinated manner.

Keywords Information systems · Life cycle assessment · Hazelnuts · Agri-tech · Digital transformation

14.1 Introduction

Agriculture and, in particular, agri-food products have specific life cycles. The attention of the producer and the individual consumer converges on this aspect. Therefore, it is increasingly necessary to evaluate the entire supply chain of agri-food products to understand where and how to intervene to improve their production.

C. Amendola · M. Savastano (✉)
Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: carlo.amendola@uniroma1.it; marco.savastano@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_14

At the European Union (EU) level, the recent European Green Deal focuses greatly on the role of digitalization in the ecological transition and sustainable growth of this sector. Accordingly, the European Commission asks member states to take advantage of the potential of the digitalization process based on new technologies in agriculture that allow us to track and trace every single process within the life cycle of the products, aiming at improving sustainability and competitiveness while enhancing the conditions of farmers by simplifying their daily work and food security for consumers (Savastano et al. 2022a, b). This is essential to achieve the objectives set by the current and future common agricultural policy (CAP) and the EU Farm to Fork strategy (European Commission 2020).

This work aims to analyse the life cycle impacts of hazelnuts produced, transported, and treated by the Calabrian *Hazelnut Enhancement and Protection Consortium* and finally delivered to a processing centre in the area of Viterbo (Lazio, Italy) to improve the production process.

For the analysis of the production process, specific software developed by the consortium was used. This system supports companies in the management of their data and can be updated directly, continuously, and coordinated by individual producers. It allows companies to correct the data collected in the preliminary phase and calculate the results of the product life cycle using the data originated by the consortium.

14.2 Review of the Existing Scientific Literature

Recently, *Agriculture 4.0* and *Precision Agriculture* have spread as a new paradigm shift in the agri-food sector, along with the fourth industrial revolution (Liu et al. 2020). Indeed, the exponential growth in adopting the most disparate Internet of Things (IoT) devices and applications has also reached agriculture and food (agri-food) supply chains, attracting substantial research and innovation interest towards developing reliable and transparent traceability systems, including blockchain technological systems (Caro et al. 2018).

Recent studies show that 4.0 technologies allow for swift information exchanges between consumers, agri-tech businesses, and suppliers. Therefore, consumers might demand new products, and consequently, the agri-tech business can arrange new offerings with suppliers (Rialti et al. 2022).

By adopting advanced information systems and Internet technologies, Agriculture 4.0 allows the collection, analysis, and processing of enormous farming data, such as meteorological information, soil conditions, marketing demands, and land uses, to assist farmers in making appropriate decisions and obtaining higher-quality products and profits (Savastano et al. 2022a, b; Zhai et al. 2020).

Life cycle assessment (LCA) is currently recognized as a valid quantitative methodology for evaluating the three areas of sustainability of a product or process in several different industries, and today, it represents an interesting methodology for agri-food firms (Vinci et al. 2022). However, it still faces several limitations that mainly concern the laboriousness of the analysis; in fact, the resources required in terms of cost and time, in several cases, are huge, especially for small firms, and sometimes some data are incomplete and imprecise (Notarnicola et al. 2017).

The extant literature on LCA demonstrates the need for further refinements for the development of specific tools for agricultural production. Furthermore, the scarcity of these experiences does not allow the creation of those databases essential to identify the characteristics of the life cycle of the same product obtained in different areas.

14.3 Material and Methods

The research objective of this work is to analyse the potential impacts on the production of hazelnuts along their life cycle, from the production of the raw material until the products leave the consortium warehouse to improve the activity through innovative information systems (Mucelli 2000). The hazelnuts are tracked from production to the consortium warehouses, and the data relating to all the incoming and outgoing flows from the production process are collected in the field, obtained from the application of forecast models, or, when necessary, gathered from existing databases. In a few cases, these data come from the agronomist who follows all the production (Roversi 2020).

To carry out an analysis of this process, from production to raw processing of hazelnut by the consortium, it was necessary to first identify the different macrophases as follows:

1. Production and harvest phases of hazelnuts at the member farms in the Calabria region
2. Transport from farms to consortium warehouses
3. The cleaning and drying phase inside the warehouses
4. Delivery of the product to the processing company in the area of Viterbo (Lazio, Italy)

From the analysis of the different phases of hazelnuts, the most important phase of the life cycle is that of cultivation. This is mainly due to the production and arrangement of the land, pruning, and the use of organic pesticides. The set of all these data allowed the creation of a database from which it was possible to create specific software that allowed us to correctly manage the data collected in the preliminary phase, create an easy-to-understand model, and calculate the product life cycle results (Amendola and Calabrese 2018).

The model processes are formed by flows, in and out, consisting of data collected within the various companies of the consortium members.

The proposed information system consists of an application accessible to users through the Internet. The components of the system are as follows:

– A relational database for storing and managing data and maps of the production units
– A WebGIS interface with navigable and searchable maps containing basic cartographic layers and maps of companies and production units
– A content management system (CMS) for the complete management of the database and for the dynamic generation of statistical reports on management and production data, with access rights and functions differentiated by user profile.

14.4 Results and Discussions

The study, with a view to improving the production chain, considers a territory of 300 ha of hazelnut groves, with plantations measuring 5 × 4 m and a total of 500 hazelnut trees per hectare.

For the development of the database, with the purpose of using dedicated software in the calculation of the hazelnut production cycle (Bazzerla 2017), the following consortium data were identified:

1. Pruning of hazelnut trees per hectare (see Table 14.1)
2. Cleaning of hazelnut trees per hectare (see Table 14.2)
3. Organic system per hectare (see Table 14.3)
4. Hazelnut harvesting methods per hectare:
   - Mechanized collection (see Table 14.4)
   - Manual harvesting (for lands not allowing mechanized harvesting) (see Table 14.5)

Table 14.1 Pruning per hectare

Number of workers	Chainsaws	Litres of petrol	Gasoline for compressor	Compressed air scissors	Paraffin oil to oil chains
2	2	20	7 L	2	4 L

Table 14.2 Cleaning per hectare

Number of workers	Tractors	Diesel fuel	Brush cutter	Gas
2	2	7 hours of work per hectare approximately 50 L	2 brush cutters for cutting buds per hectare	10 L

Table 14.3 Biological system per hectare

Number of workers	Biological plant protection	Tractor
1	400 L per hectare 3 times a year	10 L of diesel

Table 14.4 Harvest per hectare

Number of workers	Number of machines	Number of tractors	Diesel fuel	Average quintals of hazelnuts per hectare
5	1 car takes 3 hours per hectare	1	25 L	20 quintals

Table 14.5 Manual harvest per hectare

Number of workers	Average quintals of hazelnuts per hectare
5	5 quintals per day per hectare

Table 14.6 Transport of hazelnuts per hectare

Number of quintals	Transport by mechanical means	Consumption	Average distance
20 quintals per day per hectare	1 tractor	10 L	10 km

Table 14.7 Consortium warehouse transport

Number of workers	Cost of transport for third parties	Kilometres travelled
1	1200 euros	700 km from the consortium deck to the factory in the Viterbo area

5. Data collection on hazelnut transport methods:
   - The first flow goes from the company to the consortium warehouses (see Table 14.6)
   - The second flow goes from the warehouses of the Calabria Hazelnut Enhancement and Protection Consortium to the laboratories of the Viterbo processing company (see Table 14.7).

After listing the main processes of hazelnut production and storage, the necessary data were collected in the system for impact assessment (Pernigotti 2011).

In particular, the impacts associated with the production and storage of hazelnuts were taken into consideration, and the emissions caused by agricultural vehicles and the combustion of fuel, in this case, diesel, used for the various agricultural machines were calculated (see Table 14.8).

Finally, Table 14.9 highlights the emission levels of the vehicles used. Ideally, this level could be further lowered if the hazelnut is processed directly at the consortium headquarters rather than transported to the company headquarters in the area of Viterbo.

Table 14.8 Carbon footprint calculation

		EF CO_2 (kg)	EF CH4 (kg)	EF N_2O (kg)	Total (kg)
N. workers/ha	2				
No chainsaws	2				
Fuel consumption/per person	10 L	23.25	0.0013	0.00191	23.25
Compressor petrol consumption/ha	7 L	16.27	0.0009	0.00134	16.28
Compressed air scissors	2				
Paraffin oil for chain/ha	4 L	17.53	0.001	0.0001	17.53
Campaign operations					
N. workers/ha	2				
N. tractors	1				
Diesel consumption/ha	50 L	145.52	0.0077	0.00766	145.53
Brushcutters	2				
Brushcutter gasoline consumption/ha	10 L	23.25	0.0013	0.00191	23.25
Biological system					
N. workers/ha	1				
Biological plant protection product/ha	400 L				
Number of steps year	3				
Diesel consumption tractor	10 L	29.10	0.0015	0.00153	29.11
Mechanized collection					
N. workers/ha	5				
N. machines/ha	1				
Harvest duration/ha	3 h				
Diesel consumption/ha	25 L	72.76	0.0038	0.00383	72.77
Oil consumption for transport	10 L	29.10	0.0015	0.00153	29.11
Average harvest/ha	2000 kg				
Manual collection					
N. workers/ha	5				
Average harvest/ha	500 kg	750			750.00
Hazelnuts transport					
Quantity	2000 kg				
Transport by mechanical means	1 consumption				
Diesel consumption	10 L	29.10	0.0015	0.00153	29.11
Average distance travelled	10 km				
					1135.93 kg CO_2/ha

Table 14.9 Total CO_2 emissions

	Density (kg/m^3)	Calorific value (MJ/kg)	EF CO_2 (kg/TJ)	EF CH_4 (kg/TJ)	EF N_2O (kg/TJ)
Gas	770	43.57	69,300	3.8	5.7
Diesel	910	43.16	74,100	3.9	3.9
GN	0.552	56	56,100	92	3
LPG	590	46.49	63,100	62	0.2
Paraffin	850	40.2	73,300	3	0.6
			EF CO_2 (kg/kg product)		
Pesticides			1.5		

Source: Authors' elaboration of consortium data

14.5 Conclusions and Future Perspectives

This study aims to digitize the entire chain of hazelnut production and their collection at the Calabria Hazelnut Enhancement and Protection Consortium.

What emerges, in line with the majority of LCA studies carried out in the agri-food sector, is that having an information system within each individual company of the consortium facilitates production and collection activities in a networked way (Del Borghi et al. 2020).

The production and maintenance phase of hazelnut groves, in fact, contributes to over 60% of the total work before reaching the raw product, while that of harvesting and storage is only 40%.

Within the supply chain, the agricultural process that generates more attention, and work is undoubtedly that of the maintenance of hazelnut plants both to have a greater production of hazelnuts and to maintain the land (Zinnanti et al. 2019).

Furthermore, regarding the collection phase, a significant fact is the diversification from manual collection to mechanized collection, the mechanized one being connected to the consumption of fossil fuels, which entails higher costs but at the same time more efficiency, meaning greater collection in less time (Zampori and Pant 2019).

Therefore, our evidence shows that the growing adoption of information systems in LCA studies applied to the agricultural sector is extremely useful and important for improving decision-making processes, sustainability, and production outputs. Finally, regarding the LCA of hazelnuts, its transport, and warehouse, an information system would help the storage process by reducing costs by more than half and reorganizing the supply chain of the entire work activity (Zampori and Pant 2019).

The results of this work can provide companies and regional entities with a tool to analytically verify the origin of hazelnuts and to develop a complete information system accessible to all stakeholders capable of supporting the company in managing company data that can be updated in a direct, continuous, and coordinated manner. In this way, it is possible to further increase the confidence in the quality of the product, allowing all parties in the supply chain, including final consumers, to have all the information relating to each batch of hazelnuts sold in the market.

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Chapter 15
Sweet Chestnut Fractions from a Sustainable Circular Process for the Control of Phytopathogenic Oomycetes

Gabriele Simone, Margherita Campo, Silvia Urciuoli, and Annalisa Romani

Abstract One natural, sustainable extract of *Castanea sativa* Mill. was tested for in vitro antimicrobial activity against three phytopathogenic Oomycetes of agronomic interest: *Pythium dissotocum*, *P. sylvaticum*, and *P. ultimum*. The extract is obtained from chestnut culture waste by hot water extraction and membrane fractionation/concentration. The chemical characterization of bioactive secondary metabolites highlighted the presence of gallic and ellagic hydrolysable tannins (26.0% vs weight of powder), with a prevalence of vescalagin and castalagin (4.8% and 9.8%). The extract showed good inhibition of mycelial growth, particularly for *P. sylvaticum*, for which an inhibition of 79.4% with 0.1% w/V extract was observed. For *P. dissotocum* and *P. ultimum,* the inhibition was 57.1% and 56.5%, respectively, at 0.1% extract. Furthermore, in all tests, a different phenotype (laxer mycelium) was observed. This evidence could open perspectives for using sweet chestnut tannins for the contrast of phytopathogenic *Pythium*, e.g. in sowing substrates or for crop biodefence, or even in substrates for hydroponic crops, given the dependence of *Pythium* spp. in aquatic environments. This study is in line with the growing interest in eco-sustainable solutions for reducing chemical inputs in agriculture.

Keywords *Castanea sativa* Mill. · HPLC-DAD-MS · Hydrolysable tannins · Antimicrobial activity · *Pythium* spp. · Oomycete

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Annalisa Romani died before publication of this work was completed.

A. Romani (Deceased)

G. Simone
INSTM – National Interuniversity Consortium of Materials Science and Technology, Florence, Italy
e-mail: gabriele.s@hotmail.it

M. Campo (✉) · S. Urciuoli
DiSIA-Phytolab – University of Florence, Florence, Italy
e-mail: margherita.campo@unifi.it; silvia.urciuoli@unifi.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_15

15.1 Introduction

Sweet chestnut growing in Italy has ancient origins, and in many areas, it has played, and continues to play, an important role in defining the characteristics of landscape and territory. To date, the land occupied by chestnut trees in Italy is approximately 800,000 ha across all regions, but in recent years, socioeconomic changes and the spread of pathologies have caused a decrease in activities with a corresponding increase in imports from abroad, particularly fruits for food purposes (Castellini et al. 2009). The enhancement of chestnut growth in the current context requires the application of modern and innovative strategies that involve the supply chains traditionally associated with that of chestnut and their integration with new supply chains to promote recovery at productive, economic, and social levels. The recovery of waste and byproducts of both food and wood production activities and their use to obtain new products applicable in multiple sectors according to circular economy models can guarantee the evolution of the sector towards greater environmental and economic sustainability and allow the connection between companies and realities operating in different sectors (Romani et al. 2020). The presence of considerable amounts of hydrolysable tannins with antioxidant and antimicrobial properties in the woody tissues of sweet chestnut suggests the possibility of using the waste to produce natural extracts rich in bioactive compounds to be used as semifinished or finished products with high added value for applications in sectors such as textiles/tanning, agronomics, cosmetics, feed, food/nutraceuticals, and wine (Pagliaro et al. 2021; Pizzi 2021; Romani et al. 2021). The sweet chestnut dry extract investigated in this work is an industrial fraction obtained by green methodologies in the plant of Gruppo Mauro Saviola in Radicofani (Si), allowing the sustainable reuse of wood chips yielded as a byproduct during the processing of wood. As previously described (Campo et al. 2016; Lucarini et al. 2018), after hot water extraction, the raw extract is purified and concentrated by a series of filtration steps on membranes with different molecular cut-offs to obtain fractions enriched in different bioactive hydrolysable tannins. The two commercial standardized products are a liquid purified and concentrated fraction and the spray-dried powder obtained from the latter, which is the dry extract object of this study in which some of the possible agronomic applications were evaluated. More specifically, quali-quantitative HPLC-DAD-MS (High Performance Liquid Chromatography coupled with Diode Array Detector and Mass Spectrometer) analysis was performed for the chemical characterization of the hydrolysable tannins in the dry extract before testing it for in vitro antimicrobial activity against three phytopathogenic Oomycetes of agronomic interest: *Pythium dissotocum*, *P. sylvaticum*, and *P. ultimum*. A good inhibition of mycelial growth was observed, and a different phenotype (laxer mycelium) was observed with doses of 0.1–0.5% w/V, confirming the antimicrobial effect of sweet chestnut tannins towards the tested *Pythium*. This preliminary study will be followed by further in vitro and in vivo tests to assess possible new perspectives for sweet chestnut tannin–based products in contrast to phytopathogenic *Pythium*. The innovative applications could be particularly useful, e.g., for sowing substrates for horticultural and ornamental plants or for crop biodefence, in line with the growing interest in eco-sustainable solutions for the reduction of chemical inputs in agriculture. A further area of study will concern the possible application of the extract in substrates for hydroponic crops, a sector in progressive diffusion, given the dependence of *Pythium* spp. in aquatic environments.

15.2 Materials and Methods

15.2.1 Chemicals

All solvents (HPLC grade) and formic acid (American Chemical Society) were purchased from Sigma Aldrich Chemical Company Inc. (Milwaukee, Wisconsin, USA). Gallic and ellagic acids, of analytical grade, were purchased from Extrasynthèse S.A. (Lyon, Nord-Genay, France). HPLC-grade water was obtained via double distillation and purification with a Labconco Water Pro PS polishing station (Labconco Corporation, Kansas City, USA). Potato dextrose agar (PDA) was purchased from VWR International (Radnor, Pennsylvania, USA).

15.2.2 Extract

The sweet chestnut dry extract was a commercial fraction furnished by Gruppo Mauro Saviola Srl (Viadana, MN, Italy). This fraction is obtained after ten circular and solvent-free process streams by the industrial tannin extraction and concentration/purification plant operating in Radicofani (SI, Italy), as previously described (Campo et al. 2016; Lucarini et al. 2018).

15.2.3 HPLC-DAD-MS Analysis

The extract was analysed with an HP-1260 liquid chromatograph equipped with a DAD detector and an MSD (Mass Selective Detector) API-electrospray (Atmospheric Pressure Ionization) (Agilent Technologies, Santa Clara, CA) in negative ionization mode. A Luna, C18 250 × 4.60 mm, 5 μm column (Phenomenex, Torrance, CA) at 26 °C was used. Eluents: 5% HCOOH in water and CH_3CN. A four-step linear solvent gradient from 100% H_2O up to 100% CH_3CN was performed over a 55-minute period, as previously described (Campo et al. 2016; Lucarini et al. 2018). Mass spectrometer operating conditions: gas temperature 350 °C, flow rate 10.0 L/min, nebulizer pressure 30 psi, quadrupole temperature 30 °C, and capillary voltage 3500 V. Fragmentor 120 eV. Tannins were identified by comparing their retention times, UV–vis, and mass spectra with those of the commercial standards. Compounds were quantified using five-point regression curves ($r^2 \geq 0.9998$) in gallic and ellagic acids. Analyses were carried out in triplicate, and the results were recorded as the mean values with standard deviations ≤5%.

15.2.4 In Vitro Test

The species used for the in vitro test were *Pythium dissotocum* Py_diss01, *P. sylvaticum* Py_sylv02, and *P. ultimum* Py_ult36 (CREA-AA Bologna), maintained on PDA at 25 °C in darkness. The substrate was prepared by adding the sweet chestnut extract to PDA at concentrations of 0% (control), 0.01%, 0.05%, 0.1%, 0.5%, and 1.0% w/V. The pH was corrected to 5.6 with a KOH solution. The plates (85 mm) were inoculated in the centre with a 5-mm disc of mycelium obtained from an actively growing colony and incubated at 25 °C in the dark. The two perpendicular colony diameters were registered every 4–6 hours until the plate edge was reached. The growth inhibition (%) was calculated as follows:

$$\left[\left(\text{diam.ctrl} - \text{diam.treated}\right) / \text{diam.ctrl}\right] * 100$$

The final result was obtained with the mean of five replicates and two repetitions of the same experiment. The statistical analysis was performed with DSAASTAT through variance analysis (ANOVA). The mean separation was made using Fisher's LSD prior to the angular transformations of the percentage values, and the statistical significance was evaluated with $p < 0{,}01$.

15.3 Results and Discussion

15.3.1 Chemical Characterization of Tannin Content

The HPLC-DAD-MS quali-quantitative chemical characterization of hydrolysable tannins in the sweet chestnut dry fraction is shown in Table 15.1.

Both gallic and ellagic tannins were found, and the composition confirms the standardization and stability of the commercial natural extract, for which in-depth analyses were carried out on previous batches (Campo et al. 2016). The total tannin content in the powder is 26% weight, with a prevalence of gallic acid, vescalagin, and castalagin, which are representative compounds of the vegetal species under study (1.6%, 4.8%, and 9.8%, respectively). It is also interesting to note the small relative amounts of partial hydrolysis-derived compounds such as vescalin, castalin, and pedunculagin: despite the extraction conditions in high-temperature water, high-molecular-weight tannins are mostly preserved during extraction. The extract

Table 15.1 Quali-quantitative HPLC-DAD-MS characterization of the hydrolysable tannins in sweet chestnut dry extract

Compounds	mg/g
Vescalin	9.260
Castalin	8.126
Pedunculagin I	9.974
Monogalloyl glucose	3.811
Gallic acid	16.157
Vescalagin	47.633
Dehydrated tergallic-C-glucoside	9.262
Castalagin	97.742
Digalloyl glucose	19.618
Trigalloyl glucose	20.566
Tetragalloyl glucose	7.703
Ellagic acid	6.072
Pentagalloyl glucose	4.258
Total	260.180

Data expressed in mg compounds per g of extract

Table 15.2 Inhibitory value (%) for each pathogen and extract concentration

Pathogens	0.01%	0.05%	0.1%	0.5%	1.0%
Pythium dissotocum	13.29a	44.27b	57.14c	99.38d	100.0d
Pythium sylvaticum	19.44a	73.05b	79.39c	100.0d	100.0d
Pythium ultimum	3.13a	48.18b	56.51c	96.56d	100.0e

was chemically stable, as demonstrated by control HPLC-DAD-MS analysis after 6 and 12 months.

15.3.2 In Vitro Test

The sweet chestnut extract demonstrated good inhibitory activity against the mycelial growth of the tested *Pythium* (Table 15.2). The best results were obtained against *P. sylvaticum*, with scarce effect at the lowest dose (19.4% inhibition at 0.01%) but higher effects at the next two doses (73.0% and 79.4% inhibition at 0.05% and 0.1%). Higher concentrations showed a 100% inhibition value. The same effect was observed with *P. dissotocum*, with inhibition of 13.9% at the 0.01% dose, reaching 44.3, 57.1%, and 99.4% with extract concentrations of 0.05%, 0.1%, and 0.5%, respectively. Additionally, in this case, a 100% inhibition percentage was observed at 1.0% extract. Similarly, against *P. ultimum,* the inhibition percentage was 3.0% at 0.01% sweet chestnut extract, increasing to 48.2%, 56.5%, and 96.6% with doses of 0.05%, 0.1%, and 0.5% w/V, respectively. Again, at 1.0% w/V, the inhibition was 100%. In all the tests, aside from the reduced colony growth speed, a minor mycelial density was also observed.

In the literature, there is some evidence about the vulnerability of *Pythium* to tannins. In a paper by Khan et al. (1996), 100% inhibition of *P. aphanidermatum* was observed using 0.1% gallic acid. In other studies, on lines of cotton (Kenneth 2009), broad bean (Kantar et al. 1996), and peas (Kraft 1974), a correlation was observed between tannins and other polyphenols in the seed integuments or in seedling exudates and resistance against some *Pythium*. This work confirms this hypothesis, demonstrating that sweet chestnut hydrolysable tannins have repressive activity against the mycelial growth of the tested pathogens. A concentration of 0.5% resulted in inhibition just under 100%, while a 1.0% dose allowed the complete inhibition of all the *Pythium* tested.

15.4 Conclusions and Future Perspectives

The results shown are quite promising, and more tests are necessary to confirm this evidence in vivo. If confirmed, innovative applications could be hypothesized in the development of useful products for the defence against phytopathogens *Pythium*, which is also in line with the growing interest in eco-sustainable solutions for the reduction of chemical inputs in agriculture.

The possible applications range from the use of sowing substrates for ornamental and vegetable seedlings to prevent *Pythium* infestations to the development of products aimed at the biodefence of cultures. Moreover, due to the dependence of *Pythium* spp. from the aquatic environment and the damage that it can cause to hydroponic cultures (Kanjanamaneesathan et al. 2014), it could be interesting to investigate the application of tannins in this sector, especially for prevention.

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Chapter 16
A Circular Bioeconomy Chain: Indicators Applied to the Sustainable Production of Microalgae for Industrial Purposes

Tiziana Beltrani, Gabriele Raciti, Sergio Arfo', Agata Matarazzo, Rachele Castro, and Santi Tomaselli

Abstract The importance of environmental sustainability, together with its economic and social pillar, and circular economy issues permeates more and more any aspect of our daily life through proactive initiatives, tending towards zero-waste and zero-pollutant production processes to the ongoing ecological transition. Hence, there is a need for some industries, such as the nutraceutical, pharmaceutical, and cosmetic industries, to innovate their production processes from a circular perspective, trying to ensure the minimum environmental impact, a high level of quality throughout the life cycle assessment (LCA) of its products and services and the maximum expression of the hi-tech–hi-green performance combination. This chapter aims to demonstrate how internationally shared sustainability objectives can guide and bring actual benefits through companies that embrace a circular bioeconomy approach and how this, in turn, can be the basis of a multi-output production process related to markets and bioeconomy sectors. To this end, a case was studied concerning a pilot project dedicated to research and development activities applied to the nutraceutical, cosmetic, pharmaceutical, and green agriculture sectors, allowing the export of sustainable production models to places other than Sicily.

T. Beltrani
Laboratory for Resources Valorization (RISE), Department for Sustainability, ENEA-Italian National Agency for NewTechnologies, Energy and Sustainable Economic Development, Rome, Italy

G. Raciti · S. Arfo' · A. Matarazzo (✉)
Department of Economics and Business, University of Catania, Catania, Italy
e-mail: amatara@unict.it

R. Castro
Consiglio Nazionale delle Ricerche, Istituto per la Ricerca e l'Innovazione Biomedica (CNR-IRIB), Palermo, Italy

S. Tomaselli
Department of International Economics at European Funds, University of Milan, Milan, Italy

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_16

Keywords Bioeconomy · Sustainability · Circular economy · Nutraceuticals sector · Micro Algae District

16.1 Introduction

The last few years have been characterized by a positive change from a technological point of view and environmental sensitivity (Ziesel 1999). In every international, European, and national scenario, this renewed sensitivity guides both individuals' lifestyles and industrial and production opportunities and processes. Within the Sicilian Region, there is great turmoil in this direction, as evidenced by the yet-to-be-established *Micro Algae District* (MAD), which, from a circular perspective, aims to create exemplary plants for the treatment of microalgae to produce micro-granular capsules and other products for the pharmaceutical, cosmetic, and nutraceutical markets (Ministerial Decree 9 luglio 2012). This chapter aims to illustrate how the Micro Algae District, which is expected to be effective from autumn 2022 or early 2023 in the Green Energy Valley, will embody an economic actor in the ecological transition through investments in microalgae plants (e.g. Spirulina, Chlorella, and Dunaliella), thanks to an innovative circular vision along with a connection language sensor system; moreover, algae-derived hydrocolloids and other bioactive compounds are regularly used in cosmetics production, not to mention the enhanced quality of pharmaceuticals derived from the adaptation of classical fermenter to photosynthetic organisms and the use of heterotrophic algae (Ministerial Decree 2012). Moreover, alignment with the objectives set, such as the 2030 Agenda's SDGs and the Paris Agreement and carbon neutrality, will allow the export of similar sustainable production models to other places so that Sicily would strengthen its central role in the Mediterranean basin.

After a description of the case study, the chapter focuses on the identification of the main indicators, highlighting the most relevant environmental and economic features of the project. The main results in terms of the valuation of suitable indicators are presented. Some considerations on the value of the project, also in terms of future perspectives, conclude the study.

16.2 Case Study

The ambition of the *Micro Algae District* is to create an area focused on green bioenergy, where a range of algal species can be marketed in the nutraceutical, pharmaceutical, and cosmetic sectors. Moreover, these outputs will also become inputs for materials used in agriculture and zootechnics (Ullmann and Grim 2021). The innovation of the district is given precisely by the use of algorithms based on artificial intelligence and by its focus on environmental sustainability, since CO_2 will be naturally reduced through photosynthesis, which transforms CO_2 into oxygen and sugars. Additionally, water resources will be indirectly protected, as they will not be directly consumed (European Commission, *The European Green Deal*, Brussels 2019). MAD increases the extraction and conversion of microalgal lipids and carbohydrates that can be converted into different organic compounds of interest.

In turn, MAD is part of the "Green Energy Valley" joint venture, which includes other Italian and foreign companies, institutions, and universities:

- MAD, Micro Algae District (the province of Ragusa is the projected location), with Ragusa Algae Project SRL, Ragusa Green World SRL
- EmmeC2 Artificial Intelligence District
- E.I.F.E. International Economy Department European Funds & Innovation
- PAL 4 Solar Energy LLC (based in the United Arab Emirates), whose adhesion and negotiation are still in progress

The Ragusa Algae Project and Ragusa Green World are both limited liability companies (LLCs). The former intends to create an agricultural division with very high technological innovation for the cultivation of microalgae aimed at the production of algae biomass. For this initiative, the company has the possession of a plot of land located in the municipality of Acate Gulfi in the district of Poggio di Ferro, with a total area of approximately 25.970 m^2 divided into macrozones called Block A (office, changing room, canteen, laboratory, inoculation PBR, warehouse, transformer room and electrical panels, and technical room for drinking water), Blocks B and B1 (osmosis technical room, nutrient box, nutrient warehouse, filtration, drying and packaging, cyclones, hot air generator, crushing mill, controlled temperature warehouse, anteroom, and toilet), Block C (water tanks of various types), Block D (greenhouse), and parking (Directive 2002/46/EC). The production process starts from the inoculum formed by a selected strain and an initial quantity of culture at the optimal temperature and pH conditions as they are constantly monitored, also providing some macro- and micronutrients important for growth, allowing the microalgae to divide and increase numerically. When the biomass reaches a critical concentration, the harvest takes place by passing the crop through some filtration stages from which a product is obtained that still contains approximately 50% of water by weight. The activity that the company intends to implement represents a milestone of the green economy as well as a novelty in the whole Sicilian territory and allows us to simultaneously obtain various benefits, including processes with extremely low environmental impact, consumption of CO_2 as a nutrient main for algal growth, placing organic products on the market, and improvement of local employment levels. Indeed, the company aims to enter a rapidly expanding market by presenting itself on the Sicilian and national territory through the integration of innovative projects and advanced technologies. In fact, the Agricultural Division for the intensive cultivation of microalgae consists of an innovative plant where the algae cultivation cycle takes place inside closed photobioreactors located inside a greenhouse to allow the creation of a constant microclimate, while the transformation activity takes place in special technical spaces.

The cultivation and transformation cycles are aimed at obtaining Spirulina or, alternatively, Chlorella, Dunaliella, or Haematococcus (Santini et al. 2017).

16.3 Materials and Methods

It is important first to identify reference sectors, types of companies or entities, and the number of subjects potentially interested. Then, a maturity analysis evaluates the maturity stages for the application of good practice; it is followed by the assessment of the impact in terms of magnitude and economic, environmental, and social performance.

Actor characterization takes place by identifying again the reference sector, type of company and/or entity (turnover, number of employees, and dimension), any relevant attributes, geographical location, any collaborations with other actors, amount of investment, and possible use of a patent. Subsequently, the target population is defined, quantifying the number of companies and/or entities, their geographical location, and the names of possible implementers (Verma and Popli 2018). To quantify the magnitude of the impact, it is necessary to multiply the number of implementers by the results achieved, taking into account their degree of circular economy maturity (Regulation (EC) No. 258/1997).

Given that the Micro Algae District is still in its planning phase, the company intends to respect the preliminary indicators named below, elaborated by Italian Circular Economy Stakeholder Platform (ICESP) Working Group 6, which allows us to carry out a replicability comparison, distinguishing environmental, economic, and social results. Those most consistent with the company's activities will be verified and tested only when data are available and reliable; on the other hand, those that are not well matched with the company's activities will contribute to the quantification of further indicators of the circular economy (European Commission Brussels 2020).

- Environmental results: percentage of materials used that are recycled as input materials; energy consumption within the organization; reduction of water consumption; reduction of energy consumption; extension of the life cycle of materials after recycling; reduction of CO_2 emissions; rate of biodiversity loss; percentage of recycled waste (packaging); quantification of ecological footprint (through SIMA PRO software); percentage of recycled biomass; water sources significantly affected by water withdrawal; water exploitation index (WEI); percentage of use of materials with low environmental impact; percentage and total volume of water recycled and reused; percentage of use of self-produced electricity from renewable resources. These are indices given by quantity ratios.
- Economic results: reduction of waste disposal costs; reduction of raw material costs; reduction of energy costs; reduction of water costs; reduction of transport costs; increase in revenues; increase in corporate reputation; increase in waste treatment costs; increase in equipment costs; increase in costs of specialized personnel; NPV of the investment; payback period; revenues from the sale of new products generated by the use of biomass; revenues from the sale of new products generated by the use of waste; cost savings resulting from the use of recycled products; public financial support and private investments; additional costs resulting from the adoption of good practice (Directive 2004/24/EC). These are indices based on economic values.

- Social results: human health improvement; job creation; quality of life improvement; increased consumer awareness; education of workers on the green economy; number of stakeholders from various groups involved in consultations; job retention. These are indicators of different natures, sometimes even composite ones.

16.4 Results and Discussions

The biodistrict is unique in its kind, which is why it will attract further investments and funds and will be a starting point for the creation of new forms of the sustainable supply chain.

For the granting of European Union (EU) funding, which amounts to approximately 8–10 million euros, there must be an incremental innovative benefit given by a pending patent that will affect the added value of the extracted elements useful in the sectors of interest of the actors and, in particular, the pharmaceutical and agricultural sectors. The high cost of closed photobioreactors can only be offset by a high-value product. Photosynthetic production costs are expected to be higher than approximately €140/kg dry weight, representing a substantial part of the production cost. This suggests the need to focus on improved algal productivity and efficiency of production at the required scale to improve competitiveness, as their value in aquaculture is well recognized. Again, these economic benefits are in line with the requirements of the replicability study since they involve cost reductions, revenues from new products, image, and reputation (Nasri et al. 2014). One of the most expensive items in the cultivation of Spirulina is represented by the cost of nutrients, which are mainly salts containing nitrogen, phosphorus, iron, calcium, or chemical compounds with a wide range of uses and therefore easily available in a variety of formats that appear to be sort of pure depending on the presence of contaminants. One method to reduce the cost of nutrients is to recycle the culture medium, a practice that is carried out by injecting the cultivation water back into the PBRs during or after the filtration processes necessary for harvesting (Pagliaro 2020).

According to the World Health Organization, malnutrition or lack of essential amino acids, fatty acids, minerals, antioxidants, and vitamins are linked to numerous diseases of growing concern, such as nutritional anaemia (iron and vitamin B_{12} deficiency), xerophthalmia (vitamin A deficiency), and endemic goitre (iodine deficiency). There is huge potential for developing a sustainable algae industry along the whole value chain, supported by applied research and the valorization of strain collections and genetic resources along with patents, new applications, technologies, and product developments (Palahí et al. 2020).

This could be an important step towards developing a bioeconomy while creating new education possibilities, innovations, services, indirect employment (including suppliers of resources and technology necessary for algal biofuels, such as nutrients, CO_2, polyethylene liners, PBRs, and pumps), low- and high-profile jobs linked to the cultural, technological, and cognitive growth of specialists (Regulation (EC), n. 178/2002).

Table 16.1 Preliminary computation of the replicability study indicators

Indicator	Method(s)	Result
Water sources significantly affected by water withdrawal	Life cycle water use	32 (L/L)
Percentage of water recycled and reused	Water recycled (L) × 100/total water (L)	80%
Percentage of use of self-produced electricity from renewable resources	Self-produced energy × 100/total energy produced	80%
Reduction of CO_2 emissions	Life cycle CO_2 emissions	−1.1 kg CO_2
Reduction of waste disposal costs	Regional tables comparison	−20%
Job creation	Estimation	76+

Social acceptability and transparency in how indicators are reported and the extent to which a company's sustainability goals are implemented in facility operations, products, and general strategies are important factors (Pursula et al. 2018) in evaluating a new project (Rajeev 2017).

Currently, the indicators in Table 16.1 can be quantified through a meta-analysis (Results) based on literature that meets the dimensional requirements and aspirations the District intends to achieve (Garcia et al. 2017). These indicators are water sources significantly affected by water withdrawal, the percentage of water recycled and reused, the percentage of use of self-produced electricity from renewable resources, and the reduction of CO_2 emissions for the environmental indicators (Bröring et al. 2020). The reduction of waste disposal costs is among the economic indicators. Job creation is for the social indicators (Regulation (EC) No. 1924/2006).

The social benefits include not only the number of potential jobs but also their quality in terms of safety at work (European Commission 2020). These goals include security of operation and, therefore, workdays lost to injury, even if few types of health issues or injuries are specific to algal production (Bröring et al. 2020). However, employment numbers are sensitive to many technical parameters, such as biomass productivity, project duration, lipid content extraction, and conversion rate (Pinto da Costa 2017).

Table 16.2 shows an estimation of the human resources involved in the project, which could amount to 76 individuals/year considering the positions that will be needed (Bux et al. 2016).

To these, multifirm medical representatives, who deal with the sale of active ingredients, should be added (Basu et al. 2007). In the future, the model will likely be exported by creating different branches, and therefore, it would be possible to multiply the number of jobs (Regulation (EC) n.178/2002).

These social advantages match the requirements of replicability studies since they involve positive impacts on society (Ellen MacArthur Foundation 2019) and compliance with legislation (DG Environment 2018).

Table 16.2 Estimation of the human resources involved, as studied in this chapter

Section or job	Description	Total
Construction of structures and outbuildings	2 teams of 10 workers	20
Artificial intelligence algorithms and renewable energy sources	Team of photovoltaic installers (5 workers) + Management and installation of cables and sensors (5 workers)	10
Technical management of the plant	Nursery (3 biologists +1 chemist) + factory (2 sensor workers +3 technicians) + R&D (5 multidisciplinary team)	14
Technical scientific committee	DEI (6) + EmmeC2 (3) + E.I.F.E. (3) + PAL 4 Solar Energy (3)	15
Research grants and researchers	1 × physics, computer science, economics, biology, chemistry, engineering	6
Security	Surveillance activities in the morning (2) and evening (2)	4
Commercial and communication office	Sales manager (1) + operators (3) + secretary (1)	5
Practices management unit	Engineer (1) + assistant (1)	2
Total: 76		

Source: Personal valuation based on current personnel needs

To support corporate decisions and to better understand the context surrounding the site of the Micro Algae District (MAD), it is possible to quantify, individually, some of the indicators that make up the Human Resource Development Index (HRDI) (Bryden et al. 2017). In particular, as displayed in Table 16.3, the HRDI is a flexible index made up of 6 subindices: The Employment Index; the Education Index, which, in turn, is given by the weighted sum of the Literacy Index and the Educational Facility Index; the Sex Ratio Index; the Health Facilities Index; the Living Conditions Index that is being replaced by the Climate Risk Index (CRI); and the Income Index (Wong et al. 2015).

16.5 Conclusions

The analysis of the HRDI considers the population in the province of Ragusa in 2019, the year of the most recent data, which accounts for 315,601 individuals (Ellen MacArthur Foundation 2015). The six indices provide an overall view of the main areas concerning the social, economic, and environmental aspects in the province of Ragusa (Regulation (EC), n.178/2002). These data show an economic-social situation and a still rather unsatisfactory quality of life. Therefore, the realization of economic activities such as the one analysed should be encouraged and could have significant positive effects on the territory (Zingale et al. 2022).

Table 16.3 Computation of the human resource development index factors

Index	Factors	Result	Source(s)
Employment Index	Total number of workers/total population	0.504	Istat
Education Index	1/3 literacy index (Total number of literates/total population)	0.283	Istat, Comune di Ragusa, scuolaitaly.it
	2/3 Educational Facility Index (Total number of schools and colleges/Total population)		
Sex Ratio Index	Number of females per 1000 males	1016.130	UrbiStat
Health Facilities Index	Total number of hospitals/total population	0.0000190	ASP Ragusa
Climate Risk Index	A multifactor index that shows to what extent countries and regions have been affected by impacts of weather-related loss events	0.261	CMCC Foundation
Income Index	Total income/ Total population	€ 12,824.00	Osservatorio Findomestic–Prometeia

Source: Personal valuation via lab24.ilsole24ore.com/qualita-della-vita/Ragusa/

Acknowledgements The authors wish to acknowledge the support of the Italian Ministero dell'Istruzione, dell'Universita e della Ricerca (MIUR) through the project "Ottimizzazione delle Prestazioni di Turbine Eoliche e loro Impieghi Particolari- Analisi di Fattibilità Tecnico-Economica ed Ambientale" of the Department of Civil Engineering and Architecture and Department of Economics and Business of the University of Catania-Piano di incentivi per la Ricerca 2020/2022 (PIA.CE.RI).

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Chapter 17
The ILCIDAF Project for the Development of an Italian Database of Life Cycle Inventory of Agri-food Products: The Wheat Milling Phase

Bruno Notarnicola, Giuseppe Tassielli, Pietro A. Renzulli, Rosa Di Capua, and Francesco Astuto

Abstract The project "Italian Life Cycle Inventory Database of Agri-Food Products" (ILCIDAF), funded by the Ministry of University and Research, aims to promote the sustainability of the agri-food sector through the development of an Italian database for some important food chains in our country (bread and pasta, wine, olive oil, and citrus fruits). The research project is being developed by four scientific units: the University of Bari, Chieti-Pescara, Messina, and Reggio Calabria. The database is constructed considering the entire supply chain of the indicated foodstuffs. In particular, in this work, the milling activities of durum and soft wheat are analysed, and the construction of datasets related to the production phase of durum and soft wheat flour is proposed.

Keywords Milling · Wheat · Database · Flour · Semolina · Bread · Pasta

17.1 Introduction

The Project of Relevant National Interest titled "Promoting Agri Food Sustainability: Development of an Italian Life Cycle Inventory Database of Agri-Food Products" (ILCIDAF) aims to build a database dedicated to the Italian agri-food sector (Notarnicola et al., (2022)). The database is structured in such a way as to describe all phases of a food production chain: the agricultural phase of cultivation and the industrial phase of transformation of intermediate and final products. In this

B. Notarnicola (✉) · G. Tassielli · P. A. Renzulli · R. Di Capua · F. Astuto
Ionian Department of Law, Economics and Environmen, University of Bari Aldo Moro, Taranto, Italy
e-mail: bruno.notarnicola@uniba.it; giuseppe.tassielli@uniba.it; pietro.renzulli@uniba.it; rosa.dicapua@uniba.it; francesco.astuto@uniba.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_17

chapter, the supply chain of wheat products is discussed, with a particular focus on the wheat milling phase to build datasets on the production phase of durum and soft wheat flour. In commercial databases, there is no characterization for the different flour classes that exist. Agribalyse describes only the five different types of French soft wheat flour. The ILCIDAF project, on the other hand, provides eight different types of flour: three types of durum wheat (semolina, semolate, and wholemeal semolina) and five soft wheat (type 00, 0, 1, 2 and wholemeal flour).

The milling process is essential for the production of durum and soft wheat flour necessary for the production of pasta and bread. Once harvested, the wheat is separated from extraneous substances (stones, soil, and metal residues) and then transported and stored at controlled temperatures to promote slow drying. Before being milled, the grains are further cleaned to remove plant residues and soaked (conditioned) to facilitate grain crushing. Subsequently, the milling process consists of several steps: crushing of the grains, husking, and regrinding. Finally, sifting (by means of a plansichter device) before entering the cylinders (or rolling mills) allows for the classification and selection of the products before they are subjected to grinding again or arrive at the semolina mill for the sifting process.

17.2 Literature Review

The data relating to the wheat milling phase studied in this work are the result of a literature analysis with the aim of acquiring data on the use of resources (energy consumption and water resources), input flows (type of wheat), and output flows from the system (type of flour, coproducts, and waste). The bibliographic collection concerns the following:

1. Scientific articles published in journals: Eleven articles were selected (Table 17.1), of which six were related to durum wheat and five to soft wheat;

Table 17.1 Bibliographic collection of the degree of sifting of durum and common wheat flours

N.	Wheat type	Sifting	Average	Source
		%		
1	Durum	75.57	70.50	Bevilacqua et al. (2007)
2		78.99		Ingrao et al. (2018)
3		64.10		Lo Giudice et al. (2011)
4		65.36		Notarnicola et al. (2004)
5		66.25		Notarnicola et al. (2004)
6		72.73		Seget et al. (2020)
7	Common	67.62	75.85	Camara-Salim et al. (2020)
8		89.84		Chiarico et al. (2017)
9		61.76		Comino et al. (2021)
10		80.00		Kulak et al. (2015)
11		80.00		Parenti et al. (2020)

2. Italian Environmental Product Declaration (EPDs) related to the production of “uncooked pasta, not stuffed or otherwise prepared” (CPC 2731): 14 EPDs were selected, of which 13 were related to semolina and 1 to wholemeal semolina;
3. Italian EPDs referring to “grain mill products” (CPC 2311). Five EPDs were selected: one for semolina; two for 00- and 0-type flour; and two for wholemeal flour.

The data collected in the company were supplemented with data from EPDs.

17.3 Materials and Methods

Note that EPDs for pasta production express data associated with the production of 1 kg of dry pasta. It was necessary to research data on the yield of the pasta production process. In a study by Notarnicola et al. (2004) and Lo Giudice et al. (2011), 1.06 kg of semolina (94.34% yield) is required to produce 1 kg of pasta. For pasta production, according to the most common recipes, 1.1 kg of semolina produces 0.95 kg of pasta (86.36%). In the studies by Notarnicola et al., (2001) and Notarnicola et al. (2004), 1 kg of couscous (90.25%) was obtained from 1.108 kg of semolina. The average of the yields (90.3%) was used to correct the data of the indicated EPDs so that the results refer to 1 kg of semolina.

17.3.1 Grain Milling Yield

Table 17.1 shows the type of grain considered, the percentages of the different papers analysed, the average, and the bibliographical sources. The milling of durum and soft wheat yields, as is well known, different products. The extraction percentage depends on the type of product to be obtained from the milling and subsequent sifting of the grain.

Different classes of flour as indicated in D.P.R. No. 187/2001 (modified by (Decree of the President of the Republbic) D.P.R. n° 41/2013) were considered. Each of the associated products corresponds to a percentage of sifting. In particular, for soft wheat, there are five types of flour for which it was easy to associate the average extraction yield (Table 17.2). For durum wheat, semolina, semolate,

Table 17.2 Properties relating to types of soft wheat flour

Common wheat flour	Sifting %	Max ash	Multiplicative factor
Flour type 00	50	0.55	1.6000
Flour type 0	72	0.65	1.1111
Flour type 1	80	0.80	1.0000
Flour type 2	85	0.95	0.9410
Wholemeal flour	100	1.70	0.8000

and wholemeal semolina were considered. Durum wheat flour is excluded because it constitutes a different product with a nongranular structure, although the intermediate ash content among the others suggests that it is solely the result of a different yield from the same milling process. The degree of souring of durum wheat flour was determined by evaluating it together with the ash content, and these quantities were compared to understand the relationship between the two. The results show that it was possible to attribute a linear, albeit approximate, correspondence between the quantities considered (unlike soft wheat). In this way, it was possible to associate the relative degree of sifting to the three types of durum wheat flour: considering an average percentage of 68% (resulting from the average of the data from the publications on semolina) for semolina and assuming a yield of 100% for wholewheat, it was possible to attribute an average degree of sifting of 84% to semolina. Distinguishing the data collected from publications and EPDs, the results were averaged to associate a corresponding flour production. The average of the data collected from EPDs related to durum wheat was associated with the production of "semolina." Knowing the yield of semolina and wholemeal semolina, the ratio used as a multiplier for the environmental profile of the durum wheat flours considered was calculated. For soft wheat, the average data were combined with the yield of "type 1 flour." Noting the yield of type 1 flour and calculating the relationship with the other yields (00, 0, 2 and wholemeal), the factors for each type of flour were determined. Tables 17.2 and 17.3 show the different classes of flour laid down in the regulations, supplemented by the multiplication factor. The fraction will be greater or less than "1" depending on whether the type of flour considered is more or less refined than that associated with the starting flour. Multiplication factors were used to estimate resource consumption data (energy and water) so that the datasets for the milling phase could be defined.

The coproducts were quantified by mass balancing in the milling process and considering the weight percentages expressed in the cited publications. The coproducts consist of bran and shorts, pollard, germ, and screenings (other subproducts). The weight percentage of bran decreases as the sifting percentage increases and vice versa. For durum wheat, the average percentage is 92.78%, and the remainder consists of middlings, grains, and rejects; for soft wheat, the average percentage is 98.10%, and the difference indicates process rejects. Therefore, even wholegrain flour has a certain, albeit minimal, amount of byproducts.

Table 17.3 Properties relating to types of durum wheat flour

	Sifting		
Durum wheat flour	%	Max ash	Multiplicative factor
Semolina	68	0.90	1.0000
Semolate	84	1.35	0.8095
Wholemeal semolina	100	1.80	0.6800

17.4 Results and Discussions

A total of 16 wheat milling datasets were constructed: eight estimated from published data (three for durum wheat and five for soft wheat) and eight derived from data extracted from EPDs and supplemented with on-farm data (three durum wheat and five soft wheat). The flours analysed are as follows:

- Durum wheat semolina.
- Durum wheat semolate.
- Durum wheat wholemeal flour.
- Common wheat flour type 00.
- Common wheat flour type 0.
- Common wheat flour type 1.
- Common wheat flour type 2.
- Common wheat wholemeal flour.

Table 17.4 shows, for illustrative purposes (and in compact form), the durum wheat semolina dataset resulting from the collection of data from EPDs integrated with company data.

Applying the described methodology to the collected data, it is possible to produce wheat milling datasets for the different flour classes considered. Furthermore, they were estimated from different sources, i.e. scientific articles and EPDs relating to "uncooked pasta, not stuffed or otherwise prepared" (CPC 2731) and EPDs relating to "grain mill products" (CPC 2311) and integrated with data collected in the factory.

17.5 Conclusion and Future Prospects

The data calculated and included in the datasets produced, independent of the source selected, are comparable with each other and consistent in terms of energy consumption, water consumption, and mass balance. The data are not given in disaggregated form, i.e. for each stage of the milling process (cleaning, storage, conditioning, grinding, and sieving), but in aggregate form. The data described refer to the Italian territory, and in the case of EPDs, the average technology installed in mills is also considered. The ILCIDAF project's special feature of characterizing both soft and durum wheat flour constitutes an added value to the database made freely available online. Other commercial databases offer data on generic flour and its byproducts. Only Agribalyse describes some flour classes, but only for soft wheat. A future implementation of these datasets could include the disaggregation of data on the subprocesses of the grain milling phase, but this is only feasible with great effort and cooperation from the milling industry.

Table 17.4 Datasets derived from EPD data collection supplemented with field data on the production of 1 kg of durum wheat semolina

Process information	Description		
Process name	Durum wheat semolina production, national average.		
Geography	The data on durum wheat semolina production represent the production of flour in the main Italian mills, which account for 90% of national production.		
Technology	The reference technology, with regard to energy consumption, considers both the renewable primary resource and the non-renewable primary resource installed in plants		
Time period	The milling process data is for 2020.		
Source	National average, based on statistical data and on-field data.		
Literature references	EPD “uncooked pasta, not stuffed or otherwise prepared” (CPC 2731); EPD “grain mill products” (CPC 2311).		
Allocation rules	In the joint production of semolina and coproducts, data were not allocated. For possible allocation, the factors 0.89; 0.089; 0.01; 0.011 (for semolina, bran, pollard, germ, respectively) should be used.		
Data tratment	The dataset is the result of combining literature data collected by EPDs and data collected directly in the mills that collaborated with the ILCIDAF project.		
Completeness check	All relevant flows quantified.		
Inventory data			
Product/functional unit	Name	Amount	Unit
Functional unit	Quantity	1	kg
product	semolina		
Input flows			
Type	Name	Amount	Unit
Resources from the environment	Durum wheat	1.47E+00	kg
Energy input	Renewable primary energy resources (as energy carrier)	8.31E-02	kWh
	Renewable primary energy resources (as a resource)	5.60E-04	kWh
	Non-renewable primary energy resources (as energy carrier)	2.02E-01	kWh
	Non-renewable primary energy resources (as a resource)	2.91E-02	kWh
Water input	Use of water resources	1.85E+00	L

(continued)

Table 17.4 (continued)

Process information	Description		
Output flows			
Type	Name	Amount	Unit
Product	Semolina	1.00E+00	kg
Coproduct	Bran	3.64E-01	kg
	Pollard	4.09E-02	kg
	Germ	4.09E-02	kg
	Screenings	2.44E-02	kg
Waste to treatment	Hazardous wastes	1.13E-06	kg
	Non-hazardous wastes	5.70E-02	kg
	Radioactive waste	2.59E-05	kg
Administrative information			
Commissioner of dataset	MUR – PRIN		
Data entry by	University of Bari, Aldo Moro		
Quality check by	University of Bari, Aldo Moro		
Pubblication and ownership	Free of change for all users and uses		

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Chapter 18
Life Cycle Inventory Data for the Italian Olive Oil Supply Chain: How to Ensure Representativeness

Teresa Maria Gulotta, Giuseppe Saija, Giovanni Mondello, Roberta Salomone, and Patrizia Primerano

Abstract Life cycle assessment (LCA) is increasingly used to assess the potential environmental impacts of agri-food products, but practitioners face many problems in identifying and solving various methodological and data availability issues. One of the main critical issues is linked to the lack of reliable site-specific data representing the specificities of the Italian agri-food production processes. These reliable data are still missing in commercial databases, which generally use approximate data or data related to other countries. To reduce this lack, the project "Promoting Agri-Food Sustainability: Development of an Italian Life Cycle Inventory Database of Agri-Food Products (ILCIDAF)" aims to develop a database of life cycle inventory (LCI) for some Italian agri-food products. This chapter reports preliminary results related to the Italian olive oil supply chain showing two different LCI data collection approaches: (i) combining statistical and secondary data and (ii) using primary data collected through surveys. Although differences in data among the proposed approaches exist, the datasets result in a high level of detail that could be used for representing, from macro (country) to micro (organization) levels, the specificities of Italian olive oil production, showing a higher quality of data compared to existing commercial LCI databases.

Keywords Olive oil · Life cycle assessment (LCA) · Agri-food · Life cycle inventory (LCI)

T. M. Gulotta (✉) · G. Saija · G. Mondello · R. Salomone
Department of Economics, University of Messina, Messina, Italy
e-mail: teresamaria.gulotta@unime.it; giuseppe.saija@unime.it; giovanni.mondello@unime.it; roberta.salomone@unime.it

P. Primerano
Department of Engineering, University of Messina, Messina, Italy
e-mail: patrizia.primerano@unime.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_18

18.1 Introduction

The evaluation of the environmental impacts of agri-food products using the life cycle assessment (LCA) method has experienced a growing interest in recent years due to the need to develop a carbon-neutral economy, looking for sustainable strategies to reduce resources and increase production performances (Notarnicola et al. 2017). However, reliable site-specific life cycle inventories (LCIs) representing the specificities of the Italian agri-food production processes are still missing in commercial databases (Notarnicola et al. 2022). To reduce this lack, the project (PRIN – Progetti di Ricerca di Interesse Nazionale 2017-Prot. 2017EC9 WF2, sector ERC SH2, Linea C – financed by the Ministry of University and Research) "Promoting Agri-food Sustainability: Development of an Italian Life Cycle Inventory Database of Agri-Food Products (ILCIDAF)" aims to develop a database of LCI for four Italian agri-food products: olive oil, citrus, wine, and grain products. However, it is essential to highlight that building reliable inventory data for the assessed products is challenging because data used at the flow level need to be characterized with a high level of representativeness, which is influenced by temporal, geographic, and technological aspects (Samarghandian et al. 2016).

In this chapter, preliminary results related to modelling the Italian olive oil supply chain are reported to highlight how data representativeness could be ensured. In particular, this is done by showing the methods and materials used to develop LCI datasets for the Italian context and calculating the data quality scores through the pedigree matrix (Samarghandian et al. 2016). Then, these results are compared to the data quality calculated for the only dataset available on Ecoinvent for Italian olive production (Notarnicola et al. 2022). This preliminary study aims to provide critical qualitative analysis of data reliability and representativeness for the specific Italian context.

18.2 Materials and Methods

The European Union (EU) accounts for more than 67% of the world's olive oil produced (European Commission 2020). Italy is one of the largest producers of olive oil in the EU after Spain, producing approximately 20% of EU olive oil in 2021 (European Commission 2021). The Italian regions contributing to approximately 80% of this production are Apulia, Sicily, Calabria, Lazio, and Campania (ISTAT 2021). The olive oil supply chain consists of five main phases: (i) agricultural phase, (ii) olive oil production phase, (iii) packaging phase, (iv) distribution and consumption phase, and (v) waste management phase (Espadas-Aldana et al. 2019; Salomone et al. 2015). For this preliminary study, only the data quality reached by the agricultural phase is presented, referring to the Sicilian context in 2021. To compare the datasets, the pedigree matrix data quality assessment method is applied at the flow level following the framework reported by Thomas Nemecek et al. (2019) and

Samarghandian et al. (2016). A detailed description of the two data gathering approaches is reported in the following sections. Instead, the common calculations of both approaches are detailed in Sect. 18.2.3.

18.2.1 First Approach: Primary Data for LCI

For the first approach, the datasets are developed using primary data from surveys to represent specific areas of Sicilian cultivated land for producing olives used for extra virgin olive oil production. A questionnaire for each phase was developed and shared with farm owners to gather information on, e.g. the variety of cultivars, cultivation practices, substances used for fertilization and/or pest control, and techniques used for waste or byproduct management. The data collected refer to the seasonal period 2020–2021.

18.2.2 Second Approach: Statistical and Secondary Data for LCI

For this approach, the datasets representing Sicilian regional processes of olive production are elaborated by combining statistical and secondary data provided by (i) the Italian statistical database (ISTAT 2021), (ii) Integrated Production Regulations (IPR) (Regione Siciliana 2021), and (iii) a technical handbook of agriculture (Ribaudo 2017). The inputs acquired from the national statistical databases are related to cultivated land and quantity of produced olives, considering a time interval between 2015 and 2020. The consumption of fuel, lubricating oil, electricity, and water used in irrigation practices and soil management are estimated based on the data reported by Ribaudo (2017). Instead, the Sicilian IPR recommendations are used to estimate the amounts of fertilizers and pesticides usable per hectare.

18.2.3 Emission Calculations for LCI

The inputs relating to olive production are used for calculating the emissions in the field derived from the application of fertilizers, the distribution of pesticides, and the combustion of fuels; these are calculated according to the suggestions provided by Notarnicola et al. (2022). In particular, (i) the emissions linked to fertilization processes are estimated using the methodology described by Zampori and Pant (2019) and Prasuhn (2006); (ii) emissions linked to pesticides are calculated according to the assumptions reported in Zampori and Pant (2019); (iii) emissions from fuel combustion are estimated by Nemecek and Kägi (2007); and (iv) the emissions linked to natural phenomena, such as erosion and leaching, are calculated using the Swiss Agricultural Life Cycle Assessment (SALCA) model (Freiermuth 2006), adequately customized for Italian regions.

18.3 Results and Discussion

Table 18.1 shows the data quality scores estimated for the two proposed approaches compared with the "olive production IT" process available in the Ecoinvent database (Wernet et al. 2016). The indicators are calculated at the flow level using a 1–5 scoring system, where 1 is the best and 5 is the poorest or unavailable data (Edelen and Ingwersen 2018).

Among the three datasets, the first approach is characterized by the best data quality scores. The datasets developed in the context of the ILCIDAF project are characterized by "very good quality" (<2) for representing the Sicilian context in 2021, while the Ecoinvent dataset has a "good quality" score (between 2 and 3). Looking at flow levels, not all the data gathered for the two approaches are better than the data in Ecoinvent. In fact, with the first approach, not all data were available to build the dataset, and missing data had to be covered using secondary data or entering the number 5 as scores. Generally, farm owners cannot provide information on direct emissions linked to processes or split contributions to energy and water consumed by plants, providing only a highly detailed overview of global consumption of energy, materials, water, and fuel for transport but is always site specific. In contrast, in the second approach, detailed information on energy and materials contributions to the type of operation is estimated considering geographic representativeness within one level of resolution or less if data are specific to a particular region.

Although the first two indicators (R and C) are based on the way data are validated or completed, varying from 1 and 2 except for rare cases, representativeness scores depend on the goal and scope of the LCI dataset. This means that while the technological and geographic representativeness is "1" in almost all flows of the Ecoinvent dataset, the scores, if used for specific regions (meso) or farms (micro) case studies, could become 2 and 3, respectively, affecting the uncertainty of environmental results. In addition, among 70 inputs and outputs in the Ecoinvent dataset, only 6% refer to Italian boundaries, while the remaining are related to the global or rest of the world context (Notarnicola et al. 2022). Additionally, the calculated inputs and outputs included are approximate data or data related to other countries, such as the case of the emission of heavy metals, calculated with a Swiss data model. In contrast, in the ILCIDAF database (for both the proposed approaches), the SALCA model is adapted to the Italian context, using the concentration values of heavy metals within one level of geographic resolution and data estimated by less than 3 years. These methodological choices make the proposed database more representative of the Italian agri-food situation.

Table 18.1 Data quality indicators (DQI) of reliability (R), completeness (C), time-related (TiR), geographical (GR), and technological representativeness (TeR) aspects at the flow level

	Data gathering approaches																	
References flow	*First approach*						*Second approach*						*Ecoinvent dataset*					
Productivity	11.84				tonnes/ha		1.92				tonnes/ha		4.3				tonnes/ha	
Land per olive	0.084				ha/tonnes		0.521				ha/tonnes		0.233				ha/tonnes	
Olive trees	2385				–		n.a.				–		250				–	
Age of orchard	More than 40				years		n.a.				years		40				Years	
Cultivation	Integrated						Integrated						Conventional					
Time period	2020–2021						2015–2020						2001–2008					
Geographic area	Area of Sicily – IT (micro)						Sicily – IT (meso)						IT (Macro)					
	Indicators																	
Agricultural phases	R	C	TiR	GR	TeR	DQI	R	C	TiR	GR	TeR	DQI	R	C	TiR	GR	TeR	DQI
Soil operation	5	5	5	5	5	5	2	1	2	1	1	1.4	2	1	4	1	1	1.8
Planting trees	1	1	1	1	1	1	2	1	2	2	2	1.8	2	1	4	1	1	1.8
Fertilization (F)	1	1	1	1	2	1.2	2	1	2	2	2	1.8	2	1	4	1	1	1.8
Pest treatment (P)	1	1	1	1	3	1.4	2	1	2	2	3	2	2	2	4	1	1	2
Packaging for F&P	4	3	4	5	4	4	4	3	4	5	4	4	4	3	4	5	4	4
Pruning	2	1	1	1	2	1.4	2	2	2	2	2	2	5	5	5	5	5	5
Irrigation	2	1	1	1	2	1.4	2	1	2	2	3	2	2	1	4	1	1	1.8
Harvesting	1	1	1	1	1	1	2	1	2	2	2	1.8	2	1	4	1	1	1.8
Waste transport	2	1	1	1	3	1.6	2	2	2	2	3	2.2	2	1	4	1	1	1.8
Treatment of residues	2	1	2	1	2	1.6	2	1	2	2	4	2.2	2	1	4	1	1	1.8
Transport	2	1	1	1	1	1.2	2	2	2	2	2	2	4	1	4	1	1	2.2
Emissions to soil	2	2	1	2	1	1.6	2	2	1	1	1	1.4	2	2	4	1	1	2
Emissions to water	2	2	1	2	1	1.6	2	2	1	1	1	1.4	2	2	4	1	1	2
Emissions to air	2	2	1	2	1	1.6	2	2	1	1	1	1.4	2	2	4	1	1	2
Data quality scores	2.1	1.6	1.6	1.8	2.1	1.8	2.1	1.6	1.9	1.9	2.2	2	2.5	1.7	4.1	1.6	1.5	2.3

Furthermore, concerning the temporal aspect, high discrepancies exist among the ILCIDAF datasets and Ecoinvent due to the data collection period. It is crucial to note that in the second approach, contrary to the first, the data on productivity consider medium- to long-term values for reducing the influence (negative or positive) caused by the yearly fluctuation of perennial trees in data estimation but without specifying the relative productivity for ages of the orchard. Concerning the time-related representativeness of flows, the following observations can be made: (i) in the first case, the differences between the data collected and the reference period time of study are less than 3 years; (ii) for the second case, the data on the management of soil and technology operation are estimated from a handbook published more than 3 years ago; and (iii) finally, in the case of Ecoinvent, data are older than 10 years. For that reason, almost all data are characterized by a very low temporal representativeness.

Finally, although the first approach provides data only for 1 year of production, it is characterized by high data quality scores for specific situations in terms of geographic, temporal, and technological aspects. Therefore, considering the site-specific operations, cultivar, climatic conditions, and soil characteristics that affect regions in Italy, only one dataset for representing Italian agri-food production is insufficient.

18.4 Conclusions

This study shows preliminary results reached in the context of the ILCIDAF project for the olive oil supply chain. It aims to identify how to ensure representativeness in LCI for Italian agri-food products. The first evidence is that more site-specific LCI datasets for agri-food products are needed, and flow data must ensure high data quality scores. Comparing the two proposed approaches – one based on primary data and the second on technical and statistical data – with the only one existing in commercial databases for Italy, high discrepancies are highlighted among data and their quality, especially for geographical and temporal representativeness. In commercial databases, except for olive production, all life cycle phases and representative processes of the olive supply chain are still missing. Finally, this study confirms the high need for having LCI datasets for more geographical resolution degrees from micro to macro levels to reduce the uncertainty in LCA models and to represent the goals and scopes established by LCA practitioners.

Funding This article is part of the results of the research project "Promoting Agri-food Sustainability: Development of an Italian LCI Database of Agri-Food Products (ILCIDAF)" (PRIN – Progetti di Ricerca di Interesse Nazionale 2017-Prot. 2017EC9 WF2, settore ERC SH2, Linea C – funded by the Ministry of University and Research).

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Chapter 19
Carbon Footprint of Seasonal Meals: The Case of School Canteens

Giovanni Mondello, Elena Neri, Roberta Salomone, Teresa Maria Gulotta, Riccardo Maria Pulselli, Gaia Esposito, and Eleonora Tancredi

Abstract School canteens may play an important role in promoting sustainable diets based on the selection of seasonal meals and nutritional values. In this study, the life cycle assessment method was applied to evaluate the environmental performance, in terms of global warming, related to the life cycle of four seasonal menus supplied to school canteens. Furthermore, the aim is also to understand how environmental sustainability may be linked to strategic choices oriented to seasonal menus and nutritional values of ingredients. The functional unit is referred to as "one seasonal menu delivered to a school canteen," while system boundaries are defined, including three different phases: (1) ingredient production and transport, (2) meal preparation, and (3) meal delivery. The results underscore that, in all the investigated menus, ingredient production (phase 1) causes the main contribution to the impacts, followed by cooking processes (phase 2). Furthermore, high variability is identified when the impacts of ingredients are compared to their nutritional values, and an improvement in global warming performance is identified when seasonal food products are adopted. The study also points out the need for more specific frameworks aimed at helping decision-makers in choices regarding sustainable and nutritionally balanced diets.

Keywords School canteen · Life cycle assessment (LCA) · Food services · Sustainable diet · Agri-food · Climate change

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G. Mondello (✉) · R. Salomone · T. M. Gulotta
Department of Economics, Sustainability Lab, University of Messina, Messina, Italy
e-mail: giovanni.mondello@unime.it

E. Neri · R. M. Pulselli · G. Esposito
INDACO2 srl, Siena, Italy

LABORIOSO, Laboratorio di Ricerca Congiunto, University of Siena, Siena, Italy

E. Tancredi
Qualità e Servizi, Florence, Italy

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_19

19.1 Introduction

The transition towards sustainable food systems represents a priority among European policies due to the need to reduce malnutrition and food poverty as well as improve food environmental performance (EC 2022). With specific regard to environmental sustainability, food production is responsible for significant impacts (Notarnicola et al. 2012) that are expected to further increase in relation to the increasing demand for food by 2050. Guyomard et al. (2012) highlighted the link between dietary patterns and the sustainability of food systems and production. Furthermore, various national documents, particularly in Europe (e.g. Italy and Germany), that provide food-based dietary guidelines include recommendations on how to achieve sustainability in diets (FAO 2022). Such recommendations commonly refer to the sustainability of the whole life cycle of food products, including production, packaging, transport, and consumption (e.g. CREA 2019).

Schools and related food services may play a very important role in promoting sustainable diets (CREA 2018). Indeed, school canteens may contribute to educating people about good nutrition and sustainable foods (e.g. by promoting sustainable healthy menus). For this reason, the design and preparation of a menu for school canteens must consider the environmental impacts of meals and related ingredients, in addition to nutritional values and seasonality. Considering the strong link between food, dietary habits, seasonality, and environmental sustainability, there is increasing interest among the scientific community in assessment methods that are able to capture this complexity. Among those methods, life cycle assessment (LCA) is considered the main approach used to evaluate the environmental sustainability of food production and diets (Aldaya et al. 2021).

In this context, this study aims to assess the potential environmental impacts, through the LCA method, connected to the preparation of menus and related services for school canteens, focusing on the amount and nutritional value of meals and highlighting the role of strategic choices linked to seasonality.

19.2 Material and Methods

The potential environmental impacts of the menus provided to school canteens have been evaluated by applying the LCA method, according to ISO 14040-44:2006. LCA is a standardized method used for the assessment of the potential environmental impacts of a product, process, or service throughout its whole life cycle, from raw material extraction to the end-of-life (EoL) (ISO 2006a, b).

19.2.1 Goal and Scope Definition

The LCA method has been applied to assess the environmental performance connected to the preparation and delivery of seasonal menus supplied by an Italian food service company to school canteens. In particular, the study investigates four menus (i.e. one per season) that are characterized by different ingredients and similar nutritional values. The scope is, on the one hand, to evaluate the environmental impacts of meals provided to school canteens, focusing on a life cycle perspective, and on the other hand, to understand how choices for diets based on the use of seasonal ingredients in menus and nutritional value are linked to environmental sustainability considerations.

According to Sonesson et al. (2017), a mass-based functional unit was identified. In this context, the functional unit (FU) selected was represented by "one seasonal menu delivered to a school canteen," thus considering the amount (expressed in kg) of each menu. Choosing this FU permits the investigation of the four meals by considering the amount and nutritional value of each ingredient as well as their seasonality. Furthermore, system boundaries were defined, including three main phases: (1) ingredient production and transport to the food service company; (2) meal preparation at the service company; and (3) meal delivery to the school canteen. In addition, the packaging used for ingredients was considered in phase 1. Cut-off criteria include the end-of-life (EoL) of the menu after consumption, assuming zero food waste. This choice was due to the lack of information and data related to the EoL of meals.

19.2.2 Inventory Analysis

The life cycle inventory (LCI) was built using primary and secondary data. Primary data were collected through direct interviews and questionnaires provided to the food service company, while secondary data were gathered using dedicated databases (e.g. Ecoinvent, World Food LCA Database - (WFLDB), etc.). Based on company communication, the main ingredients characterizing each of the investigated menus and the related nutritional values are reported in Table 19.1.

Regarding the meal preparation phase and, in particular, cooking through natural gas stoves, data were calculated considering the amount and heating capacity of the ingredients used in the menus as well as assuming specific cooking times per meal preparation. Furthermore, in phase 3, a distance of 25 km was assumed to transport the meals from the food service company to the different schools.

Table 19.1 Main ingredients used in the menus (company communication; Am = amount (grams); NV = nutritional value (kcal); grey background: seasonal ingredients and related amount)

Menu		Autumn		Winter		Spring		Summer	
Food category	Ingredient	Am	NV	Am	NV	Am	NV	Am	NV
Cereal based	Rice	50	177	–	–	50	177	–	–
	Pasta	–	–	50	186			50	186
	Breadcrumbs	–	–	5	19	5	19	–	–
	Bread	30	71	30	71	30	71	30	71
Vegetable	Pumpkin	50	10	–	–	–	–	–	–
	Cauliflower	–	–	150	38	–	–	–	–
	Onion	1	0	–	–	–	–	–	–
	Bean	100	19	–	–	–	–	30	90
	Spinach	–	–	–	–	40	11	–	–
	Lettuce	–	–	–	–	40	7	–	–
	Radicchio	–	–	–	–	15	2	–	–
	Tomato	–	–	–	–	–	–	100	19
	Herbs	1	1			–	–	1	1
	Garlic	–	–	–	–	1	0	1	0
Meat	Turkey	–	–	–	–	50	53	–	–
Fish	Codfish	–	–	70	51	–	–	–	–
Dairy	Cow milk	5	2	–	–			–	–
	Ricotta	–	–	–	–	5	7	5	7
	Parmesan	2	8	–	–	–	–	–	–
	Butter	–	–	5	38	–	–	–	–
Fruit	Fresh fruit	150	89	150	89	150	89	150	89
	Chicken egg	60	77	10	5	10	13	–	–
Other	Lemon juice	–	–	8	3	–	–	–	–
	Tomato sauce	–	–	–	–	–	–	15	3
	Olive oil	10	90	6	54	15	135	15	135
	Sunflower oil	5	45	5	45	–	–	–	–
	Total	464	589	489	599	411	584	397	601

19.2.3 Impact Assessment

The life cycle impact assessment (LCIA) was performed using the SimaPro 9.3 software (PRé Sustainability 2021), and the impacts related to global warming were assessed through the IPCC 2021 GWP100 method (IPCC 2021). This impact category was selected because it is among the most adopted in LCA studies related to the agri-food sector (Dijkman et al. 2018).

19.3 Results and Discussions

The results reported in Fig. 19.1 show that the potential global warming impacts of the four menus are caused by phase 1 (mainly due to the production of ingredients), followed by the preparation of the meals (phase 2).

The global warming impacts caused by the four menus range from 1.08 kg of CO_2 eq per FU in the spring menu to 0.44 kg of CO_2 eq per FU in the summer menu. In particular, the highest impact caused by the spring menu is due to turkey meat production, which contributes 38.9% to the total global warming. Furthermore, the results highlight that the average contribution of the ingredients to global warming is approximately 66% in all menus except for the summer menu, in which the contribution to the impacts decreases to 51.7%. As reported in Table 19.1, the summer menu is mostly based on seasonal ingredients (i.e. beans and tomatoes); in addition, it is the only menu characterized by seasonal fresh fruit. In addition, as reported in Table 19.1, the recipe used in this menu allows the nutritional value of the meals to be maximized (601 kcal) while reducing their amount as input (397 g) in comparison with the other analysed menus. This points out that strategic choices oriented towards identifying a menu based on high nutritional value, seasonal ingredients, and low amount of input are fundamental to achieve environmental sustainability in diets. Regarding the other processes evaluated in phase 1, the contribution to global

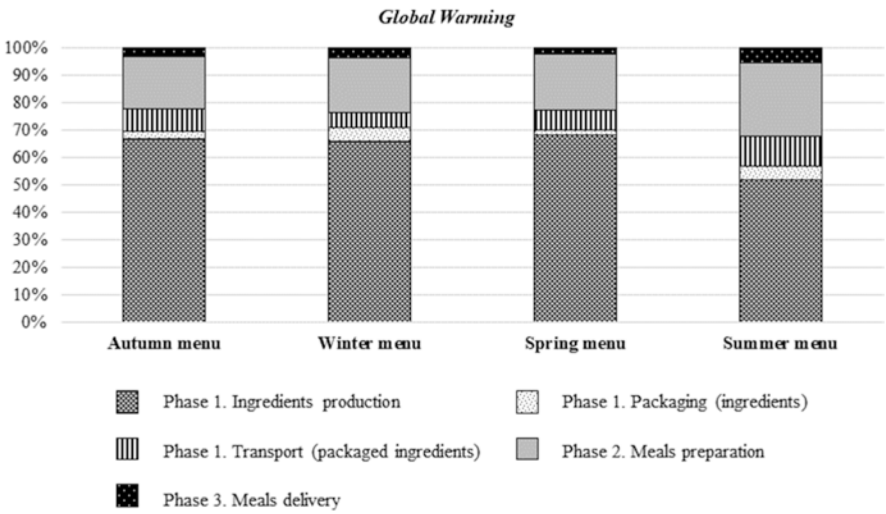

Fig. 19.1 Contribution analysis of the investigated seasonal menus and related life cycle phases. (Characterization results IPCC 2021 GWP100 method)

warming of the packaging materials ranges from 5.2% to 1.8%, and of the transport of packaged ingredients to the food service company ranges from 10.8% to 5.6%. In particular, the main impacts related to packaging are due to the polyethylene (PE) film used for various ingredients (e.g. pasta, rice, etc.) and the steel cans used for olive oil. Furthermore, the impacts caused by the preparation of meals in phase 2 are strongly related to the type of meals and recipes characterizing each menu. Indeed, the main contribution is related to the boiling processes in the winter and summer menus, the frying process in the autumn menu, and the oven cooking in the spring menu. The results also show that the delivery of meals to schools causes a contribution to global warming ranging from 5.3% to 2.2%. To better understand the link between environmental sustainability and choices for seasonal ingredients in menus and nutritional value, the results are also discussed by comparing the percentage contribution to global warming of the ingredients grouped by food category (as presented in Table 19.1) as well as to the related nutritional values, per menu (Fig. 19.2). The main findings highlight a high variability between impacts and nutritional values, resulting in circumstances of trade-offs between the selection of more environmentally friendly ingredients or nutritionally balanced menus. This is particularly true when meat or dairy products are included in the menus. Nevertheless, the results also underscore that high nutritional value and lower global warming impacts may occur when cereal-based products, vegetables, and fruit represent the main portion of menus. Despite this, it is important to highlight that these ingredients have a nutritional value lower than meat and dairy products. Regarding the link between seasonality and environmental impacts, as for the summer menu, environmental advantages in terms of global warming due to the use of seasonal vegetables and fruit are also identified in the other menus. For example, cauliflower and grapes in the winter menu cause a lower contribution to the impacts compared to the other ingredients.

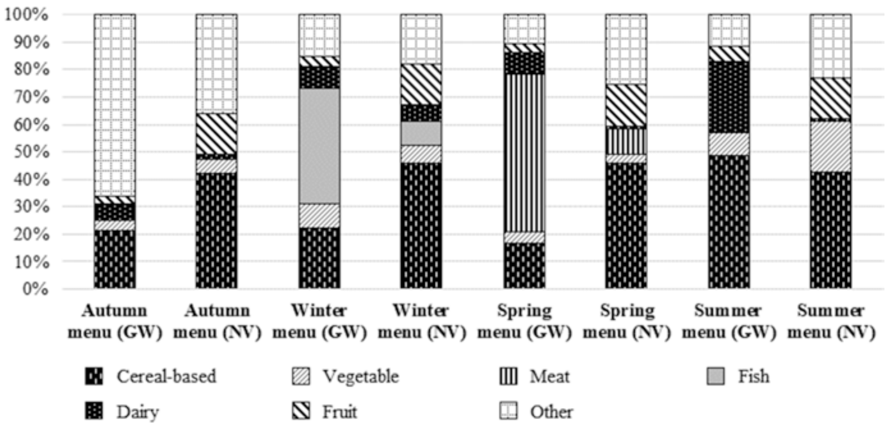

Fig. 19.2 Comparison between global warming (GW) and nutritional value (NV) per menu

19.4 Conclusions

The aim of this study was to evaluate the environmental performance, in terms of global warming, of four seasonal menus for school canteens, following a life cycle perspective and including the phases from the production of the ingredients to the delivery of the meal to the school canteens. The analysis also aimed to evaluate the link between environmental sustainability and strategic choices for seasonal food products as well as nutritional values in diets. The main results highlight that the production of ingredients and the preparation of meals (i.e. cooking processes) are responsible for the higher global warming impacts in all the menus investigated. The study also pointed out that trade-offs may occur between environmental impacts and the nutritional value of the ingredients. This points to the complexity in understanding how to move towards sustainable and nutritionally balanced diets as well as the need for more dedicated frameworks for an integrated evaluation of the environmental sustainability and nutritional value of food products, as pointed out by McLaren et al. (2021). Finally, the results confirm that low global warming occurs when seasonal ingredients are used in menus. Considering some limitations of this study, further future analyses should be oriented towards including the EoL stage of meals in the system boundaries, considering other nutritional values (e.g. protein content) for defining the FU, and evaluating more impact categories to obtain a detailed picture of the environmental performance of the menus.

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Chapter 20
Water Footprint of Agri-food Products from MENA Countries vs. EU Countries

Margherita Tiradritti, Laura Gobbi, and Giuliana Vinci

Abstract According to the United Nations (UN), since the 1980s, the global rate of water use has increased by 1% per year, and by 2050, humanity's water footprint is projected to exceed 30% of current levels. Water security and resource management issues are particularly evident in the Middle East and North Africa (MENA) region. This area (approx. 14,951,232 km^2) is generally arid, with more than 355 million people to date. Therefore, the risk of water stress is among the highest in the world. Of great importance to the economies of MENA countries are the exports of agricultural products, which can reach a gross production value per hectare cultivated of $226,000. In 2004, the European Union (EU) launched the European Neighborhood Policy, also with some countries of the MENA region, to promote the stability and economic security of the countries involved, encouraging, in particular, the exchange of agri-food products from and to these countries. Overall, the EU mainly exports beef, cereals, and dairy products and imports fruit, vegetables, and olive oil. Starting from an aggregate analysis of the products most exported from the countries to the EU, the study aims to investigate the water footprint of 1 t of these products. Through an analysis of the literature (Scopus, Google Scholar, Web of Science), the analysis of data available on the FAOSTAT (Food and Agriculture Organization Corporate Statistical Database), and the implementation of the SimaPro software, the study assesses a basket's water footprint of agri-food products. It highlights that the two main impacting productions in terms of water are avocados, whose production has rapidly increased in the last few years, and dates. To progress towards more sustainable agriculture paths and more responsible uses of natural resources, it could be crucial for water-stressed regions to narrow those productions that contribute to a high level of water discharge.

Keywords Agri-food products · LCA · Water footprint · MENA region · European Union

M. Tiradritti (✉) · L. Gobbi · G. Vinci
Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: margherita.tiradritti@uniroma1.it; laura.gobbi@uniroma1.it; giuliana.vinci@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_20

20.1 Introduction

The agri-food sector can be considered one of the most crucial sectors in many economies, both in developing and industrialized countries (Egilmez and Park 2014). Its production has increased exponentially in recent decades. As a consequence of this trend, agri-food supply chains have expanded. With the increase in the global population and the related increase in global food demand, the agri-food sector will be forced to reshape its production strategies (Horton et al. 2016; Lawrence et al. 2019) to meet the demand that is predicted to increase by +70% by 2050 (FAO 2019). In recent years, the international community has highlighted answers to the challenges that the increase in agri-food production will create. Among the actions taken, it is possible to find the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs), the European Green Deal, and the "Farm to Fork" strategy (European Commission 2020). The international community is worthy of attention to the impacts that the agri-food sector generally has on the environment, such as greenhouse gas (GHG) production, land use, soil erosion, and resource depletion. In particular, the principal damages are related not only to agricultural practices that are repeated over time and that compromise the balance of the ecosystems (Kibblewhite et al. 2008) but also to the intensive use of synthetic fertilizers, which can unbalance the mineral and microbiological levels of soil (Lohar and Hase 2021), leading to soil erosion (Raclot et al. 2009) and loss of biodiversity (Paredes et al. 2021). Strictly linked to the increase in the agri-food trend of production is the use and depletion of freshwater. It has been calculated that the agricultural sector consumes 80% of blue water reserves (Souissi et al. 2022), and the water footprint (WF) of food consumption is calculated to be more than 86% of the total water footprint. According to the World Health Organization (WHO), water stress is a situation where water availability per capita/year is less than 1700 m^3. When the situation worsens to 1000 m^3 per capita/year, a shortage occurs; when water per capita/year drops to 500 m^3, water becomes a constraint to development (WTO 2015; Siddiqi and Diaz Anadon 2011). In 2003, and then renewed in 2021, the EU launched the European Neighbourhood Policy (ENP) to govern the relationship with 16 of its closest eastern and southern neighbours to reinforce stability and prosperity through economics and trade agreements and bilateral cooperation (European Commission 2021). Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine are as eastern countries. Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, and Tunisia are as southern countries. Focusing on the latter, these countries belong to the so-called Middle East and North Africa (MENA) region. This particular geographical area is classified as arid and semiarid, and it can be considered the area with the most significant water deficit in the world (Bozorg-Hadda et al. 2020) and is already a water-stressed region (Madani 2014; Luo et al. 2015) (Fig. 20.1).

According to projections, water availability could fall to 1000 m^3 per capita/per year by 2050 (Rijsberman 2006). The causes that create this extreme situation can be found in the increasing population growth (between 2010 and 2050, the

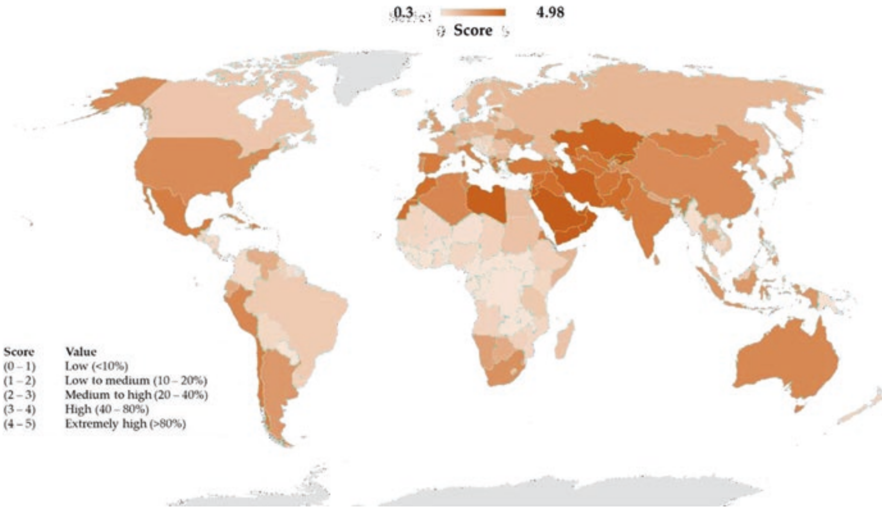

Fig. 20.1 Global water stress. (Luo et al. 2015)

population is expected to increase by +20%), and the economic development and the new lifestyle people adopted. It has been estimated that 85% of water in the MENA region is used for irrigation (The World Bank 2010). Moreover, the situation is exacerbated by the increasing effects of climate change, which increases temperature and decreases rainfall. Local water demand is higher than the local self-sufficient capacity of food production (Souissi et al. 2022). By identifying the most imported agri-food products traded in the context of the ENP during 2019, this chapter aims to examine which products have a higher water footprint to determine the impact on the local environment in terms of water.

20.2 Materials and Methods

To assess the study, first, the main products imported by the EU from some of the MENA region countries inside the ENP were investigated. To do that, agri-food trade statistical factsheets for each country have been analysed.[1] In particular, the data in the statistical factsheets cover a period of 5 years (2016–2020). For the study, 2019 was considered to have a prepandemic trade situation. Table 20.1 reports the main product classes exported from the 10 MENA countries in the EU in 2019 and the related economic values. Even if Syria is considered in the ENP, no data have been found related to product class exports.

[1] European Commission (no date) ENP South. Available at: https://agriculture.ec.europa.eu/international/agricultural-trade/bilateral-agreements/efta-enp-countries/enp-south_en (Accessed: 17th February 2022).

Table 20.1 Most exported products from the MENA region to Europe (2019)

Countries	Product category	Value (mln €)
Algeria	Tropical fruits, spices, nuts	40
	Sugarbeet and sugarcane	12
Egypt	Vegetables	402
	Fruits (except tropical fruits and citrus)	225
	Citrus fruits	102
	Tropical fruits, spices, nuts	206
Israel	Vegetables	119
	Citrus fruits	99
Jordan	Vegetables	6
	Tropical fruits, spices, and nuts	3
Lebanon	Tobacco	17
	Tropical fruits, spices, and nuts	5
Libya	–	–
	Vegetables	959
Morocco	Fruits (except tropical fruits and citrus)	603
	Citrus fruits	136
	Tropical fruits, spices, and nuts	57
Syria	–	–
	Olive oil	277
Tunisia	Tropical fruits, spices, and nuts	105
	Vegetables	55
Palestine	Tropical fruits, spices, and nuts	10
	Olive oil	5

For Libya and Syria, data are not available

Since agri-food trade statistical factsheets report the economic value of classes of products only, for each category, products have been selected by using FAOSTAT based on the total production of that particular product in the economy of the country (Table 20.2).

Then, to quantify the potential water stress of the various countries, the water footprint was calculated for each product identified. The formula proposed by Mekonnen and Hoekstra et al. (2011) was used for the calculation and is expressed as the sum of the blue, green, and grey water footprints of the i-th agri-food product (Eq. 20.1 and 20.2):

$$\mathrm{WF}_{i,\mathrm{TOTAL}} = \mathrm{WF}_{i,\mathrm{blue}} + \mathrm{WF}_{i,\mathrm{green}} + \mathrm{WF}_{i,\mathrm{grey}} \tag{20.1}$$

$$\text{Water Footprint} = \sum \mathrm{WF}_{i,\mathrm{TOTAL}} \tag{20.2}$$

where $\mathrm{WF}_{\mathrm{blue}}$ represents the volume of freshwater withdrawn from the surface and groundwater for agricultural, domestic, and industrial uses, used and not returned (or returned at another time), and $\mathrm{WF}_{\mathrm{green}}$ indicates rainwater evaporating or

Table 20.2 Major fruit and vegetable production in the MENA area (2019)

Countries	Product categories	Products	Production(t)	Area (ha)	Export (t)	Export value (1000 USD)
Algeria	Tropical fruits, spices, and nuts	Dates	1,136,025	169,786	102,016	93,096
		Almonds	72,412	35,380	–	–
		Cashews	12,602	4886	–	–
	Sugarbeet and sugar cane	Sugarbeet	–	–	–	–
		Sugarcane	–	–	–	–
Egypt	Vegetables	Tomatoes	6,814,460	174,730	107,403	48,960
		Cucumbers	566,155	25,734	6028	257
		Zucchini	1,347,230	49,897	3659	1812
	Fruits (except tropical fruits and citrus fruits)	Grapes	1,595,380	72,517	154,207	234,888
		Melon	120,400	4459	3445	1669
		Watermelon	1,401,300	42,464	12,254	4606
		Apples	701,435	28,057	1468	555
		Apricots	76,650	4509	165	67
		Strawberries	545,284	14,350	38,543	88,364
	Citrus fruits	Orange	3,067,630	122,705	1,817,406	656,594
		Tangerine	965,960	45,596	119,334	46,760
		Lemon	313,540	13,064	96,207	33,330
Israel	Tropical fruits, spices, and nuts	Dates	10,006	473	104,909	203,381
		Almonds	10,006	473	95	709
		Avocado	138,766	10,520	43,121	76,890
	Vegetables	Tomatoes	299,082	4689	642	1318
	Citrus	Orange	74,878	4020	2368	2211
		Lemon	75,565	2575	371	451
Jordan	Vegetables	Cauliflowers	46,799	900	11,943	6773
		Cucumbers	163,484	1585	34,944	21,458
	Tropical fruits, spices, and nuts	Dates	23,375	3372	6205	22,333
Lebanon	Tobacco		9602	7912	8883	29,558
	Tropical fruits, spices, and nuts	Dates	–	–	422	1609
Libya	–	–	–	–	–	–
Morocco	Vegetables	Tomatoes	1,347,085	14,861	587,819	764,876
		Beans	216,626	9235	135,638	262,187
	Fruits (except tropical fruits and citrus fruits)	Blueberries	71	16	25,201	181,816
		Apples	809,762	49,731	114	86
Syria	Citrus	Lemon	44,919	3208	15,254	8699
	Tropical fruits, spices, and nuts	Avocados	54,576	5069	19,363	51,422
	–	–	–	–	–	–
	Olive oil	–	–	–	163,423	466,473

(continued)

Table 20.2 (continued)

Countries	Product categories	Products	Production(t)	Area (ha)	Export (t)	Export value (1000 USD)
Tunisia	Tropical fruits, spices, and nuts	Dates	289,000	63,073	113,887	265,775
Palestine	Tropical fruits	Dates	7734	710	6274	29,233
	Olive oil	–	–	–	11,000	52,962

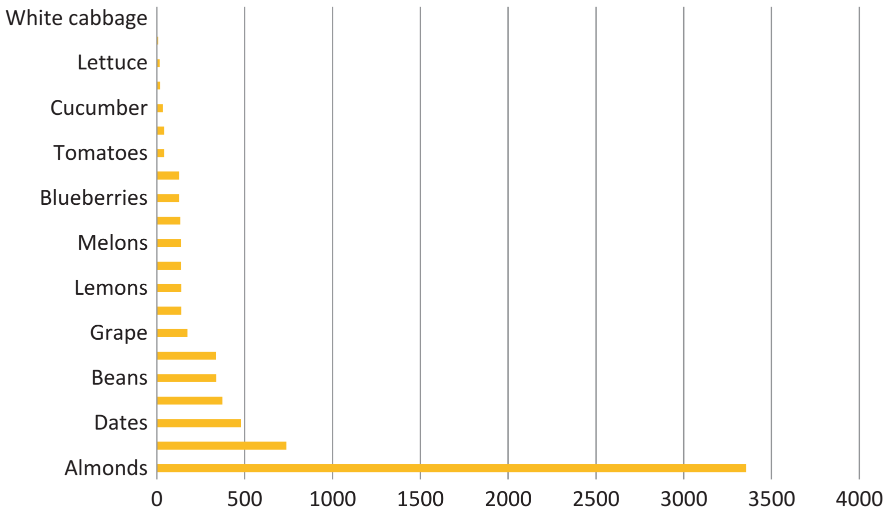

Fig. 20.2 Water footprint of major fruits and vegetables in the MENA region

transpiring in plants and soils. WF_{grey} indicates the amount of water needed to dilute the volume of pollutants so that water quality in the environment where the pollution occurred remains above predetermined water standards. WF was calculated using SimaPro 9.2 software. Due to the unavailability of data, the following products were excluded: cashews, sugarcane, strawberries, tangerines, tobacco, and olive oil. In addition, because there are currently no databases specific to agricultural production in MENA countries, the global average production for each commodity was considered for the calculation of WF.

20.3 Results and Discussions

The cultivation of 1 ton of product was chosen as the functional unit. As shown in Fig. 20.2, the most water-consuming is the production of almonds, accounting for 49% of the total water consumption. This particular fruit is native to Central Asia, but it is mainly cultivated in the hot Mediterranean region (Casas-Agustench et al. 2011). In recent years, the production of almonds has increased because of the beneficial and nutritional effects of consistent, daily consumption of this fruit (Barreca et al. 2020). The second impacting product resulting from the analysis is avocado, which impacts 12% of water consumption. The country that, according to FAOSTAT, has the most significant production of this kind of product among those considered is Israel, with 138,766 tons produced in 2019. In general, avocado global production and consumption have drastically increased in the last 150 years. This is mainly due to the expansions of markets where the product was not initially consumed in the past, such as Europe, China, and Japan (Schaffer et al. 2013). Moreover, avocado is not only consumed as a fresh product but is also used by the cosmetic industry (Duarte et al. 2016). To stress the economic importance of the market, in 2018, it reached more than US$ 13 billion with Mexico as the primary producer with 2.1 Mt (Million Metric Tons). Focusing on the Mediterranean area, Israel is the leading producer, followed by Spain with 90,000 t (Kourgialas and Dokou 2021). The second crucial product in water consumption is dates, with 477.35 m^3 of water used to produce 1 ton. Both avocado and date water consumption are linked to the cultivation irrigation phase. The largest producer of dates among the countries considered in the study is Tunisia, with 289,000 t. The country has limited water resources and is mainly used for animal farming (Soussi et al. 2022). As shown in Table 20.2, among the countries and productions considered, Egypt is the main producer of oranges and grapes. The related water footprints are 134 m^3 and 174 m^3, respectively.

20.4 Conclusions and Future Perspectives

Starting from the aggregated value of products exported by some MENA countries inside the European Neighborhood Policy towards the EU, the chapter analyses the water footprint of 1 t of the main agri-food productions. The chapter stresses the importance of the market in leading the increase, or the decrease, in producing determined products, such as almonds and avocados. In this sense, it could be crucial for the economies and for a more sustainable way of production to organize agri-food productions according to their water footprint, applying those with the lower one in areas with lower water availability. In this sense, this could be the way to develop a new solution for achieving SDG 6. This could be considered a “sustainable design” of agricultural production that could help reduce negative impacts while respecting the limits of the environment and those of the nearby population. In this way, it could be possible to produce more suitable products by using a lower amount of resources. The study does not focus on the political and governance constraints affecting the countries considered. Future research could implement this aspect to shape a more complex situation since these kinds of constraints deeply affect the division of the water resource shares and their uses.

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Chapter 21
The Air Indicator of VIVA Certification for the Sustainability of Italian Wine: Analysis and Perspectives

Nicola Casolani and Lolita Liberatore

Abstract The agri-food sector contributes significantly to greenhouse gas emissions, which are responsible for global climate change. Carbon emissions represent a critical issue in the wine sector. The air indicator of Italian VIVA certification expresses the impact of wine production on climate change. This chapter analyses the impacts of air indicators of VIVA-certified wines in the different stages of production (agricultural production, industrial processing, and bottling) and, furthermore, the data variability. The sample is represented by 45 wines produced by Italian companies (functional unit refers to a bottle of wine of 0.75 L). The results reveal average values of 0.25 kg CO_2/bottle in the agricultural phase, while in the industrial processing phase, the values are slightly higher (0.28 kg CO_2/bottle). The production of packaging (bottling) represents the most impactful phase (0.58 kg CO_2/bottle). The values of the coefficient of variation applied to the impact of the entire production cycle ranged between 0.05 and 1.46 kg CO_2/bottle, revealing a very heterogeneous scenario.

Monitoring the performance of VIVA-certified companies and implementing eco-sustainable business management strategies are essential issues for reducing climate-altering gas emissions. Strategies for carbon emissions reduction (especially in the bottling phase) are needed, in line with the continuous improvement philosophy.

Keywords VIVA certification · Carbon footprint · Climate-altering gases · Wine sustainability

N. Casolani (✉) · L. Liberatore
Department of Economic Studies, University G. D'Annunzio of Chieti-Pescara, Pescara, Italy
e-mail: nicola.casolani@unich.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_21

21.1 Introduction

Italy, France, and Spain together produce more than 50% of the world's wine production and have approximately 33% of the vineyards in the world (Ferrara and De Feo 2018). The environmental issues of wine industries were left unexplored for a long time (Christ and Buritt 2013) and have appeared only in recent years. Studies have been published mainly from 2013 onwards (Ferrara and De Feo 2018). Agriculture contributes to climate change with carbon emissions (Pant 2009), and its determinations represent a critical issue (Notarnicola et al. 2003; Rugani et al. 2013); market and regulatory drivers push the wine industry to assess, reduce, and communicate carbon emissions (Pattara et al. 2012). The carbon footprint (CF) is an indicator of greenhouse gas emissions that measures the impact of human activities in terms of the quantity of greenhouse gases produced (Weidema et al. 2008; Röös et al. 2013) and is useful for understanding the contribution to the global warming potential (GWP).

In 2011, the Italian Ministry of the Environment and the Protection of the Territory and the Sea launched the national project VIVA "Sustainability in viticulture in Italy"; this program aims to measure the sustainability performance of the wine supply chain through the application of indicators based on international standards and guidelines: air indicator (climate footprint), water indicator (water footprint), vineyard indicator (impact of agronomic management practices), and territory indicator (socioeconomic-cultural impact). VIVA certification uses a supply chain approach (Corbo et al. 2014). The air indicator expresses the impact that the production of a specific product and/or company activities have on climate change and is referred, in terms of functional unit, to a bottle of 0.75 L. The air indicator follows the standard ISO 14067:2018 (Greenhouse gases – Carbon Footprint of Products – Requirements and guidelines for quantification), the standard ISO 14044:2006 (Environmental management – Life cycle assessment – Principles and framework), and the standard ISO 14026:2017 (Environmental Labels and declarations – Principles, requirements and guidelines for communication of footprint information). The VIVA methodology framework for air indicators was described by D'Ammaro et al. (2021).

The Italian context lacks life cycle inventory (LCI) datasets related to Italian wine (Notarnicola et al. 2022), and more specific data related to greenhouse gas emissions are limited to a few studies (e.g. Bosco et al. 2011; Bonamente et al. 2016; D'Ammaro et al. 2021).

This chapter aims to analyse the impacts of the air indicator of VIVA 2.0-certified wines (and subsequent update 2.1, hereinafter reported only as VIVA 2.0) and the degree of variability.

21.2 Materials and Methods

The sample investigated is represented by VIVA 2.0-certified wines (n = 45) on 23-02-2022. Most of the products are located in Italian regions such as Tuscany (13), Emilia-Romagna (9), Veneto (8), Piedmont (6), Friuli Venezia Giulia (3), Umbria (3), Marche (2), and Sicily (1).

Most of the sample (53%) is represented by red wines (n = 24) and 20% of white wines (n = 9), while the sparkling type represents approximately 27% (n = 12). In this chapter, the following phases will be considered: vineyard management (hereinafter referred to as the "agricultural phase"), industrial transformation of grapes into wine (hereinafter referred to as the "industrial phase"), and packaging production (hereinafter referred to as the "bottling phase").

This chapter does not consider the distribution and end-of-life phases of the products, considering an approach "from cradle to gate."

The values of the air indicator were taken from the latest VIVA 2.0 report, which is available on the site: http://www.viticolturasostenibile.org/ProdottiViva.aspx.

21.3 Results and Discussions

Table 21.1 shows the grape yield and air indicator values of VIVA 2.0-certified wines in relation to the phase of production. The average value of the air indicator for the agricultural phase is 0.25 kg CO_2/bottle. In relation to the industrial phase, the air indicator shows slightly higher values (0.28 kg CO_2/bottle). The production of packaging represents the most impactful phase, with the average values of the air indicator of 0.58 kg CO_2/bottle; furthermore, the standard deviation of this phase has lower values than others, revealing a lower variability of the data. The total impact (sum of agricultural, industrial, and bottling phase impacts) ranged between 0.73 and 2.08 kg CO_2/bottle, with an average of 1.11 kg CO_2/bottle.

Table 21.1 Grape yield and air indicator values of VIVA 2.0-certified wines

Calculated value	Grape yield (q/ha)	Agricultural phase (kg CO_2/bottle)	Industrial phase (kg CO_2/bottle)	Bottling phase (kg CO_2/bottle)	Total impact (kg CO_2/bottle)
Minimum	37	0.05	0.03	0.30	0.73
Maximum	180	0.80	1.03	0.94	2.08
Average	104	0.25	0.28	0.58	1.11
Standard deviation	42	0.18	0.20	0.12	0.27

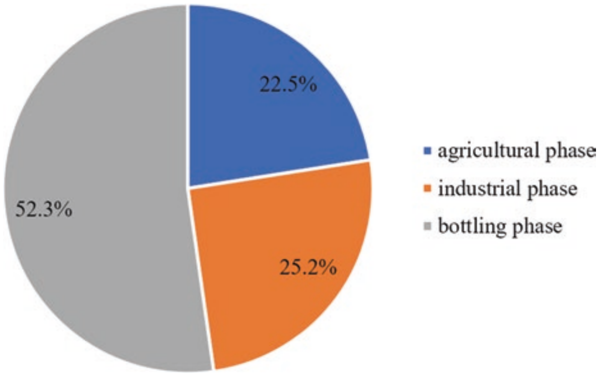

Fig. 21.1 Average impact of the air indicator of VIVA-certified wines for each phase

In terms of average impact, the agricultural phase represents 22.5% of the total impact, while the industrial phase and bottling phase represent 25.2% and 52.3%, respectively (Fig. 21.1). Packaging production, according to other authors (e.g. Bosco et al. 2011; Ponstein et al. 2019), is the most impactful phase. Ponstein et al. (2019), in a study conducted in Germany, found that 19% of emissions of wine production are related to the agricultural phase, while 81% are related to industrial production, mainly due to packaging materials (57%); in the same way, Bosco et al. (2011) found that the main impact of wine chains was the production of bottle glass.

Figure 21.2 shows the distribution of the air indicator for the cultivation of grapes on the productivity (yield per hectare) of VIVA 2.0-certified grapes. The range that takes into account a production yield from 60 to 80 quintals per hectare presents a high number of wines (n = 17; 37.8%), and values of the air indicators ranging between 0.11 and 0.43 kg CO_2/bottle correspond to it. Bosco et al. (2011) highlight that the use of fertilizers represents one of the interventions that most affects the carbon footprint in the agricultural phase. In addition, fuel consumption strongly improves the carbon footprint in the agricultural phase (Litskas et al. 2020).

Figure 21.3 shows the total distribution of the air indicator values in all stages of production; 4 wines (8.9%) present values up to 0.76 kg CO_2/bottle, and 15 wines (33.3%) show values up to 0.90 kg CO_2/bottle. The range between 1.02 and 1.46 kg CO_2/bottle is represented by 25 wines (55.5%). Only two wines have values that are more than 1.5 kg CO_2/bottle.

The coefficient of variation (Lovie 2005) applied to the agricultural, industrial, and bottling phases for each VIVA 2.0-certified wine was calculated (Fig. 21.4). The coefficient of variation ranges from a minimum of 0.05 kg CO_2/bottle to a maximum of 1.46 kg CO_2/bottle, while the sum of the air indicator values for the three phases ranges between 0.73 and 2.08 kg CO_2/bottle, revealing a very heterogeneous scenario.

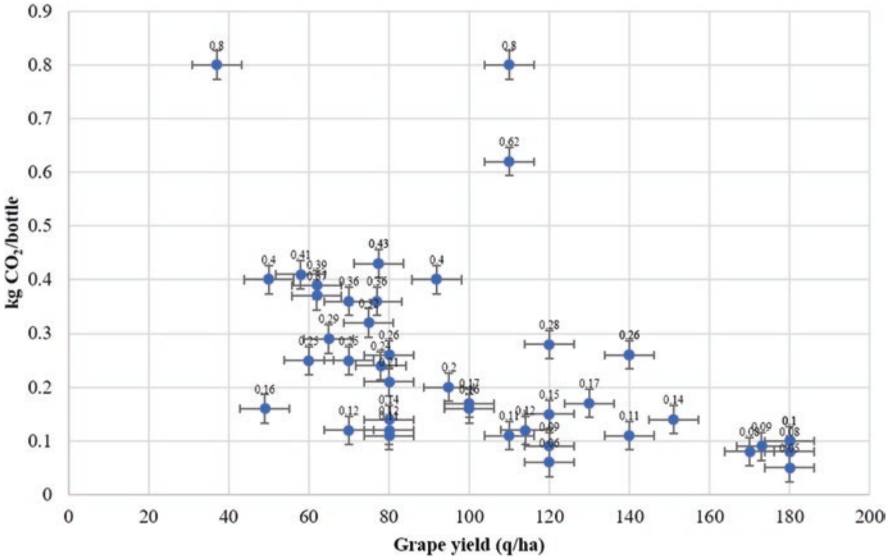

Fig. 21.2 Distribution of the air indicator (agricultural phase) on the production yield of the sample

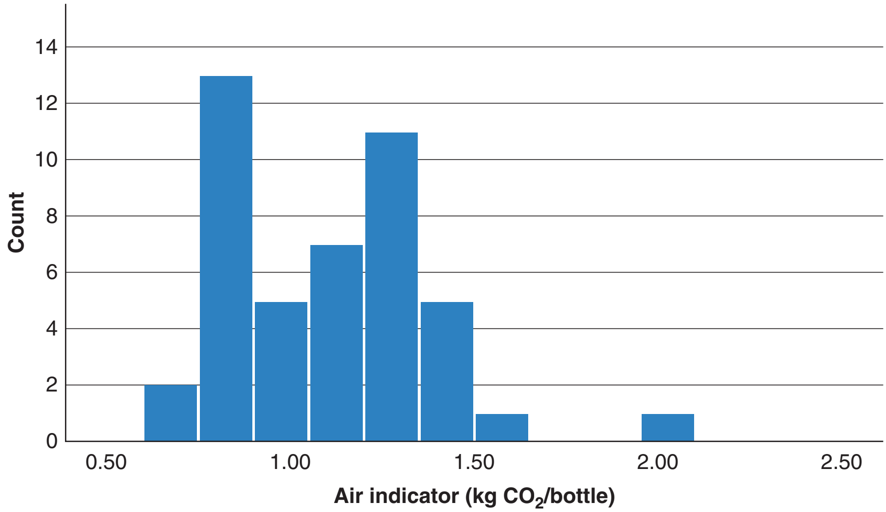

Fig. 21.3 Total distribution of the air indicator values (sum of agricultural phase, industrial phase, and bottling phase)

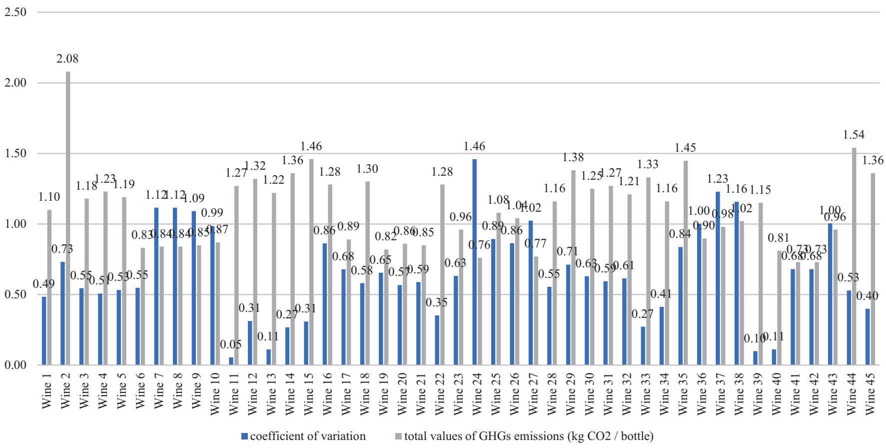

Fig. 21.4 Distribution of the coefficient of variation of VIVA 2.0-certified wines and total values of the air indicator (sum of agricultural phase, industrial phase, and bottling phase)

21.4 Conclusions

Wine production in Italy constitutes an important asset of the national economy and plays an important role in international markets. In recent years, various programs for environmental sustainability in the agri-food sector have been offered in Italy; VIVA represents a tool for the assessment and improvement of sustainability in wine production. This study is limited to the analysis of the air indicator, which refers to the impact that wine production has on climate change through gas emissions, revealing significant differences depending on the production phase; from the analysis of the data, it emerges that the most impacting phase is bottling, with extreme variability in the gas emission values in relation to the different types of wines (ranging from 0.30 to 0.94 kg CO_2/bottle). This issue deserves special attention from producers, consumers, and policymakers, who are fighting for an effective decarbonization of the wine supply chain (Pointstein et al. 2019). The data of the agricultural and industrial transformation phases have similar impact and standard deviation values. These results are useful from the perspective of continuous improvement for companies that adhere to VIVA 2.0 certification.

Future research should consider the distribution and end-of-life phases of the products.

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Chapter 22
Environmental Accounting for the Circularization of the Packaged Water Sector in Italy

Vera Amicarelli, Christian Bux, and Giovanni Lagioia

Abstract Packaged water is one of the fastest growing commodities on a global scale, with significant repercussions from environmental, economic, and social perspectives. Worldwide, the total annual consumption of water is estimated at approximately 390 billion litres, corresponding to over 155 billion euros. In this context, Italy plays an important role, being the eighth country for total consumption, estimated in 2020 at over 14 billion litres, and second for per capita consumption, equal to 222 L. Under the economic perspective, its value equals approximately 2800 million euros. In Italy, over 82% of the water is packaged in plastic bottles, while 16% is packaged in glass bottles and only 2% is packaged in plastic jugs, cardboard bricks, or aluminium cans. This research applies material flow analysis to the national packaged water sector to measure the material flows associated with the entire packaged water sector in Italy. Although cardboard bricks and aluminium cans could represent a more sustainable solution from an environmental point of view in the long term, plastic packaging guarantees numerous socioeconomic advantages, namely, economic convenience, easy portability, and widespread distribution of the product. The research discusses possible circularization strategies in the packaged water sector, providing useful research directions for practitioners and academics.

Keywords Environmental accounting · Circular economy · Packaged water · Material flow analysis · Environmental sustainability

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V. Amicarelli · C. Bux (✉) · G. Lagioia
Department of Economics, Management and Business Law, University of Bari Aldo Moro, Bari, Italy
e-mail: christian.bux@uniba.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_22

22.1 Introduction

Overall, bottled water represents one of the fastest-growing commodities (Etale et al. 2018), and although tap water is safer, more accessible, cheaper and its environmental impacts have been assessed as lower than those of bottled water, packaged water continues to be preferred by consumers (Geerts et al. 2020). Water is the most consumed packaged beverage worldwide, accounting for over 450 billion L (Statista 2022), for several reasons, mainly modified consumption habits, as well as psychological factors and taste (Palomero-González et al. 2022). At the European level, the consumption of bottled water is estimated at 118 L per person per year (Statista 2022), and Italy represents the leading market, accounting for over 200 L per person per year. Italy produced more than 14,500 million L (ML) in 2020 (Acquaitalia 2022), packaged as follows: (a) 11,890 ML in plastic bottles (82%); (b) 2320 ML in glass bottled (16%); and (c) 290 ML in big bottles, bricks, and cans (2%). Plastic bottles are mainly composed of polyethylene terephthalate (PET), and their size passes from 0.5 L to 1.5 L, with increasing quantities of water sold in 2 L bottles (Lagioia et al. 2012; San Benedetto 2017; Ferrarelle 2019; Acquaitalia 2022). It is estimated that of the entire amount of sorted plastic bottles, over 46% are recycled, whereas 40% are addressed to incineration with energy recovery. Regarding water glass bottle consumption, the most widely used size is 1 L bottle, and the estimated glass bottle recycling rate reaches over 77% (Consorzio Nazionale Imballaggi 2020; Fondazione per lo sviluppo sostenibile and FISE UNICIRCULAR 2021). In recent years, returnable bottle practice has recorded a remarkable increase (San Benedetto 2017; Ferrarelle 2019; Coelho et al. 2020). A marginal but interesting role is played by the so-called plastic jugs (large PET bottles from 3 to 20 L); bricks composed on average of 75% paper, 20% low-density polyethylene (LDPE) and 5% aluminium (Zawakiak et al. 2017; Schlecht and Wellenreuther 2020); and Al cans, mainly composed of up to 50% recycled aluminium (Carlsberg Italia 2020).

In light of these premises, this research explores the material flows associated with water packaging in Italy in 2020. The study investigates the Italian packaging's separate collection rates, highlighting current challenges and suggesting possible solutions to improve the environmental management of water packaging from upstream to downstream stages of the supply chain.

22.2 Materials and Methods

Environmental accounting can be defined as the identification, allocation, and analysis of material streams in terms of natural resource consumption and waste production (Steele and Powell 2022). Among the different tools and methodologies widely used, this research applies material flow analysis described as a "systematic assessment of the state and change of material flows and stock in space and time" (Brunner and Rechberger 2017) and has been successfully applied in environmental management studies at the micro, meso, and macro levels.

This research investigates the "packaged water sector" in Italy in 2020, assuming a closed economy scenario (i.e. neither imports nor exports of materials have been considered). The functional unit is 1000 L of bottled water and refers to the primary packaging only. All material flows are expressed in milliontons (Mt). Plastic jugs are out of the analysis. System boundaries encompass materials production, either from virgin or recycled materials, materials use, waste recycling, and waste disposal pathways (Luan et al. 2021). The research relies on secondary data collected on national Environmental Product Declarations (EPDs) (San Benedetto 2017; Cerelia 2018; Ferrarelle 2019; Carlsberg Italia 2020), national reports (Consorzio Nazionale Imballaggi 2020; Fondazione per lo sviluppo sostenibile and FISE UNICIRCULAR 2021), and international studies (Lagioia et al. 2012; Schlecht and Wellenreuther 2020).

22.3 Results and Discussions

Figure 22.1 illustrates a detailed snapshot of the "packaged water sector" in Italy in 2020 based on different packaging typologies, as follows: (a) 0.5 L, 1.5 L, and 2 L PET bottles; (b) 1 L glass bottles; (c) 0.33 L bricks; and (d) 0.33 L cans.

Figure 22.2 illustrates the material flow analysis related to the Italian packaged water system, accounting for natural resources input and the material recycling rate. It provides estimates and evaluations useful for the sectoral transition towards sustainable and circular models.

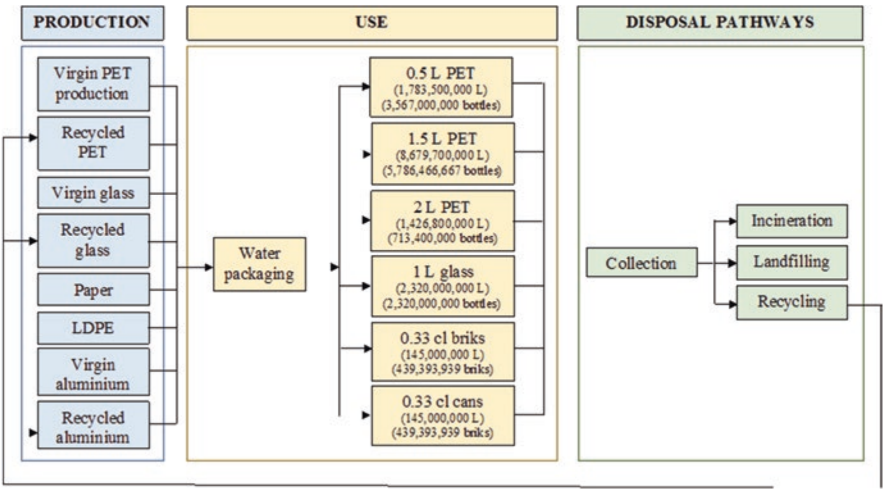

Fig. 22.1 Material flow analysis for the "packaged water sector"

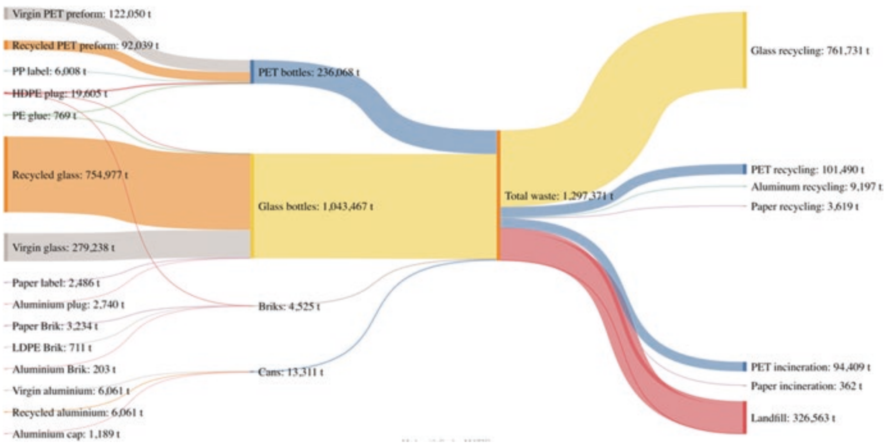

Fig. 22.2 Material flow analysis for the "packaged water sector" in Italy in 2020

Although 1.5 L PET bottles are the most consumed size, in terms of weight, the most used material is glass, for an amount of over 754,977 tons (t) of recycled glass and 279,238 t of virgin glass in 2020. In addition, 122,050 t of virgin PET and 92,039 t of recycled PET cross the entire packaged water system. On the disposal pathway side, over 326,563 t of PET and glass bottles, as well as aluminium cans and bricks, are still addressed to landfills, whereas the vast majority of recycled materials are composed of glass (approx. 761,731 t) and PET (101,490 t). According to Fig. 22.2, aluminium presents good recycling rates for an amount of 9197 t (approx. 70% of the entire amount of aluminium cans produced in 2020).

In light of the glass bottle consumption, it is essential to consider that such packaging represents 16% of domestic consumption, whereas it dominates in the Ho.Re.Ca. (Hotel/Restaurant/Catering) and door-to-door supplies. As a consequence, the returnable end-of-use system must be enhanced to avoid landfilling and reduce recycling by improving reuse technologies. Regarding bricks, which are seldom used for water, several questions are still open, mainly related to their end-of-use system. In 2020 and worldwide, the global carton package recycling rate was 27%, including approximately 170 recycling facilities (Tetra Pak 2021). If its recycling rate could be boosted, such packaging could substitute PET or glass for either domestic or outdoor consumption. Lastly, aluminium cans seem to be a good alternative to traditional packaging due to their aluminium physicochemical characteristics and their tendency to be recycled several times over time. However, one limit to aluminium cane diffusion among consumers is the lack of comfortable caps, which makes it difficult to preserve water after opening. Industries might consider the adoption of aluminium bottles, which are more suitable for both domestic and outdoor water consumption.

22.4 Conclusions and Future Perspectives

This research illustrates the status quo of the packaged water system in Italy, discussing possible circularization strategies in the packaged water sector. Material flow analysis is essential to enhance circularization in commodities production since it provides useful insights under either the economic, the environmental, or the organizational perspective. Material flow analysis offers transparent and comparable snapshots of several systems in space and time. First, it offers early recognition of potentially harmful or beneficial stocks. Furthermore, it sets priorities according to environmental protection strategies such as resource preservation (e.g. prevention) and waste management (e.g. separate collection, and recycling), as well as priorities to boost eco-design strategies towards environmental sustainability.

One of the best options to reduce resource consumption, either virgin or recycled, regards the use of non-disposable water bottles, which can be composed of materials other than plastics, such as stainless steel. It requires several changes in consumer behaviour, enlarging the availability of safe and secure tap water on a global scale through sustainable investments and education for sustainable development. Regarding the adoption of disposable packaging, the recycling percentages of plastics, glass, paper, and aluminium should be increased, reaching higher levels of either closed-loop or open-loop recycling. Finally, regarding aluminium cans, eco-designers should suggest more suitable and comfortable packaging, which can be transported once open through the use of caps. Overall, deposit return systems should be introduced in Italy, which have not yet been implemented.

Future research directions are intended to investigate natural resources (i.e. energy and water) associated with packaged water in Italy and explore the environmental impacts associated with packaging production, use, and disposal through life cycle assessment, as well as the economic costs by material flow cost accounting.

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Part III
Agriculture, Biomass, Foods and Beverages: Quality

Chapter 23
Recent Evolutions in Food Consumption Patterns During the COVID-19 Emergency. The Emerging Market of Food Delivery and Its Implications on Food Quality

Giuliana Vinci, Alessandro Bernardo, Sabrina Antonia Prencipe, and Simone Vieri

Abstract The framework developed is based on the qualitative and quantitative analysis of recent developments in consumption habits induced by the exogenous shocks of supply and demand caused by the post-pandemic scenarios and the war in Ukraine. The key role of the new processes of globalization has led companies and consumers to change their purchase of food. An emerging market, i.e. food delivery, has become one of the most commonly used channels for food distribution. It is interesting to observe both from the economic and nutritional sides the consequences that these new consumption habits have brought to consumers. In this regard, the research aims to evaluate the correlation between the emerging market of food delivery and its implications on food quality standards by consumers' willingness to pay.

Keywords Food delivery · Organic food · Quality certifications · Business model · Outsourcing · E-commerce

23.1 Introduction

Over the last few years, as a result of the post-pandemic scenarios and the war in Ukraine, companies have also evolved: Their degree of resilience has increased, and the high degree of reactivity to exogenous shocks has allowed them to survive by reinventing the way they do business. The processes of globalization and

G. Vinci · A. Bernardo (✉) · S. A. Prencipe · S. Vieri
Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: giuliana.vinci@uniroma1.it; alessandro.bernardo@uniroma1.it; sabrinaantonia.prencipe@uniroma1.it; Simone.vieri@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_23

dematerialization that characterize modern society today open the horizon towards a new technological paradigm that will invest in all sectors in a transversal way. Delivery, for example, is one of the most recent forms of enterprise or mechanism through which to do business. Worldwide, "*dabbawala*" can be considered the first home delivery company (Kinsey et al. 1996). There are changes in retail food delivery: signals for producers, processors, and distributors (Li et al. 2020). Born in 1890 in India, more precisely in the city of Mumbai, the word "*dabbawala*" in Hindi means "person who delivers the packed lunch." The concept of *dabbawala* originated in India under British rule; many English people who populated the colony did not like local food, so a lunch delivery service was created for those who lived far from work. Deliveries are still made mainly by bicycles and trains on the railway network. The main activity of these companies is the collection, in the late morning, of prepared food, with transport to their respective workplaces and then the collection of empty lunch boxes and return to the sender. The withdrawn lunch box has some characteristic signs, such as colours or symbols, which favour its recognition; hence, the current liveries with bright colours of the large multinational delivery companies are easily recognizable. In Italy, the first home delivery service developed thanks to the impulse of the activities that carried out mail order sales through catalogues such as the Milanese Postal Market, founded in 1958 (Galati et al. 2020). This service quickly acquired large market shares while at the same time assuming a decisive role in dictating fashions and trends. In the frozen food sector, two German companies established themselves: Bofrost and Eismann. Born after the Second World War, the two companies began to operate in the Italian market in the mid-1980s. The *Business Model* of both consists of proposing a wide range of frozen products (pizzas, vegetables, fish, ice cream, and ready meals) that are delivered to the customer's home, on agreed days, using truck refrigerators with which they respect the cold chain. Customers are periodically offered a new updated catalogue with all available products to allow them to choose what to order on the next visit or by calling the call centre (Geissdoerfer et al. 2018).

23.2 The Market for Food Delivery

The pioneers of actual digital food delivery in Italy were JustEat, Bacchette e Forchette, FoodPlaza, Tastifood, the Bolognese PizzaBo, Clicca e Mangia, and DeliveRex. In Italy, food delivery involves a market that had a turnover of over 350 million euros in 2018, with broad growth prospects (the increase, compared to 2017, was 69%): 500 Million euros were invoiced in 2 years only in Milan (Osservatorio e-commerce B2C Politecnico di Milano e di Netcomm 2021). In addition, the home food ordering market is currently a sector with high potential, especially since it is a market that is far from saturated: At the end of 2015, only 15% of catering services provided a home service. From the data collected by FIPE (Take My Things 2021), in 2018, 30.2% of Italians had the opportunity to order lunch or dinner online from food delivery platforms. The food and beverage sector for our country is one of the most impactful sectors on gross domestic product (GDP) both in terms of turnover and in terms of the value of its related industries. Following the post-pandemic scenarios, this sector has been hit by a strong technological acceleration dictated by the new technological paradigm imposed by the restrictive policies of *policymakers*. Thanks to the rapid takeover of the e-commerce market, large multinationals such as Just Eat, Glovo, and Uber Eats dominate the national scene by irreversibly changing the classic restaurant, which sees new opportunities arising from the implementation of home services. In Italy, there are mainly two forms of *delivery*: the one carried out directly by the restaurant business that takes the name of "direct delivery" and the one outsourced to specialized companies or "out delivery." Regardless of the type of business model, the delivery of meals at home affects more than one in three Italians (37%). This is what emerges from the report 2021 (Coldiretti-Censis 2021) analysis on food delivery released on the occasion of the release of the last ISTAT consumer basket for inflation 2020 on the new spending habits of families where takeaway sushi and home delivery of meals also enter. At the top of the list of reasons for resorting to food at home is the fact of being tired and not wanting to cook (57.3%), but there is also 34.1% that indicates resorting to it in the case of dinners with friends and relatives to amaze diners with quality dishes (Muszyński et al. 2022). The possibility of getting ready-to-eat dishes at home thus facilitates the organization of moments of conviviality even when you would not have time to get to the stove. This emerging market has spread competition on costs between the different platforms with free transport offers, promotions, and discounts, which sometimes risks affecting the entire supply chain, from staff to the accounts of restaurateurs to their suppliers of agricultural and food products (Rapa and Francesco 2021).

23.3 Materials and Methods

The data collected come from the INPS database (Osservatorio ISTAT 2021), thanks to which it was possible to calculate the time series for each product and cooking-type category. To this have been added the data streams of the new trends in food delivery (Osservatorio Just Eat 2021). Once the data in panel format had been condensed, it was possible to start the statistical analysis. The software used is R-Studio, as it allows excellent management of data matrices, especially in regard to time series. Once calculated, the indices were represented on a 100 basis in graphs to simplify the information collected and show the interesting results clearly and uniformly. The Microsoft Excel software was used.

23.4 Results and Discussion

To observe the effects of the new trends mentioned above, we analysed the data (Osservatorio ISTAT 2021) by choosing products and services typical of the new consumption baskets concerning *food delivery*. The foods chosen are in the top ten most purchased products through online platforms for home delivery. The reference period is that of 2017 to 2021, for a total of 6 years, representing the period before and after the pandemic. The goal is to emphasize the recent transformations that have gone through the *food delivery* sector.

23.4.1 Growth Rate Average Consumer Prices Connected with Food Delivery

Figure 23.1 denotes, at first glance, how the incidence of the cost in general of different foods has increased dramatically in the years of the pandemic, denoting a rather high increase in the level of inflation. Within the new 2021 consumer basket, the product that has suffered the greatest increase in the selling price is pizza (+55%), followed by cheeses and "*scamorza*" (+52%) and hamburgers (+35%). In contrast, sushi (+3%) and poké (−11%) would seem to be immune from the price increases of recent years while maintaining a cost level similar to that of 2016.

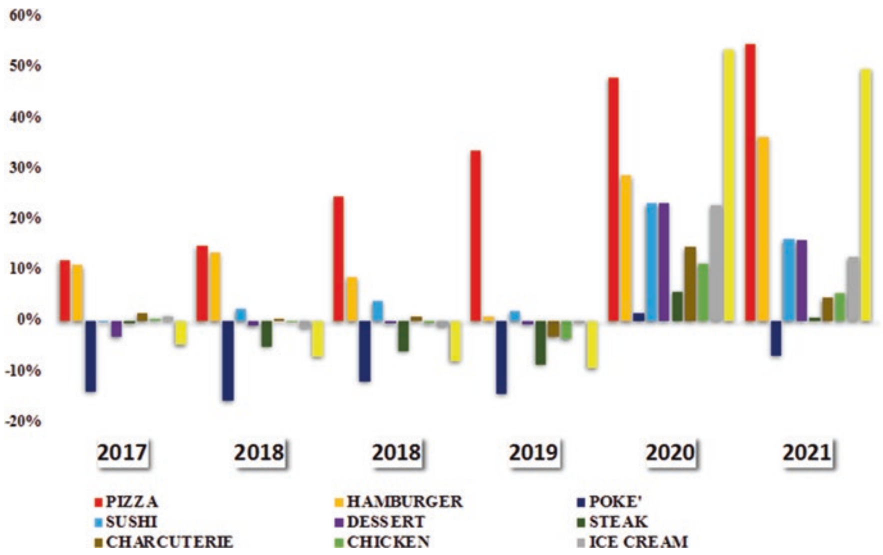

Fig. 23.1 Growth rate average consumer prices – the base year 2016 – Italy. The results are shown in the form of a percentage growth rate, i.e. how much the cost of that particular asset has increased compared to its respective price in 2016. (Source: Osservatorio ISTAT nuovi panieri di consumo 2021)

Figure 23.2 denotes a growth rate related to the various types of consumers from vegan to traditional. From 2017 to 2021, there was a boom in transactions in favour of vegetarian cuisine, with a peak of a maximum + of 127% of the previous year. Not least are the vegan and the organic, which stand, respectively, at +90% and +22%. Figure 23.3 expresses the relationship between quality and sales volume, and the percentages obtained indicate the number of transactions of branded foods carried out in total.

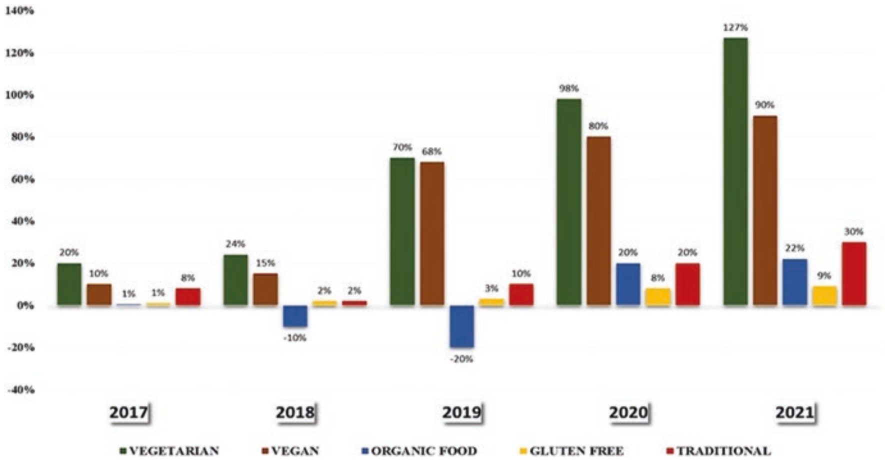

Fig. 23.2 Growth rate of delivery purchases by categories – the base year 2016 – Italy. The results are shown in the form of growth rate on a 100 basis. (Sources: Osservatorio ISTAT nuovi panieri di consumo 2021; Osservatorio Just Eat 2021)

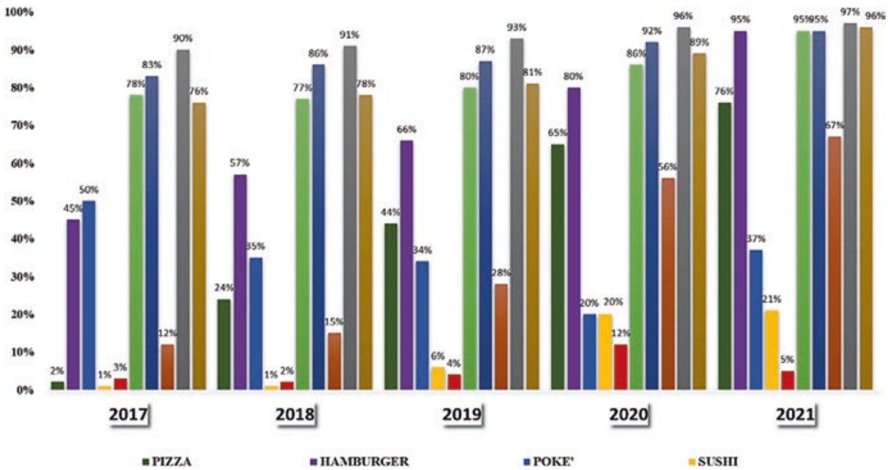

Fig. 23.3 Purchases of branded products on total purchases – delivery – Italy. The results are shown in the form of a growth rate on a 100 basis. (Sources: Osservatorio ISTAT nuovi panieri di consumo 2021; Osservatorio Just Eat 2021)

At the aggregate level, the demand for traditional Italian food delivery, such as pizza, meats, cured meats, and cheeses, is entirely composed of quality branded goods and services. At the same time, as noted in Fig. 23.1, poké and sushi are foods purchased by consumers without considering the different certifications.

23.4.2 Nutritional Quality of Meals Consumed with Food Delivery

Considering the variation in pre- and post-pandemic food consumption patterns, it is therefore important to assess the nutritional quality associated with food delivery meals. Nutritional quality is defined as the value of the product for the physical health, growth, development, reproduction, and psychological or emotional well-being of the consumer (Cakmak et al. 2009). Based on Mediterranean diet guidelines (LARN 2018), energy requirements vary depending on basal metabolism and energy consumption associated with age and daily physical activity. Energy is derived from macronutrients (carbohydrate proteins and lipids) and should be balanced as follows:

- 45–60% Carbohydrates, predominantly complex (such as cereal starches)
- 10–12% Protein, corresponding to 0.9 g per kg of body weight
- 20–35% Fats, with a proportion of saturated fats (mostly represented in almost all animal products except fish) of less than 10% (Hargreaves et al. 2021).

According to purchases of branded products delivery, it is possible to notice that the main meals delivered for which an increase in consumption of approximately 35% within the pre- and post-pandemic period (2017–2021) was observed are hamburgers, pizza, and pokè. Considering the nutritional value associated with a standard portion of 100 g per meal (Hamburger: 250 kcal; 13.6 g of protein; 7.7 g of lipid; 33.5 g of carbohydrates. Pizza: 271 kcal; 5.6 g of protein; 5.6 g of lipid; 52.9 g of carbohydrates. Pokè: 167 kcal; 7 g of protein; 5.3 g of lipid; 19.6 g of carbohydrates), it is possible to observe the distribution of macronutrients (carbohydrates, protein, and lipids) characterizing the main meals consumed via food delivery (Fig. 23.4). The percentages in the graph represent the distribution of the energy provided by each macronutrient (making 100 the total calories provided by the food) related to a 100 g standard portion. It is important to remember that carbohydrates and proteins provide 4 calories per gram, while 1 g of fat provides 9 calories. This macronutrient distribution calculated from the main meals (hamburgers, pizza, and poké) consumed during the pre- and post-pandemic periods denotes an increase in protein content that is attributable to more frequent consumption of food products of animal origin (an estimated increase in world demand for meat by 95% between 2006 and 2050), thus underlying a change in eating habits (Sáez-Almendros et al. 2013).

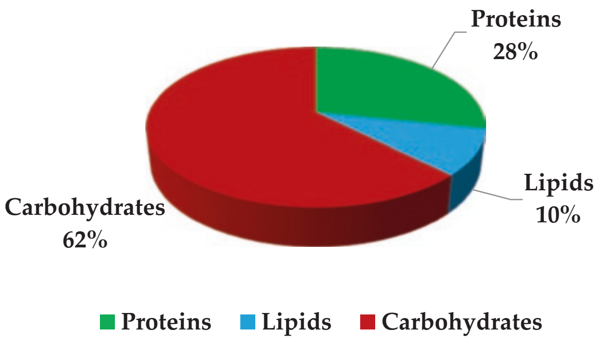

Fig. 23.4 Macronutrient distribution of meals consumed with food delivery

23.5 Conclusions

Following exogenous demand shocks due to pandemic scenarios and the war in Ukraine, there has been a change in food consumption patterns. Even companies reinvented their business model in compliance with the constraints dictated by the new technological paradigm of recent years. Food delivery, in particular, has recorded growing trends due to increasing demand. The aspects analysed take into account, in the same way, the qualitative, economic, and nutritional dimensions of the phenomenon. The analysis of the data shows that the response to the crisis by consumers is characterized by greater awareness of the purchase of certified quality products, including organic products. In the same way, the choice of consumption patterns in favour of vegetarian and vegan diets has varied more than proportionally, while the numbers of the Mediterranean diet are contained. However, the breakdown of nutrients obtained from the consumption of takeaway food was not always in line with guidelines for healthy eating. Italians, faced with the uncertainty of food supplies linked to the international crisis, see in these consumption models an increasingly safe response to their need for healthy, quality, and guaranteed locally sourced food, not always giving importance to the correct distribution of nutrients.

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Chapter 24
Foods Supplements: Quality Assessment of Formulations by an Expert Panel

Salvatore Ciano, Séverine Goscinny, Mattia Rapa, Vanessa Giannetti, and Maurizio Boccacci Mariani

Abstract In Europe, food supplements are classified as foodstuffs and regulated by Directive 2002/46/EC. They are a concentrated source of nutrients (e.g. vitamins, amino acids, minerals, etc.) or bioactive compounds extracted from plants or herbs. The Italian market for food supplements is showing rapid growth, especially through business to consumer (B2C) e-commerce. However, it is highly competitive and fragmented. No single company has an adequate influence to lead the industry in a specific direction, and countless formulations are listed in the "National Register of Food Supplements." Quality products can therefore be the key to a competitive advantage. In this study, the biological–nutritional quality of 22 product formulations of an Italian start-up, MyLab Nutrition Group, was evaluated by a panel of seven experts recruited through public competition and led by a coordinator. The products were compared with the best seller in the category, or the standard of care used by the participants, using the Likert scale as a quality indicator. The average score given by the panel for the products was 3.8 ± 1.1. This result showed that the start-up's products are highly comparable with those on the market, confirming their competitiveness with the leading Italian brands.

Keywords Food supplement · Quality assessment · Formulation · Expert panel

S. Ciano (✉) · S. Goscinny
Department of Chemical and Physical Health Risks, Sciensano, Ixelles, Belgium
e-mail: salvatore.ciano@sciensano.be; severine.goscinny@sciensano.be

M. Rapa · V. Giannetti · M. B. Mariani
Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: mattia.rapa@uniroma1.it; vanessa.giannetti@uniroma1.it; maurizio.boccaccimariani@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_24

24.1 Introduction

Consumers are constantly more careful about their health and the well-being of their lives. The evolution in dietary styles, and now the COVID-19 pandemic, combined with the growing attention of consumers for beneficial and healthy food, have accelerated the demand for nutritional supplements that improve the immune system, increase physical/mental performance, or supplement the standard diet in general. According to their dietary role or origin, food supplements can be classified into three main categories: substances with recognized nutritional value, extracts of botanic products, and other substances with physiological effects (Faqi and Yan 2017). Vitamins, minerals, botanicals, and other substances (e.g. amino acids) marketed in "dose" form are part of the routine of many adults (and sometimes even children) in the Western world. Statistical data show that more than 25% of the European population is a food supplement user; this value rises to 59% in the population with specific dietary needs, e.g. pregnant women (Domínguez et al. 2021).

In Europe, Directive 2002/46/EC (and subsequent amendments) defines food supplements as *"foodstuffs the purpose of which is to supplement the normal diet and which are concentrated sources of nutrients or other substances with a nutritional or physiological effect, alone or in combination, marketed in dose form, namely, forms such as capsules, pastilles, tablets, pills and other similar forms, sachets of powder, ampoules of liquids, drop dispensing bottles, and other similar forms of liquids and powders designed to be taken in measured small unit quantities."* The regulation also lays down a complete list of minerals and vitamins that can be added to food supplements and authorized sources (Directive 2002/46/EC).

The Italian market for food supplements is rapidly growing, especially thanks to B2C e-commerce. It is a highly competitive and fragmented sector (Foresti et al. 2021), and no single company has sufficient influence to lead the industry in a specific direction. Countless formulations are currently listed in the "National Register of Food Supplements," and the pursuit of product quality is the key to a competitive advantage. In this context, our study proposes a nonclinical biological–nutritional assessment of food supplements produced and selected by an Italian start-up (*MyLab Nutrition Group*) through an expert panel combined with the Likert scale approach. The Likert scale (1932) belongs to the category of rating scales. It is a summative scale and asks the respondent to select a value on an ordered set of positions, such as 1–5. It has been used in survey research and, more recently, in quality assessment investigations (Ponsiglione et al. 2022). To the best of our knowledge, this is the first study applying the Likert scale evaluation by a panel of experts to evaluate the quality of dietary supplements.

24.2 Methodology

The first step in the experimental design involved the expert panel constitution. The panel consisted of seven experts led by a coordinator and recruited through a public competition (Bellizzi et al. 2016). The experts' profile was as follows: Master's degree in Human Nutrition Science, biology or food science and technology; membership in the National Order of Biologists; and proven experience in the field of food and nutrition (higher than three years). The panel coordinator was a professional with a PhD in a relevant field, with a proven experience superior to 5 years in the food and nutrition sector, focused on applied research. MyLab Nutrition Group selected 22 products already included in its online catalogue to assess the formulation. The investigated products are reported in Table 24.1. Each panellist evaluated ten products, according to Table 24.1. The allocation strategy followed the criteria

Table 24.1 Product assignment scheme to each nutrition expert

No	Food supplement type	Properties	P1	P2	P3	P4	P5	P6	P7
1	360 Life Defender	Multimineral, multivitamin	X	X	X		X		
2	Articoss Articolaz-Ossa	Bones and cartilages maintenance	X	X	X				
3	Big B. Expl. Pre-Workout	Branched amino acids for intense training	X	X	X				
4	Omega 3 Epa + Dha	Rich natural omega-3 source				X	X	X	
5	Phoenix PostWorkout	Recovery after training				X	X	X	
6	Rexiburn Bruciagrassi	Body weight control				X	X	X	
7	Viking's Recovery Night	Nocturnal muscle recovery	X	X					X
8	Ananas & Bromelina	Cellulite treatment	X	X					X
9	Biotinker	Well-being of skin and hair	X	X					X
10	Fegadep	Liver support and purification			X	X	X	X	
11	Fermacol K	Cholesterol level management			X	X	X		
12	Flora B-Complex	Human microbiome balance			X	X	X		
13	Grani Di Herbe	Intestinal transit regulation	X					X	X
14	Localdol	Contrasts localized tensions	X					X	X
15	Melatofast	Relaxation and sleep improvement	X					X	X
16	Mirtillo	Urinary tract microcirculation support		X	X	X			X
17	Nutriserep	Normal prostatic function maintenance		X	X	X			
18	Papayn Plus	Antioxidant and tonic for immune system		X	X	X			
19	Seresil Donna	Menstrual and menopause disorders					X	X	X
20	Vitalight Detox	Body fluids purification and drainage					X	X	X
21	Vitalight Slim	Body weight balance					X	X	X
22	Pasithea Relax	Relax and sleep promotion	X	X	X	X			

of random assignment, as long as it was possible to have at least three repetitions by different panellists for each food supplement. Each panellist attributed a score from 1 to 5 (Likert scale) to the formulation of the food supplements, also evaluating the differences with the bestseller for that category. Specifically, a score of 1 denoted a complete lack of the requirements of the product formulation; 2 expressed significant deficiencies in the product preparation; 3 represented a sufficient structure, but with some gaps, especially in comparison with the competitors; 4 a good product design; and 5 expressed an outstanding assessment (Cheng et al. 2021).

24.3 Results and Discussions

The obtained average scores for the products assessed are shown in Fig. 24.1. The overall score was 3.8 ± 1.1, showing an intermediate dispersion of the evaluations. This result is also confirmed by looking at the individual scores. The range varies

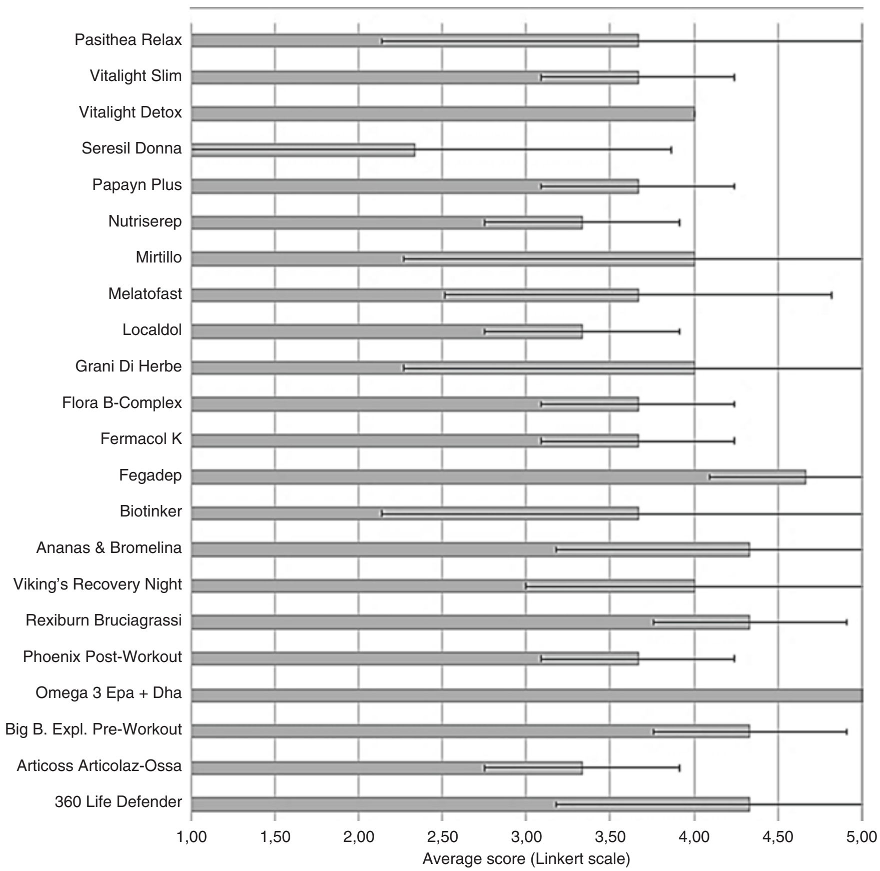

Fig. 24.1 Average score (in Likert scale) for the products assessed. Error bars represent standard deviation. The dashed-dotted line represents the overall average score

from 5.0 ± 0.0 of the *Omega 3 EPA + DHA* product to 2.3 ± 1.5 of the food supplement *Seresil Donna.* Ten products obtained an average value ≥4.0, while the above-mentioned *Seresil Donna* obtained a score ≤ 3.0, showing a generally positive evaluation of the producer catalogue.

The experts were also asked to evaluate the formulations in quali-quantitative terms and to provide remarks on the scores. The comments are summarized in Table 24.2. The suggestions from experts could be a valuable tool for producers to improve their product formulation.

Table 24.2 Expert's remarks on the product evaluated

Product	Remarks
360 Life Defender	An interesting product, even if the quantity of active ingredients is low, to have greater effectiveness, it would be advisable to administer at least two tablets/day.
Articoss Articolaz-Ossa	A balanced product in the dosages of active molecules, well-distributed components, and all functional for prevention probably should be assisted with the administration of Hydroxy Methyl Butyrate (HMB) and omega 3. Suggested increase in the dosage of proline and collagen peptides.
Big B. Expl. Pre-Workout	A balanced product in the dosages, well-distributed components, and all functional for prevention probably assisted it with the administration of HMB and omega 3. Suggested increase in the dosage of proline and collagen peptides.
Omega 3 Epa + Dha	
Phoenix PostWorkout	The product has a higher and better-balanced quantity of amino acids for the same weight as other products, in addition to the added value of vitamins and minerals. Creatine content is similar compared to the competitor. The competitor product contains hydroxy-methyl-butyrate, helpful in preserving muscle tone and especially sugars, essential for adequate recovery.. Phoenix should be combined with another supplement or sugar-rich foods.
Rexiburn Bruciagrassi	The quantity of garcinia is much lower than the competitor, but it contains many more active ingredients. It is hoped that the amounts of its numerous active ingredients work synergistically with each other, but there are not enough elements in the literature to validate it.
Viking's Recovery Night	Products with the right components but too low dosage, considering that the main target is athletes. Dosage of: Zinc (15 mg), ac. aspartic (1.5 g). In addition, it is desirable to enter vitamin D.
Ananas & Bromelina	Adequate component/dosage ratio, even if the product's efficacy is questionable for the intended purpose.
Biotinker	Vitamin C is missing, and the amount of zinc is too low.
Fegadep	Extract content superior to others available on the market, making it an excellent product.
Fermacol K	
Flora B-Complex	It looks like a great product. Good combination with vitamin B.
Grani Di Herbe	Adequate component/dosage ratio; advised addition of agar–agar or psyllium.
Localdol	Adequate component/dosage ratio; suggested the addition of *Rhodiola rosea*, phosphatidylserine, and Devil's Claw or 5HTP.

(continued)

Table 24.2 (continued)

Product	Remarks
Melatofast	Adequate component/dosage ratio; two tablets/dose recommended.
Mirtillo	
Nutriserep	Good product, but it is preferable to recommend taking two capsules, one in the morning and one in the evening.
Papayn Plus	The sachet formulation involves difficulty in administration. The package has 15 sachets, but to cover a month, 30 doses are needed.
Seresil Donna	The supplements targeted for disorders related to the menstrual cycle are generally based on the chaste tree or evening primrose oil, principles that are not present in the product.
Vitalight Detox	
Vitalight Slim	Synephrine is missing, but it contains a larger amount of caffeine. Given the annoying effects of caffeine abuse, it might be appropriate to diversify the active ingredients (formulate a phytocomplex to reduce the amount of caffeine).
Pasithea Relax	Adequate component/dosage ratio; suggested synergy with Localdol.

Some considered products exhibited a competitive formulation for the intended scope, but the dosage recommended was insufficient (*360 Life Defender, Big B. Expl. Pre-Workout, Rexiburn Bruciagrassi, Viking's Recovery Night, Melatofast, Nutriserep*). Others lacked critical components for a quality supplement (*Biotinker, Seresil Donna, Vitalight Slim*). In contrast, for others, the addition was only suggested for an overall improvement (*Locadol, Grani di erbe, Phoenix PostWorkout, Big B. Expl. Pre-Workout, Articoss Articolaz-Ossa*). Finally, the experts recommended the synergistic use of two products, *Pasithea Relax* and *Locadol,* opening the way for a new marketing strategy.

24.4 Conclusions and Future Perspectives

The study aimed to assess the food supplement formulations in quali-quantitative terms produced by an Italian start-up. The Likert scale was used by an expert panel previously constituted to evaluate the selected food supplements.

The average score given by the panel for the product set was 3.8 ± 1.1. The study results showed that the start-up's products are highly comparable with those on the market, confirming their competitiveness with the leading Italian brands. However, a few improvements were suggested for some products, and only one product (*Seresil Donna*) was found to be inappropriate.

Further research developments should focus on a panel composed of a larger number of experts and the selection of experts for each category of dietary supplements considered.

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Chapter 25
Wine Quality Improvement Based on the Perception of Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI): Evidence from Bulgaria

Vesselina Dimitrova, Georgi Marinov, and Petyo Boshnakov

Abstract In recent years, there has been a trend towards more in-depth study of the factors that affect the willingness of wine manufacturers to use quality labels such as protected designation of origin (PDO) and protected geographical indication (PGI). Key issues such as the influence of climate on wine production, authenticity of wine quality, and technological innovations in wine production are subjects of research for PDO indication. The possibility of classifying the chemical composition of wines and the use of PGI as a harmonized strategy for lower production costs and increased consumer interest are the other areas of research. This study aims to test the above-mentioned groups of factors and their ability to improve the quality of wine production in Bulgaria as well as to analyse the existing practices of assessment for Bulgarian wine producers. The study involves wine producers and experts from the National Viticulture Agency, and their perceptions will be analysed through the fuzzy AHP approach.

Keywords Wine quality improvement · Authenticity · Protected designation of origin (PDO) · Protected geographical indication (PGI)

25.1 Introduction

Wine production in the European Union (EU) as well as worldwide today aims to promote high-quality wines and to meet certain quality standards. Those labels and schemes are well known in the EU and have been successfully implemented mainly

V. Dimitrova (✉) · G. Marinov · P. Boshnakov
Department of International Economic Relations, University of Economics-Varna, Varna, Bulgaria
e-mail: vesselina.dimitrova@ue-varna.bg

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_25

in countries located in the south of the EU, such as France, Italy, Spain, Portugal, and Greece. The quality schemes or quality labels are referred to as geographical indications (GIs) with two specific types: protected designation of origin (PDO) and protected geographical indication (PGI). These quality schemes are described in detail in EU regulations for quality control such as Regulation 2081/1992, Regulation 2082/1992, and Regulation 1151/2012 (Dias and Mendes 2018). GIs give value to territory thanks to certifications (including International Organization for Standardization (ISO) and Hazard Analysis and Critical Control Point (HACCP)) and require strong collaboration between various institutions. Usually, the policy to manage the designation of origin in EU countries is delegated to some relevant institution or consortia recognized by the Ministry of Agriculture as Institut National de l'origine e de la qualité (INAO) in France or Federdoc, which is a voluntary consortia and National Confederation for the Protection of the Italian Wines Designations, in Italy. GI serves as a vehicle of protection against different abuses by guaranteeing the uniqueness, non-reproducibility, and traceability of the products. At the same time, GI is a protective tool for consumers and producers reflected in the final price, which is likely to be higher in comparison with the regular product without GI (Kireeva 2011). PDO and PGI are important indicators of the competitiveness of wine producers based on local traditions. PDO represents a system of rules. PDO covers wine production, processing, and preparation in a specific geographical area and serves as a mark for regional know-how. To obtain PDO, the qualities and characteristics of wine refer to the geographical environment, including natural and human factors. PGI allows the use of raw materials in wine production from another region, taking into consideration that at least one stage of production, processing, and preparation occurs in a specific geographical area. In this context, PGI also serves as a certification scheme or should be accepted as a collective agri-food brand because of the required more than 25-year-long tradition from the execution of the entire production or part of a specific geographical area (Sgroi and Mondica 2022).

This study aims to test which factors affect quality schemes in Bulgarian wine production, taking into account that Bulgarian wine producers are currently focused mainly on wine-making without PDO and PGI. Bulgarian PDO and PGI wine production with 33% ranks behind the production of wines without PDO and PGI (National Vine and Wine Chamber 2018). Bulgaria reports for the period 2007–2016 a decline and variations in the quantities of wines produced with PDO and PGI, which are also in a low-price range (unlike the European trend). Furthermore, the research question of this study is "Which factors influence Bulgarian wine producers in the implementation of PDO and PGI schemes?" Our results are part of the information of great value for Bulgarian winemakers because they can consider, in case of interest for PDO and PGI labels, which barriers are unavoidable and which development factors for wine quality improvement must be observed and followed.

25.2 Review of Literature

In recent years, there has been a trend towards more in-depth study of the factors that affect the willingness of wine manufacturers to use quality labels. Key issues such as the influence of climate on wine production and technological innovations in wine production are subjects of research for PDO indication. Especially in Mediterranean countries, winemakers suffer from frequent water stress, lower acidity of wines, and general loss of production as a result of extreme climatic events. This requires new production solutions and innovative strategies for wine technologists (Boyer and Touzard 2021; Jones and Webb 2010). The possibility of classifying the chemical composition of wines and the use of PGI as a harmonized strategy for lower production costs and increased consumer interest are other areas of research (Lancellotti et al. 2021). Some authors group the factors influencing both PDO and PGI in three main directions: particularities of local resources, environmental balance between natural resources and regional traditions, and entrepreneurial skills to organize and innovate production and technological processes (Mazzocchi and Sali 2022). PDO and PGI varieties are perceived as products of higher quality than non-PDO or non-PGI varieties. Bonnet and Simoni (2001) mentioned that consumers are not always aware of the difference between PDO and non-PDO varieties. The authenticity of wines represents another important aspect considered because of the close relation with the wine brand. According to Chhabra et al. (2013), authenticity is projected by terms such as "ethic," "symbolic," "stereotyped," "real thing," "traditions," and "origins." Words, images, packaging, smell, symbols, and origins such as "château" or "domaine" are norms for geographical certification of the origin of wine. Le et al. (2022) confirmed a strong relationship between "consumer behaviour" and "authenticity perceptions." According to the authors, the judgements for authenticity for consumers or observers and producers are based on different essences. For consumers, the existing knowledge connection with histories, events, values, persons, and places is important. For producers, the values, intentions, goals, qualities, and characteristics have higher weight. PDO and PGI as geographical indications mean not only quality but also reputation (Raustiala and Munzer 2007). They are indicators for good trade, appropriate agricultural policy, and protected intellectual property. Additionally, Barham (2003) confirms that PDO and PGI have positive effects on trade flows. One of the problems that can emerge for PDO and PGI quality is related to online retail because in this case, wine authenticity should be considered under risk. Another possible problem could be related to a crisis or pandemic situation. In these cases, "wine loyalty" is strongly important for quality schemes. PDO and PGI should serve as public quality standards and could help the regulation of quality claims, especially when concerning trade between EU and third countries (Biénabe and Marie-Vivien 2017). Highly requested products with PDO and PGI contribute to greater regional cohesion and serve as promoters of "something more," such as labels, quality, and traditions

(Napoli et al. 2014). Based on econometric analysis for European NUTS3 regions in France, Italy, and Spain Cei (2021) shows that the cooperation between producers and tradition in the use of GI tools are major factors to protect quality using PDO and PGI labels.

This study, to our knowledge, offers some additional insight and extends the literature with preliminary results from Bulgaria, comparing the similar influence of factors for PDO and PGI quality according to the opinion of wine producers.

25.3 Data and Methodology

Wine quality improvement is a subject of various studies outlining a wide range of factors that influence the assessment by producers of PDO and PGI wines. Further research can only enrich existing knowledge with new recommendations. Such is the case for Bulgaria which we consider here.

Following (Calabrese et al. 2013), we apply their methodology based on the classical AHP analysis of Saaty (1990) and extend it to allow for fuzzy assessments (Chang 1996). The Analytic Hierarchy Process (AHP) starts with a construction of a "hierarchy," a tree structure with several levels – "goal" (the top level), "criteria," "sub-criteria," etc. For each item in the hierarchy, experts assess how it relates to the item of the level above. In the fuzzy AHP variant, the assessments experts make consist of triads of values ("low," "middle," and "high"). Furthermore, the fuzzy triads are converted to "crisp" values to construct the AHP matrix. The goal is to obtain weights of the different items so that the decision-making process can be enhanced, although AHP does not fully replace expert decision-making.

Technically, first, the fuzzy comparison matrices are converted to crisp comparison matrices by centre of gravity defuzzification (see Calabrese et al. 2013, for details). Then, the consistency index and consistency ratio are calculated to analyse the consistency of each comparison matrix. Next, the local priority weight of each criterion is determined.

The hierarchy elaborated for our analysis consists of three layers, and experts come from the wine industry of Bulgaria. We explore two hierarchies, with PDO and PGI as "goals"; however, since PDO and PGI have some mixed perceptions, we analyse the sub-criteria only regarding their upper level, the criteria.

25.4 Results and Discussions

Four criteria for PDO and PGI were selected as "bioclimatic changes," "uniqueness of wines," "methods for detecting fraud and guaranteeing wine authenticity" and "marketing tool for wine producers," and different sub-criteria were selected for each criterion. The choice of individual criteria reflects recent publications and research studies for GIs. Table 25.1 presents the results from the fuzzy AHP for both hierarchies, with PDO and PGI as a "goal". Consistency tests show that all the

Table 25.1 PDO and PGI in the wine industry – decision hierarchies

PDO	PGI
Bioclimatic changes (0.18): Rise of temperature (0.32) Exceptional hailstorms and flooding (0.32) Intense drought (0.36)	Bioclimatic changes (0.24): Rise of temperature (0.32) Exceptional hailstorms and flooding (0.32) Intense drought (0.36)
Uniqueness of wines (0.23): Different concentrations of elements (Ca, Mn, Co, Zn …) among wines (0.52) “Creativity” of oenologist to change terroir (0.48)	Uniqueness of wines (0.19): Different concentrations of elements (Ca, Mn, Co, Zn …) among wines (0.52) “Creativity” of oenologist to change terroir (0.48)
Methods for detecting fraud and guaranteeing wine authenticity (0.32): Broad variability of quality within the same PDO which confuses the consumers (0.24) No long and solid tradition of quality standards to last for the loyal consumer (0.30) Enhancing the effectiveness of the quality wine protection system (0.46)	Methods for detecting fraud and guaranteeing wine authenticity (0.29): Broad variability of quality within the same PDO which confuses the consumers (0.24) No long and solid tradition of quality standards to last for the loyal consumer (0.30) Enhancing the effectiveness of the quality wine protection system (0.46)
Marketing tool for wine producers (0.28): Reducing consumer’s information search costs (0.22) Raising willingness of consumers to pay (0.22) Export potential (0.32) Extending loyalty of high-educated customers (0.24)	Marketing tool for wine producers (0.28): Reducing consumer’s information search costs (0.22) Raising willingness of consumers to pay (0.22) Export potential (0.32) Extending loyalty of high-educated customers (0.24)

matrices are consistent, with confidence interval (CI) values well below 0.1; therefore, the assessments can be accepted.

The results show two important aspects for Bulgarian wine-making producers, namely the question of authenticity of GI wine and the manner in which it is promoted. Bulgarian producers emphasize the importance of PDO and PGI primarily as vehicles against fraud (local decision weights of “methods for detecting fraud and guaranteeing wine authenticity” are 0.32 for PDO and 0.29 for PGI), with marketing aspects in second place (0.28 for both PDO and PGI). The first aspect explains the desire of Bulgarian winemakers for clear laws and precise regulations to guarantee the authenticity of the wine quality. For example, Bulgarian law allows (Article 85) the designations PDO and PGI not to be indicated when “Guaranteed and controlled designation of origin” is written. The latter creates ambiguity in interpretation and the possibility of confusion, fraud, or origin manipulation.

The use of PDO and PGI wines as a powerful marketing tool is not surprising, especially since it is embedded in the regulations of the country. For example, the National Program for Support of the Vine and Wine Sector in Bulgaria for the period 2019–2023 of the Ministry of Agriculture, Food and Forestry states that according to Regulation 1308/2013, PDO and PGI should be used as a means of informing and promoting Bulgarian quality wines in case of export in third countries.

25.5 Conclusions and Future Perspectives

This research study shows some challenges and opportunities related to PDO and PGI wines in Bulgaria and their quality improvement. The measures of the Bulgarian Ministry of Agriculture, Food and Forestry are primarily aimed at marketing and promoting PDO and PGI wines to third countries compared to European and world practice for quality control or encouraging producers for PDO and PGI wine production. Undoubtedly, it is difficult for the uninformed wine producer to understand the regulations and to determine the differences between PDO and PGI wines and non-PDO and non-PGI wines. One positive note from the results is the attention drawn to the potential threat of manipulation and falsification of the authenticity of PDO and PGI wines. In this regard, it is necessary to clarify the "uniqueness" of the chemical composition of wines, the issuance of certificates, the activities of the regional tasting commissions by area of origin, and the work of the reference laboratories for PDO and PGI wines. Bioclimatic trends and the conservation of resources in viticulture and wine-making must become a priority for both producers of GI wines and for relevant institutions such as the Bulgarian Ministry of Agriculture, Food and Forestry National Vine and Wine Chamber. All these sustainability issues related to PDO and PGI wines should be studied and monitored further among Bulgarian wine producers. The collection of surveys or the publication of data on PDO and PGI wines is quite obsolete in Bulgaria. It also does not include detailed price information, as is the case in countries such as Italy, where Istituto di Servizi per il Mercato Agricolo Alimentare (ISMEA) publishes information by year and by region for PDO and PGI wines, including unit average prices. Future research studies should analyse the lack of surveys on consumer preferences for PDO and PGI wines in Bulgaria.

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Chapter 26
Multi-element Characterization and Multivariate Analysis of Venetian Protected Designation of Origin (PDO) Wines

Mattia Rapa, Marco Ferrante, Ilia Rodushkin, and Marcelo Enrique Conti

Abstract Veneto is Italy's leading wine producer, contributing 23.1% to the entire national production. Veneto production mainly concentrates on protected designation of origin (PDO) wines with 1212 million euros as market value. The definition of some typical markers in wines is an excellent tool for the traceability and authenticity of the Veneto wine supply chain. In this context, the profile of 35 elements by High Resolution - Inductively Coupled - Plasma Mass Spectrometry (HR-ICP–MS) was determined in 12 wine samples belonging to different PDOs of the Veneto region. An exploratory data assessment using principal component analysis (PCA) was conducted on the results dataset. The red wine samples were well grouped in a score plot area with a strong influence of macroelements such as Na, K, Mg, and P, while the white and sparkling wine samples were not differentiated. Subsequently, a linear discriminant analysis (LDA) was carried out, which gave excellent results for classifying all wine categories (75–100% correct classification). In conclusion, it can be stated that multi-element analysis of quality wine samples gave good results for characterizing Venetian PDOs.

Keywords Veneto PDO wines · Multi-element analysis · Multivariate analysis

M. Rapa (✉) · M. E. Conti
Department of Management, University of Rome, Rome, Italy
e-mail: mattia.rapa@uniroma1.it

M. Ferrante
Trace Technologies S.r.l., Nereto, Italy

I. Rodushkin
Division of Applied Geochemistry, Luleå University of Technology, Luleå, Sweden

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_26

26.1 Introduction

European countries in 2019 produced 16 million tons of wine, accounting for 60% of worldwide production (Anderson and Pinilla 2022). Italy is the leading producer, and its production accounts for 43.5% of protected designation of origin (PDO) wines (Pizzol et al. 2021). Veneto is Italy's leading wine producer, contributing 23.1% to the entire national production. Veneto production mainly concentrates on PDO wines with 1212 million euros as market value (Pomarici et al. 2021). Foreign markets represent a fundamental channel. Indeed, 70% of the production is destined for export. In addition, it is well known that the wine sector is one of the most predisposed to fraud and adulteration (Previti et al. 2022). These illegal practices increased the economic losses in this chain. Therefore, the definition of some typical markers in wines is an excellent tool for the traceability and authenticity of the Veneto wine supply chain. Thus, the potential of trustworthy wine geographical origin verification is becoming of great interest to stakeholders in this field. In this regard, the use of elemental analysis to prevent fraud in the wine sector was also indicated by art. n° 39 of regulation EU 2018/2732, aiming to build an analytical database of multi-element data. In this context, this paper aimed to develop a recognition model to identify Venetian PDO wines. For this purpose, the profile of 35 elements (Al, B, Ba, Be, Bi, Ca, Co, Cr, Cs, Fe, Ga, Hf, K, Li, Mg, Mn, Mo, Na, Nb, P, Rb, Re, S, Sb, Se, Si, Sn, Sr, Ta, Ti, Tl, W, V, Zn, and Zr) was determined by HR-ICP–MS in 12 wine samples belonging to different PDOs of the Veneto region (Conti et al. 2018). Chemometric tools such as principal component analysis (PCA) and linear discriminant analysis (LDA) were successfully applied to classify samples according to their wine-making process (Ciano et al. 2022).

26.2 Materials and Methods

26.2.1 Instrumentation

All measurements of element concentrations were performed by a double-focusing sector field Inductively Coupled Plasma-Mass Spectrometry (ICP–MS) ELEMENT XR (Thermo Scientific, Bremen, Germany). Operating conditions and measurement parameters for concentration measurements were conducted as previously reported (Engström et al. 2004).

26.2.2 Sample Preparation and Analysis

Personnel wearing clean room attire performed sample preparation in Class 10,000 clean laboratory areas. For multi-element analyses, wine samples were diluted 40-fold with 1.4 M HNO3. A set of method blanks and Certified Reference Materials

(CRMs) was prepared with each batch of samples, and concentrations of the 35 elements were determined by Inductively Coupled Plasma-Sector Field Mass Spectrometry (ICP-SFMS). Matrix effect correction was accomplished by internal standardization (indium added to all measurement solutions at 2.5 μg/l concentration), and quantification was performed by external calibration with synthetic, concentration-matched standards (Rodushkin et al. 2005).

26.2.3 Analytical Validation

The limits of detection (LOD) and limits of quantification (LOQ) were calculated as three times the standard deviation for element concentrations detected in preparation blanks ($n > 10$). The accuracy of the data was assessed by analyses of the CRMs and presented as the mean recoveries calculated as a ratio of ICP-SFMS results to certified values. Method reproducibility was evaluated from replicate preparation/analysis of samples and CRMs, and Relative Standard Deviation (RSD) for elements presented in tested matrices at concentrations ten times above respective LODs was better than 10% (Rodushkin et al. 2016).

26.2.4 Statistical Analysis

Analysis of variance (ANOVA) and mean comparison by Tukey's honest significant difference (HSD) for unequal numbers of samples at the 5% level were performed using the JMP 15 Pro software (SAS Institute). Principal component analysis (PCA) and linear discriminant analysis (LDA) were performed with JMP 15 Pro. Before the chemometric assessment, an autoscaling pretreatment was carried out on the data matrix.

26.3 Results and Discussion

26.3.1 Multi-element Characterization

Thirty-five elements (Al, B, Ba, Be, Bi, Ca, Co, Cr, Cs, Fe, Ga, Hf, K, Li, Mg, Mn, Mo, Na, Nb, P, Rb, Re, S, Sb, Se, Si, Sn, Sr, Ta, Ti, Tl, W, V, Zn, and Zr) were measured in 12 wine samples by HR-ICP–MS. The choice to use a multi-element screening analysis was made to select the most promising specific markers for the Venetian wines according to their type (white, red, or sparkling). The analytical results are reported in Table 26.1, expressed as each wine type's mean and standard deviation. Tukey's honestly significant difference was elaborated on the data matrix at 5% of differences, and the results for significant differences with a p value <0.05 are also reported in Table 26.1.

Table 26.1 Results of the multi-element analysis of 12 Venetian wines, expressed as μg/L

Elements (μg/L)	White	Red	Sparkling
Al	700 ± 57[a]	510 ± 120[b]	660 ± 92[a]
B	3700 ± 220[a]	5000 ± 1400[b]	2800 ± 440[c]
Ba	64 ± 13[a]	120 ± 25[b]	47 ± 4.4[c]
Be	1.4 ± 0.92[a]	0.45 ± 0.13[b]	1.3 ± 0.81[a]
Bi	0.077 ± 0.032[a]	0.025 ± 0.0023[b]	0.049 ± 0.023[c]
Ca	86,000 ± 14,000[a]	88,000 ± 17,000[a]	80,000 ± 13,000[a]
Co	2.1 ± 0.28[a]	2.9 ± 0.45[b]	2.5 ± 0.47[a]
Cr	10 ± 0.7[a]	17 ± 3.3[b]	13 ± 9[ab]
Cs	6.8 ± 1.2[a]	7.8 ± 2.6[a]	4 ± 0.71[b]
Fe	870 ± 420[a]	1800 ± 150[b]	670 ± 230[a]
Ga	0.14 ± 0.034[a]	0.045 ± 0.017[b]	0.13 ± 0.084[a]
Hf	0.086 ± 0.048[a]	0.068 ± 0.043[ab]	0.033 ± 0.022[b]
K	830,000 ± 63,000[a]	1,500,000 ± 280,000[b]	540,000 ± 130,000[c]
Li	2.2 ± 0.92[a]	5.6 ± 1.9[b]	1.2 ± 0.71[a]
Mg	74,000 ± 12,000[a]	110,000 ± 18,000[b]	69,000 ± 9700[a]
Mn	750 ± 130[a]	1100 ± 200[b]	720 ± 240[a]
Mo	1.8 ± 0.58[a]	1.5 ± 0.86[a]	4.3 ± 4.7[a]
Na	20,000 ± 4200[ab]	26,000 ± 14,000[a]	17,000 ± 2700[b]
Nb	0.13 ± 0.14[ab]	0.058 ± 0.017[a]	0.16 ± 0.067[b]
P	350,000 ± 150,000[a]	380,000 ± 63,000[a]	220,000 ± 49,000[b]
Rb	800 ± 200[a]	1500 ± 710[b]	900 ± 280[a]
Re	0.0025 ± 0.0012[a]	0.021 ± 0.024[b]	0.0016 ± 0.0017[a]
S	170,000 ± 17,000[a]	250,000 ± 70,000[b]	150,000 ± 46,000[a]
Sb	0.38 ± 0.07[a]	0.41 ± 0.36[a]	0.35 ± 0.11[a]
Se	0.51 ± 0.11[a]	0.88 ± 0.71[a]	0.28 ± 0.01[a]
Si	12,000 ± 2200[a]	16,000 ± 3900[b]	12,000 ± 2800[a]
Sn	3.4 ± 2.8[a]	2.5 ± 1.1[a]	1.8 ± 1.6[a]
Sr	240 ± 33[a]	480 ± 110[b]	280 ± 100[a]
Ta	0.0044 ± 0.0019[a]	0.0036 ± 0.0006[ab]	0.0024 ± 0.00045[b]
Ti	3.4 ± 1.8[a]	2.5 ± 0.47[a]	6 ± 6.1[a]
Tl	0.31 ± 0.15[a]	0.3 ± 0.098[a]	0.24 ± 0.11[a]
W	0.35 ± 0.09[a]	0.2 ± 0.12[a]	0.4 ± 0.34[a]
V	2.3 ± 0.26[a]	1.9 ± 1.7[a]	42 ± 50[b]
Zn	760 ± 230[a]	1100 ± 290[b]	760 ± 110[a]
Zr	4.5 ± 2.6[a]	2.5 ± 1.1[b]	2.1 ± 1.3[b]

Rows in the same column not linked by the same letters (a, b) are significantly different by Tukey's HSD test

From these data, we can infer some relevant findings:

1. B, Bi, and K were the only three elements that differentiated all the wine types. Indeed, the concentration of these elements was significantly different in the three categories analysed (white, red, and sparkling). Red wines had the highest

contents of B and K, followed by white and sparkling wines. A different trend was found for Bi, which had the highest concentration in white wines, followed by sparkling and red wines.

2. The samples with the best specific pattern were the red wines. The analysed samples presented significantly different concentrations of Al, Ba, Be, Co, Fe, Ga, Li, Mg, Mn, Rb, Re, S, Si, Sr, and Zn. Except for Al, Be, and Ga, red wines have the highest concentration of these elements compared to white and sparkling wines.
3. The highest concentration of Zr in white wines discriminated the white samples from the others.
4. Cs can be used to recognize sparkling wine, which had the lowest concentration in these samples.

26.3.2 Chemometric Assessment

The analytical results of elemental determination have highlighted specific markers for wine typologies, i.e. white, red, and sparkling. Principal component analysis (PCA) and linear discriminant analysis (LDA) were applied to the data matrix to enhance characterization and create classification models for wine samples.

PCA was performed to highlight the natural grouping of samples. Autoscaling pretreatment was carried out on the dataset to exclude the variance related to the different measurement units. The scores and loadings plot of the PCA is reported in Fig. 26.1.

The first two PCs explained 53.3% of the total variance. It can be highlighted as a good grouping of samples. Red samples appeared in the right part of the score

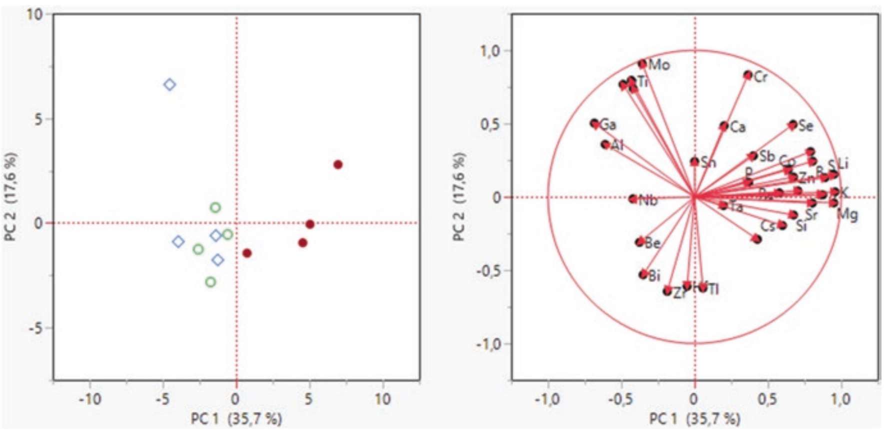

Fig. 26.1 Scores and loadings plots of PCA for the wine sample dataset. Red dots: red wines; green circles: white wines; blue rhombus: sparkling wines

Table 26.2 Confusion matrix of wine sample classification by LDA

	White	Red	Sparkling
White	4	0	0
Red	1	3	0
Sparkling	0	0	4

plot, while white and sparkling samples were all located on the left side and were not very separated.

Once the natural grouping of samples was highlighted in PCA, the 12 samples were used to build a traceability tool for Venetian wine samples. LDA was used to classify samples according to their typology (white, red, and sparkling). Table 26.2 reports the confusion matrix of wine samples according to typology.

An optimal classification rate (100%) was achieved for white and sparkling wines. A slightly less correct classification (75%) was obtained for red samples, as one red sample was classified as a white wine. Nevertheless, as we can see from Table 26.1, red and white wines are clearly recognizable, confirming the model's robustness.

26.4 Conclusions and Future Perspectives

The definition of some typical markers in wines is an excellent tool for the traceability and authenticity of the Veneto wine supply chain. For this purpose, the profile of 35 elements (Al, B, Ba, Be, Bi, Ca, Co, Cr, Cs, Fe, Ga, Hf, K, Li, Mg, Mn, Mo, Na, Nb, P, Rb, Re, S, Sb, Se, Si, Sn, Sr, Ta, Ti, Tl, W, V, Zn, and Zr) by HR-ICP–MS was determined in 12 wine samples belonging to different PDOs of the Veneto region. These analyses have indicated that B, Bi, and K differentiated all the wine types. Red wines had the best specific pattern, while white wines were discriminated by Zr concentration and sparkling wines by Cs concentration. The chemometric assessment provides a primary sample grouping by PCA and a subsequent correct classification (75–100%) by LDA. In conclusion, it can be stated that multi-element analysis of quality wine samples gave good results for characterizing Venetian PDOs.

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Chapter 27
Study of the Volatile Component and the Flavonoid Content of Edible Flowers

Vanessa Giannetti, Maurizio Boccacci Mariani, and Greta Livi

Abstract In recent years, a growing interest among farmers and chefs has been oriented towards edible flowers, which are now popular in modern cuisine and appreciated by consumers. Their expansion is not limited to the aesthetic value but also to flavour and nutritional aspects that supply food and beverages. The aim of our research is to characterize edible flowers in terms of aromatic profile and nutritional component to provide an objective approach able to discriminate one product from another on the market considering the peculiarities of each variety available. In the first step of the study, reported in this chapter, HS-SPME/GC–MS and ASE/HPLC-UV methods were developed to assess the volatile fingerprint and flavonoid content in edible flowers. The resulting chromatographic profiles of the analysis of a wide set of samples are processed by multivariate statistical analysis to build classification models (next step of research, in progress).

Keywords Edible flowers · Flavour · Flavonoids · HS-SPME/GC–MS · ASE-HPLC/UV

27.1 Introduction

According to scientific studies, edible flowers are non-toxic and innocuous flowers, and their consumption can contribute to several health benefits due to their content of bioactive compounds (Lu et al. 2016). In recent years, the evolution in food habits towards healthier and correct lifestyles and research on innovative dishes by professional chefs have resulted in a significantly increased demand for these products. The use of flowers as a food ingredient recently gained new popularity,

V. Giannetti (✉) · M. Boccacci Mariani · G. Livi
Faculty of Economics, Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: vanessa.giannetti@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_27

although it is an ancient tradition dating to 140 B.C. (Falconnier 2006). Today's edible flower availability includes several tens of species differing in form, colour, and flavour, typically used to improve the appearance, colour, and nutritional value of proposed dishes. Edible flowers are regarded as unique and imaginative ingredients that can be used both as a garnish and as a component in salads, soups, appetizers, desserts, and beverages. They are widely consumed fresh but can also be dried, powdered, crystallized, or used as foams (molecular gastronomy). The current demand for more attractive and tasty food combined with new information concerning their nutritional value places the edible flower global market in a phase of accelerated expansion (Rop et al. 2012). However, for most of them, limited information on production on a global scale has been found, and only producers' annual reports and sales data of agricultural companies are available (Fernandes et al. 2020). In 2017, Europe, the Middle East, and Africa had the largest market share (Technavio 2018). There are still no official lists by international organizations such as FAO, WHO, and EFSA of the several flower varieties; however, Lu et al. (2016) have listed 97 families, 100 genera, and 180 species, highlighting that the number of edible flowers varies from country to country. Today, a wide variety of these flowers with different appearances and organoleptic characteristics, such as size, shape, colour, aroma, and taste, are available on the domestic market. The sensory and nutritional feature assessment represents an important criterion for the food industry to gain this market segment and for small producers to support local agriculture. Additionally, on the consumer's side, these features have a significant impact on choices of food consumption focused on research on a pleasing sensory experience and a healthy lifestyle (Kelly et al. 2001). Although sensory qualities and flower variety significantly influence their acceptability in the human diet, several studies report that many other factors, such as packaging, price, education, gender, and socioeconomic class of consumers, can also impact (Rodrigues et al. 2017). In this context, the volatile and nutritional component evaluation of edible flowers is crucial to valorize food ingredients able to provide beneficial properties and aesthetic value. The volatile profile is defined by a combination of many aromatic compounds, such as alcohols, alkanes, carbonyls, esters, and terpenes, that determine flavour (Deng et al. 2004; Movafeghi et al. 2010); some of them are also beneficial for health. For example, caryophyllene is regarded as the principal anti-inflammatory agent in carnations (Lyra et al. 2008). The solid-phase microextraction (SPME) method is the most widely used procedure to analyse volatile compounds in fresh flowers because it avoids the development of newly formed compounds potentially resulting from liquid or enzymatic extraction procedures (Deng et al. 2004; Fernando and Grun 2001; Movafeghi et al. 2010; Rout et al. 2012; Ye 2013). Regarding the edible flowers' bioactive components, several studies have shown that flavonoids are the substances present in greater quantities (Yan et al. 2012). Epidemiological research has also confirmed the inverse relationship between the intake of flavonoids and the risk of chronic diseases, in addition to their high capacity as an antioxidant component (Oliveira et al. 2014; Fernandes et al. 2019; Negro et al. 2021). This chapter reports the preliminary results of our research, which is still in progress and focused on characterization based on flavour profiles and the nutritional components of different edible flower typologies, to expand the set of objective approaches available to consumers and chefs to make informed choices. The first project step involved the development of an HS-SPME/GC–MS (head space-solid phase microextraction/gas chromatography-mass spectrometry) method to assess the volatile fingerprint and an HPLC-UV (high performance liquid chromatography-ultraviolet) method to determine the flavonoid content. The next step of the research involves the analysis of a sample set of different edible flowers available on the market to characterize by statistical classification tools.

27.2 Materials and Methods

Trays containing edible flowers of mixed colours and varieties were purchased on Amazon. The flowers were biocertified and produced by an Italian agricultural company. The samples were kept in the refrigerator on their original tray and analysed within 3 days of arrival in the lab. Before analysis, the flowers were separated by typology (Antirrhinum, Dianthus, and Violet). One gram of fresh flower sample was placed in a 20-mL glass vial for autosampler to assess the volatile profile by HS-SPME/GC–MS (Triplus Autosampler/Trace 1300 Gas Chromatograph-ISQ 7000 Single Quadrupole, Thermo Fisher Scientific). A 50/30 divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS) Stable Flex fibre (2 cm) was selected. The sample vial was preheated to 40 °C for 5 min in the autosampler. The fibre was then exposed in the headspace for 10 min at the same temperature. Splitless mode was chosen as the injection modality, maintaining the valve closed for 5 min. The injector temperature was set to 220 °C with a 50 mL/min split flow. A VF-WAXms capillary column (30 m × 0.25 mm ID, 0.25 mm) was used for chromatographic separation employing helium as the carrier gas (flow rate of 1 mL/min). A temperature gradient was programmed at 60 °C for 1 min and ramped at 3 °C/min to 230 °C for 5 min. Detection was carried out using a single quadrupole in full-scan acquisition mode in a 45–450 amu range. Both the ion source and transfer line were kept at 250 °C.

An accelerated solvent extraction (ASE) followed by an HPLC/UV method was optimized to determine the flavonoid content (Dionex ASE 150, Dionex Ultimate 3000 HPLC, Thermo Fisher Scientific). Before ASE extraction, flower samples were dried in a lab oven at 40 °C for 8 h, ground for 10 s using an IKA A10 basic mill, and subsequently analysed. In the ASE system, 0.5 g of dried flowers was extracted under the following conditions: a single static cycle of 15 min, a temperature of 120 °C, and ethanol as the extraction solvent. The extraction pressure was kept constant at 1000 psi with a flush volume of 40%. A rotary evaporation system kept at 40 °C was employed for extract evaporation. Before HPLC analysis, the extracts were dissolved in 6 mL of methanol. A Kinetex® C18 LC column (5 μm 250 × 4.6 mm ID) maintained at 40 °C was used for separation. The mobile phase was a binary solvent system consisting of water (A) and acetonitrile (B), both containing 0.1% formic acid. The elution gradient was programmed as follows: 5 min at 15% B, 5–13 min at 25% B, 13–19 min at 40% B, and 20–30 min system was restored to initial conditions. The flow rate was 0.5 mL/min, and the wavelength was set at 280 nm. Data were collected using the Chromeleon 7 software for both GC and HPLC analysis.

27.3 Results and Discussions

The initial phase of this study focused on the development of an HS-SPME/GC–MS method for flavour investigation and an ASE/HPLC-UV method for flavonoid content determination to characterize different typologies of flowers. The data collected from the chromatographic analyses of a wide sample set will then be processed using multivariate statistical analysis in the second phase of the research, which is still ongoing. The goal is to build models able to classify the various types of flowers in terms of their flavour and antioxidant components and be able to place unknown edible flowers in the appropriate class. At present, only a few fresh edible flower samples belonging to three different classes (five for each class) have been analysed. Colour and taste distinguish the investigated categories: Antirrhinum with pastel mixed colours produces bitter sensations; Dianthus with red, pink, and white hues produces sweet and spicy sensations; and Violet with mixed colours produces delicate and sweet tastes. By comparing the chromatographic profiles of both the volatile and bioactive components of the analysed samples, preliminary qualitative results were obtained. Figure 27.1 shows the flavour fingerprint of the Antirrhinum and Dianthus samples. Caryophyllene, ethylene glycol, eugenol, isoledene, linalool, and longipinene were detected in Dianthus, but they were not found in the other groups (except for caryophyllene, which is also a component of Violet). Acetanisole, bergamotene, eremofilene, and isocitronelle were found only in Antirrhinum. Violet samples were instead characterized by allocimene, farnesene, humulene, limonene, menthatriene, myrcene, and ocimene. The identification of compounds was performed by comparing their mass spectra to mass spectra available in the NIST library, considering satisfactory compounds with R-match higher than 900. At this stage of the research, qualitative analysis without the use of reference standards should be reported as "putative compound identification" (Sumner et al. 2007). Figure 27.2 compares the flavonoid profiles of Antirrhinum and Dianthus, also showing significant differences between the two groups.

27.4 Conclusions and Future Perspectives

In this study, HS-SPME/GC–MS and ASE/HPLC-UV methods were developed and then applied to a limited set of edible flowers. The preliminary qualitative investigation showed significant differences among the investigated varieties with the

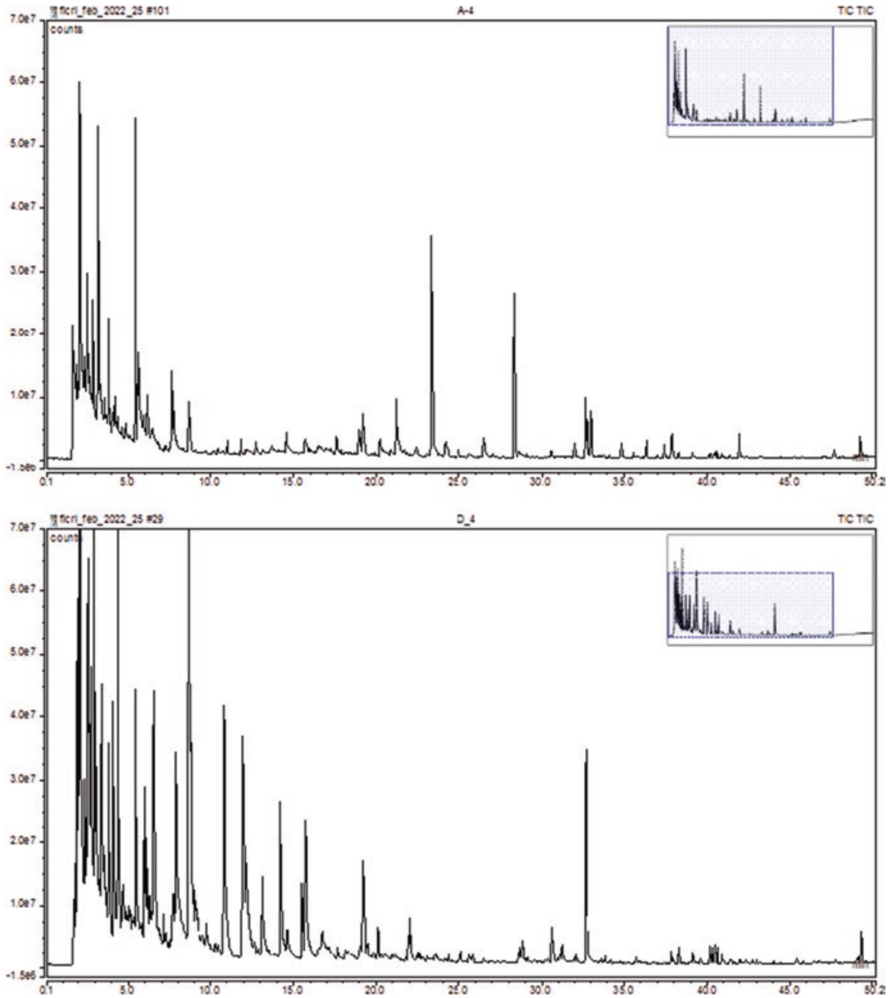

Fig. 27.1 HS-SPME/GC–MS flavour profiles of Antirrhinum (top) and Dianthus (bottom). The chromatograms are reported on the same scale as the x- and y-axes

identification of specific compounds that characterize one class over the other. This first step of the research will allow the future edible flower characterization of different typologies from both the standpoint of flavour and the bioactive component. Multivariate analysis and the obtained classification models could represent an objective approach to enable the choice of one product compared to another available on the market and identify aromatic and flavonoid compounds that could be used as product markers.

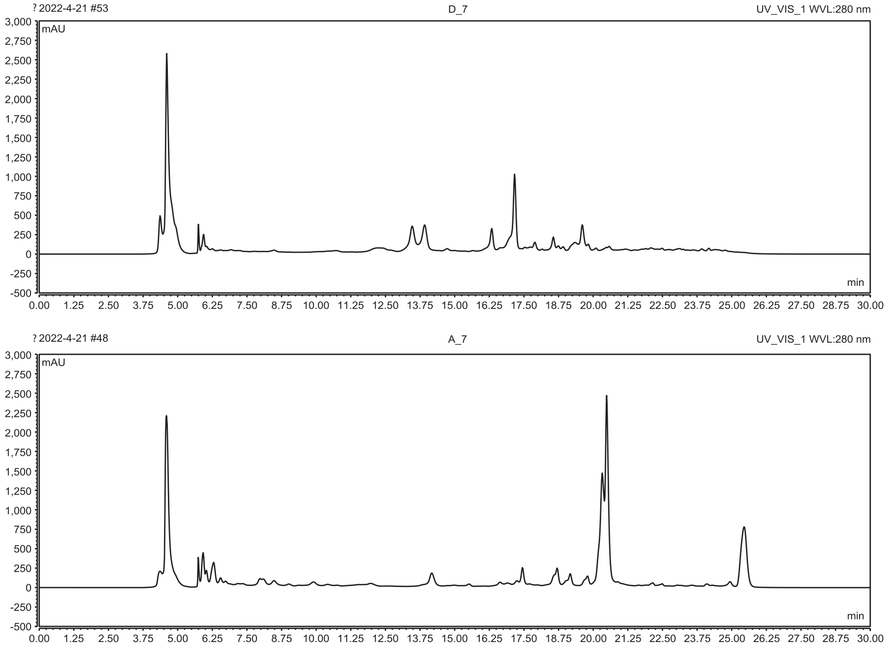

Fig. 27.2 Flavonoid components obtained by HPLC-UV analysis of Antirrhinum (top) and Dianthus (bottom). The chromatograms are reported on the same scale as the x- and y-axes

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Chapter 28
The Cultivation of *Iris pallida* as an Opportunity for the Enhancement of Tuscan Agro-Biodiversity and a Resource for the Local Economy

Francesca Ieri, Pamela Vignolini, Silvia Urciuoli, Patrizia Pinelli, and Annalisa Romani

Abstract *Iris pallida* is produced in Tuscany (Italy) in two limited hilly areas. The cultivation of Iris has undergone a progressive contraction, mainly due to the high labour requirements of the crop and to the reduction in the price of dry rhizomes on the international market of the perfume industry. To improve the value of the Iris crop as a resource for the local economy, a key aspect is to improve the quality of Iris in the Tuscan territory. Innovative biocidal and repellent products from arbutus and olive trees containing antimicrobial active ingredients have been developed to improve the critical points that compromise the quality and microbiological safety of Iris rhizomes. Gas chromatography–mass spectrometry (GC-MS) and innovative GCxGC-time-of-flight (TOF) and GC-vacuum ultraviolet (VUV) analyses have been optimized for the exhaustive characterization of irones and volatile compounds in flours with different aging degrees and in the absence or presence of cuticles to obtain an identity card of the aromatic profile of Iris, to monitor the quality of the product and to enhance the biodiversity of Tuscany. High performance liquid chromatography–photodiode-array detection–mass spectrometry (HPLC-DAD-MS) was also used to characterize the nonaromatic component with antioxidant activity to enhance its possible innovative use in the cosmetic and liqueur sectors of both flour and byproducts of the supply chain.

Keywords Irones · Isoflavones · Innovative product · Byproduct · Quality · Safety

Annalisa Romani died before publication of this work was completed.

F. Ieri (✉)
QuMAP Laboratory, PIN S.c.r.l. Educational and Scientific Services for the University of Florence, Prato, Italy
e-mail: francesca.ieri@pin.unifi.it

P. Vignolini · S. Urciuoli · P. Pinelli · A. Romani
DiSIA-PHYTOLAB Laboratory, University of Florence, Florence, Italy

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_28

28.1 Introduction

Among more than 300 species of the genus Iris (from the family Iridaceae), only *Iris pallida* and *Iris germanica* are currently used to produce natural irones, which are widely used in the perfume industry because of their attractive violet-like and powdery fragrance (Roger et al. 2010). Four main irones have been described (trans-α, cis-α, trans-γ, and β-irones), and their isomeric distribution and "sensory" properties depend on the iris species (Firmin et al. 1998). At present, *Iris pallida* is produced in Italy only in Tuscany in two limited hilly areas: in Chianti (near Florence) and in Pratomagno (near Arezzo), and it is usually complementary to olive oil and wine production. *Iris pallida* is a minor crop with high added value, and its rhizome is used by the international fragrance industry. In Italy, despite the wide globalization that has developed in the agri-food system, some traditional agricultural crops may play an important role in the environmental preservation and social and economic development of some marginal rural areas. The interest in the *Iris pallida* came from the high added value of the production, the expected potential of the existing network of local producers, and the sensitivity of the local stakeholders to the value of the traditional product not only for direct marketing reasons but also for indirect benefits coming from its high aesthetic value for the landscape and therefore for tourism and for its role in the environmental preservation of the area (Belletti et al. 2013). Once important in Western herbal medicine, *Iris pallida* rhizomes are now mainly designated to three markets: the French perfumery industry, the Italian alcoholic drinks industry, and the German children dummy industry.

Iris pallida is a rustic, vigorous, and hardy species capable of successfully adapting to difficult cultivation environments, especially in terms of physical and chemical soil characteristics (Pignatti et al. 2000). Plants are frequently attacked by slugs, snails, and porcupines. Diseases affecting Iris include bacterial soft rot and leaf spot. One of the aims of this work is to improve the critical points that compromise the quality of the Iris rhizome through the design and creation of new biocidal and repellent products, which can be used for the microbiological safety of the bulb during the refinement and aging phase. Iris cultivation may have a biennial or triennial production cycle. In the first stages after cropping, the rhizomes are cleaned of roots and washed. After this stage, the producer can follow two different paths. To obtain black-type orris, the washed rhizomes were sliced and dried outside. To obtain white-type orris, rhizomes are peeled by hand and undergo a long process of 2–3 years of drying and aging. The specific hydrodistillation of dried and crushed iris rhizomes leads to an essential oil called Iris butter. One ton of Iris rhizome produces 2 kg of essential oil, making it a highly priced substance. As this essential oil almost exclusively contains irones and fatty acids with no smell (Garnero and Joulain 1981), its commercial value is directly determined by its iron concentration. Similarly, the value of Iris rhizomes is closely related to their iron content. Depending on the distillation process used, different orris fractions are obtained, used as base notes in fragrances by perfumers but most importantly as natural fixatives to enhance other aromas and as stabilizers in cosmetics (DeBaggio and Tucker 2009).

Orris root powder is also used for making gins and cordials as a very potent natural fixative for the other components (Tonutti and Liddle 2010) and in the baking, printing, and textile industries. Gas chromatography–mass spectrometry (GC-MS) analytical methods and innovative GCxGC-time-of-flight (TOF) and GC-vacuum ultraviolet (VUV) methods have been optimized for the analysis of aromatic metabolites in Iris flour and used to obtain an identity card of the aromatic profile of the Iris of Tuscan territory to monitor the quality of the product and enhance the biodiversity of Tuscany.

The roots and rhizomes of many Iris species are well known as precious sources of isoflavones. They have been used in traditional medicine to treat respiratory disorders and decrease smooth muscle activity. Recent studies have revealed potent anticholinesterase, antineoplastic, and anti-plasmodial activities of iris constituents (Kukula-Koch et al. 2015). Except for isoflavones, the main chemical components of Iris are xanthones, quinones, flavones, flavone C-glycosides, terpenes, and simple phenolics, with multiple biological activities. Numerous findings regarding their broad pharmacological implementation shed new light on the potential use of the rhizome and other Iris constituents; therefore, the aim of this work is also to characterize the non-aromatic component by high performance liquid chromatography–photodiode-array detection–mass spectrometry (HPLC-DAD-MS) analytical methods to enhance a possible innovative use in the cosmetic and liqueur sectors of both the flour and byproducts of Iris.

28.2 Material and Methods

28.2.1 Analysis of Volatile Compounds

28.2.1.1 SPME Conditions

The volatile compound (VOC) profile was determined by solid-phase microextraction (SPME). Five hundred milligrams of pulverized bulb were placed into a 20-mL screw cap vial fitted with polytetrafluoroethylene (PTFE)/silicone septa. VOCs were absorbed by exposing a 2-cm divinylbenzene/carboxen/polydimethylsiloxane SPME fibre (DVB/CAR/PDMS by Supelco) at 60 °C for 15 min into the vial headspace and then immediately desorbed at 280 °C in a gas chromatograph injection port.

28.2.1.2 GC-MS Analysis

VOCs were analysed by a 7890a GC system operating in splitless mode, separated by a DB InnoWAX column (0.4 μm dfx0.2 mm i.d., 50 m) and detected by a quadrupole mass spectrometer 5975c MSD (Agilent Technologies, Palo Alto, CA, USA) operating in EI mode at 70 eV. The initial oven temperature was set at 40 °C, held for 0.5 min, raised to 260 °C at 6 °C/min, and held at 260 °C for 1 min. For each chromatogram, the peaks were integrated using the total ion current (TIC) areas. The percentage distribution of VOCs was obtained by normalizing the area of the peaks to the total area. In the case of irons, a quantitative analysis was carried out using 6-point calibration curves constructed using methyl-α-ionone (α-IRONE) (range 10–100 ppm, 0.99 R^2).

28.2.1.3 GCxGC-TOF Analysis

GCxGC was performed by a flow modulation system consisting of an Agilent 7890B GC (Agilent Technologies, Palo Alto, CA, USA) with a capillary flow modulator device for 2D separation coupled with a time-of-flight mass spectrometer (TOF-DS; Markes International Ltd., Llantrisant, UK) as reported in Ieri et al. (2019).

28.2.1.4 GC-VUV Analysis

A GC SRA-Agilent 7890B connected to a VUV 101 detector (VUV Analytics) equipped with a 60 m HP-Innowax 0.25 mm i.d. × 0.5 μm d.f column was used. Conditions were reported in Ieri et al. 2019.

28.2.2 HPLC-DAD-MS Analysis

The analyses for the qualitative and quantitative evaluation of non-volatile compounds were obtained using an HP-1260 liquid chromatograph equipped with a DAD detector (Agilent-Technologies, Palo Alto, USA). The HPLC system was interfaced with an Agilent MS system equipped with an ESI source (Agilent Corp, Santa Clara, CA, USA). Analyses were acquired in full-scan mode, and the mass range was set to m/z 100–1500 in both positive and negative modes. Different columns and different analytical conditions were used to descend the treated matrix (arbutus, olive leaves, iris, and liqueurs).

28.3 Results and Discussions

To enhance the crop of Iris in the Tuscan territory as a resource for the local economy, a key aspect is to improve the critical points that compromise the quality of the Iris rhizome. Innovative natural products have been developed that can be used in the growth phase of the bulb for the reduction of microbial attacks or as repellents from porcupines, greedy eaters of iris bulbs. Solutions containing antioxidant and antimicrobial active ingredients, applicable on the bulb or by immersion or by direct nebulization during the drying phase, have been optimized. Standardized solutions containing active ingredients with high repellent activities are obtained by applying aqueous or steam extraction of plant species such as arbutus and olive leaves. The solutions were characterized by the optimization of a GC/MS method for the volatile compounds and by the optimization of HPLC/DAD/MS analytical methods for the nonaromatic component with antiradical and antioxidant activity. The aqueous extract of arbutus contained procyanidins, gallic acid, monogalloyl glucose, gallotannins (polygalloylated glucose), gallagic tannins, and flavonols. The olive leaf extract was obtained by aqueous extraction of cv leccino, frantoio, rossellino, and moraiolo leaves in a rapid pressure extractor. The product obtained was enriched in hydroxytyrosol (50% of the total content). An innovative drying technology customized for the iris bulb was also used to optimize the drying phase and to preserve the molecules of interest and the organoleptic characteristics.

The value of Iris rhizomes is closely related to their irone content; therefore, various analytical methods have been optimized to obtain an identity card of the aromatic profile of the Iris of the Tuscan territory and to monitor the quality of the product. In particular, the VOC profile was determined by chromatography coupled to mass spectrometry (GC-MS) with sampling from the headspace using the solid-phase microextraction (SPME) technique. An innovative analytical method that uses a new GC detector based on vacuum ultraviolet spectroscopy (VUV), which measures the full absorption of the scan in the range 125–240 nm, has also been optimized. The VUV detector showed the ability to discriminate between different isomers of iron and quantify them in this high-value matrix. GC-VUV completes MS spectrometry by overcoming its limitations and providing a secondary confirmation method (Ieri et al. 2019). For the optimization of GC-MS and innovative GCxGC-TOF and GC-VUV analytical methods, flours of rhizomes at different degrees of aging and/or drying and with or without cuticle were analysed. Flours with and without cuticles have different relative percentages of irones; in particular, in the extracts obtained from white flour, the main iron is cis-α-Irone, and in those obtained from brown flour, the main iron is cis-γ-Irone. These results were confirmed by all GC methods (Fig. 28.1). These results suggest that irones are present in the cuticle, particularly cis-γ-Irone. These findings were confirmed by GC-MS analysis and valorization of this waste from rhizome processing.

The characterization of the nonaromatic component with antiradical and antioxidant activity was performed by HPLC-DAD-MS analysis, not only in flours of rhizomes at different degrees of aging and/or drying and with or without cuticle but also in the byproduct cuticle. The analyses confirmed the presence of compounds belonging to various polyphenolic classes, in particular isoflavones, xanthones, including mangiferin and neomangiferin and hydroxycinnamic derivatives, with a total polyphenol composition of 14.1 ± 0.05 mg/g in the cuticle waste. The phases of maceration in alcoholic and hydroalcoholic solutions of the medium-sized bulbs and of the flour have been optimized for the prototyping of macerates (0.4–0.6 mg GAE/mL) that can be used in the food sector as bases for spirits or alcoholic

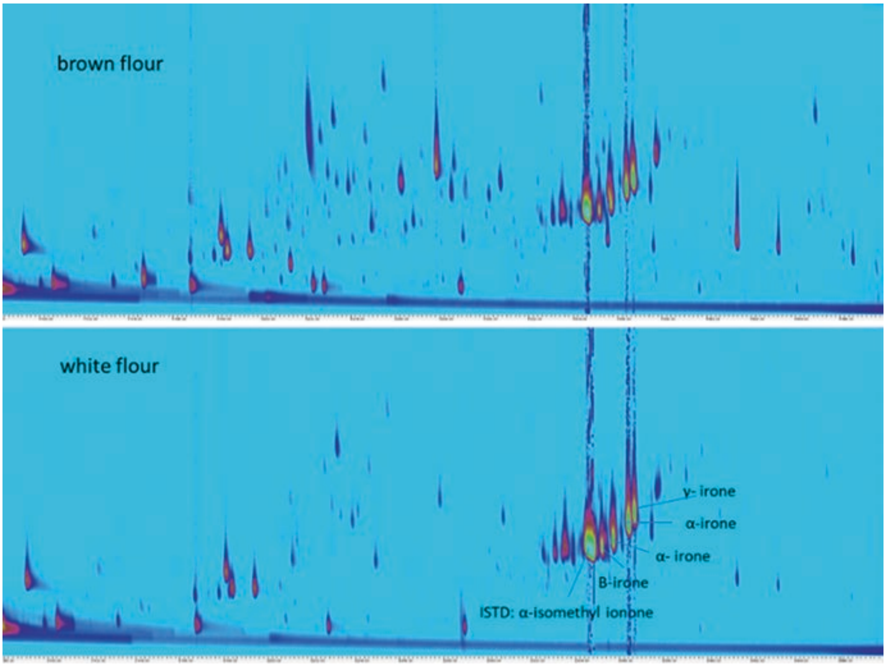

Fig. 28.1 GCxGC analysis of flours with and without cuticle

semifinished products, for food use in the bakery products sector (biscuits and cakes also from traditional recipes) or as a filling for creams and icings. The bulbs and iris flour were also extracted in a modulated steam current under vacuum to obtain suitably characterized fractions to be used for the formulation of cosmetic references. Through the innovative use in the cosmetic and food sector of iris flour and cuticle extracts, the aim is to valorize Iris with a line of food, cosmetic, and artisan products.

28.4 Conclusions and Future Perspectives

The increasing value of the traditional production of *Iris pallida* influences the territory not only for direct marketing reasons but also for the indirect benefits coming from its high aesthetic value for the landscape and therefore for tourism and for its role in the environmental preservation of the area. The creation of a line of food, cosmetic, and high added value products increases profitability and gives life to a model of territorial development. The goal is to create a territorial brand around Iris supported by a discipline of behaviours and good practices that are not only agricultural but also sociotouristic and environmentally friendly.

Acknowledgement This work was supported by GAL-START 2018 – sottomisura 16.2-Regione Toscana 2014-2020- IRIS DEL CHIANTI.

We thank Armando Miliazza and SRA Instruments S.p.A. for his help with the GC-VUV optimization.

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Chapter 29
Honey Production in Italy: Quality, Sustainability, and Innovation Strategies of Companies in the Abruzzo Region

Federica Murmura, Laura Bravi, Lolita Liberatore, and Nicola Casolani

Abstract In Italy, the beekeeping sector is extremely diversified and heterogeneous due to the production conditions, the seasonal production yield influenced by the weather, and the small economic dimension of the operators. The aim of the study is to explore the attention of small Italian honey production companies to the quality of the product and their relationship with markets and consumers, highlighting the main difficulties encountered, the innovations introduced, and the predisposition to preserve the environment. The research method adopted is a mixed method in which qualitative and quantitative data are included. The qualitative data are derived from the analysis of a multiple case study developed by interviewing the owners of six Abruzzo honey production companies. Respondents were also asked to fill out a small questionnaire to quantitatively assess some aspects detailed during the interview. The study shows that interviewed companies are microsized and family-run, and their target market is purely local and regional. They are oriented towards lower and qualitatively higher production with a higher price, covering a niche segment of the market. Companies are open to innovation, and they have had to manage significant changes in the sector over the years. Attention to environmental issues is a fundamental aspect.

Keywords Honey production · Food quality · Beekeeping sector · Case study analysis · Italian companies

F. Murmura (✉) · L. Bravi
Department of Economics, Society, Politics, University of Urbino Carlo Bo, Urbino, Italy
e-mail: federica.murmura@uniurb.it; laura.bravi@uniurb.it

L. Liberatore · N. Casolani
Department of Economic studies, University G. D'Annunzio of Chieti-Pescara, Pescara, Italy
e-mail: l.liberatore@unich.it; nicola.casolani@unich.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_29

29.1 Introduction

Beekeeping is of considerable importance as an economic activity for the environmental value of bees with their work and for obtaining natural products for humans thanks to the management of apiaries. The European Commission holds beekeeping responsible for 80% of the pollination of European agricultural products (Majewski 2017). Honey acquires importance not only as a food but also as an economic and environmental indicator since the presence of bees in an environment reveals the existence of minimum conditions for the survival of humans and many other biological forms (Salkova and Panayotova-Pencheva 2016).

In recent decades, beekeepers have had to deal with many health emergencies that have significantly affected their activity and results (Andrews 2019). To date, consumers are looking for satisfying food solutions from a sensorial and functional point of view, especially in terms of attention to health, environmental, and ethical issues (Ghvanidze et al. 2017). All this has a strong impact on the purchasing choices of individuals, who become increasingly selective, demanding, and eager to receive information about the products purchased. Regarding quality, however, there has been a progressive change that has incorporated intangible components into the product connected to the production method, the geographical origin, the ethical values, and the organization of the supply chain as a whole, and beekeeping is one of the key sectors of this movement (Dowd and Burke 2013). Furthermore, honey guarantees food safety thanks to strong protection and constant control along the entire supply chain. The production differs for the richness of precious and typical floral varieties of the territory and for the high quality, so much so that the strategies for enhancing Italian honeys are based on these two levers, appreciated by connoisseurs, and essential to beat the low-cost international competition. The crucial aspect, on the other hand, is that of the biological balance of the natural environment, which is constantly put to the test (Scepankova et al. 2021). In Italy, the number of beekeepers is constantly growing; in 2020, there were 63.408 beekeepers, 52% more than in 2016. The apiaries present in the national territory in 2020 were 153.309 (+ 80% compared to 2016), of which 57% had a commercial destination (ISMEA 2021). Hence, it is important to study this category of operators, evaluating their strategies and their difficulties so that the quality and traditionality of the honey produced by small Italian producers are not lost, and it is possible to develop aid and enhancement actions for this category. That is why the aim of the research is to explore the attention of six small Italian honey production companies to the quality of the product, their relationship with the reference markets and with the consumer, highlighting the main difficulties encountered, the innovations introduced, and the predisposition to preserve the environment closely linked to the product and the bees.

29.2 Material and Methods

The research method for this study is a mixed method based on an embedded design procedure; specifically, qualitative and quantitative data are included to answer research questions (Yin 2017). Qualitative data derived from multiple case studies have been included within a quantitative methodology, developing an experimental design as suggested by Clark et al. (2008). The embedded design permits the mixing of different datasets at the design level, developing a phenomenology design (Creswell and Creswell 2017). The survey conducted was aimed at investigating the work and future projects of six small honey companies located in the Marsicano territory, near the Abruzzo National Park in Italy, which produce with nonindustrial tools and methods. To obtain a standardized view of each company to be able to compare the acquired data during the qualitative interviews that lasted 1 hour, a semistructured questionnaire was proposed to the companies' owners. The interviews and subsequent questionnaires were submitted to the companies in the winter period (December 2021–January 2022), and the main topics of investigation were divided into three sections: general information on the company and economic-strategic and socioenvironmental analysis.

29.3 Results and Discussion

29.3.1 Companies' Profiles

The six companies examined are in the central part of Italy, exactly in the Abruzzo region, in the province of l'Aquila (see Table 29.1). Only two companies have a shop with a sales counter. The main reason for this choice for company D is the suggestive panorama of the place where it is located, while for company B, it is a logistical choice since it already has a sales point for the trade of artisanal jams, and it wanted to enrich the range of its products with the addition of honey. The market to which the six companies refer is purely local and regional; this is because the companies are oriented to the production of small quantities of honey but with higher quality than the market offer; therefore, the price is relatively higher, and the average customer is not willing to spend. The main customers of the companies are direct consumers; in the specific case of company A, there is also a tavern that uses this beekeeper's honey for bread making. Furthermore, all companies carry out conventional production. Having an organic certification would give an additional value to the product and would guarantee better results in terms of perception of the product by the consumer; however, some erroneous beliefs must be dispelled. In fact, it should be remembered that *"there is no 100% organic honey precisely because it is impossible to know where the bee will land."* The companies have declared that their production processes, means, and methods follow the standard of organic production, but they are not certified due to an aspect related to the production process,

Table 29.1 General information on the companies interviewed

	Company A	Company B	Company C	Company D	Company E	Company F
Dimension	<10 emp.	<10 emp.	<10 emp.	<10 emp.	<10 emp.	<10 emp.
Company structure	Warehouse beehives	Shop warehouse beehives	Warehouse beehives	Shop warehouse beehives	Warehouse beehives	Warehouse beehives
Reference market	Local Regional	Local national	Local national	Local Regional	Local Regional national	Local Regional
Foundation year	2020	2010	2014	1997	2017	1985
Working period	Spring summer autumn	Spring summer	Summer	Spring summer autumn winter	Spring summer autumn	Spring summer
Customers	Final customers Restaurants	Final customers	Final customers	Final customers Restaurants	Final customers	Final customers Restaurants

the wax present in the frames. The wax sheets produced by bees must be 100% natural. As stated by the owner of company E, *"the problem encountered is the high purchase cost of the wax sheets contained in the frames which would increase the price of the final product, which is already relatively high for the market. Calculating that each hive contains approximately 1 kg of wax sheets in total and, to produce that kg, bees need approximately 10 kg of honey, on balance the organic certification would not be an excellent investment."* The companies interviewed would be very interested to switch to totally organic certified production in the future, but it is a complex process that takes years, as it would be necessary to modify all the frames by inserting organic wax sheets. Doing so would reduce the adaptation time of the bees in the hive, risk hindering the brooding processes, thus exposing the family to serious survival risks.

Regarding the place of origin, it must be said that only company D can affix the "Parco Nazionale d'Abruzzo" trademark on its products since it is based in the protected area and complies with the requirements of the trademark. The quality mark has the ambitious goal of representing a powerful tool that offers advantages on the market and allows us to evoke certain characteristics only by reading it. It is a collective trademark that can be used by different companies that share the geographical location and the formal and informal rules that identify its specificity and uniqueness and create synergies between companies. The market channel of companies A, D, and E includes restaurants.

29.3.2 Economic-Strategic Analysis

The second part of the questionnaire analyses the economic-strategic aspects of the market. Most beekeepers declared to be in favour of innovation except the beekeeper of company D, who declared *"this is a historical company and deeply linked to traditions, we have adopted the same production techniques since 1852 and we would like them to remain the same, even a little to tell our more than 100-year-old story."*

Moving on to the analysis of production waste, it emerged that 50% of the companies use them exclusively as compost, and the others instead prefer to use them to create a part of waxy sheets. Packaging has been defined as fundamental by every beekeeper because it is able to personalize honey to the point of differentiating it from competitors. Each company has developed its own label. Subsequently, companies were asked to rate the difficulties encountered in marketing their honey using a 5-point Likert scale (1 = not at all; 5 = a lot) (Fig. 29.1). The competition is not relevant because, working with a niche product, each company has its own characterization. The regulations have relatively little influence because by not exercising quantitatively high production, companies do not have to submit to rigid laws and regulations. Quality is the mission of all the sample companies, the factor that has the greatest influence in this market together with the selling price. These two aspects act as a tip of the balance in consumers' choices. The COVID-19 period had a great influence only on company D; since it was in Abruzzo National Park, it has greatly reduced its sales due to the lack of an annual tourism surge. The other companies, on the other hand, have organized themselves well with online shipments, personally taking care of the honey delivery service to the customer.

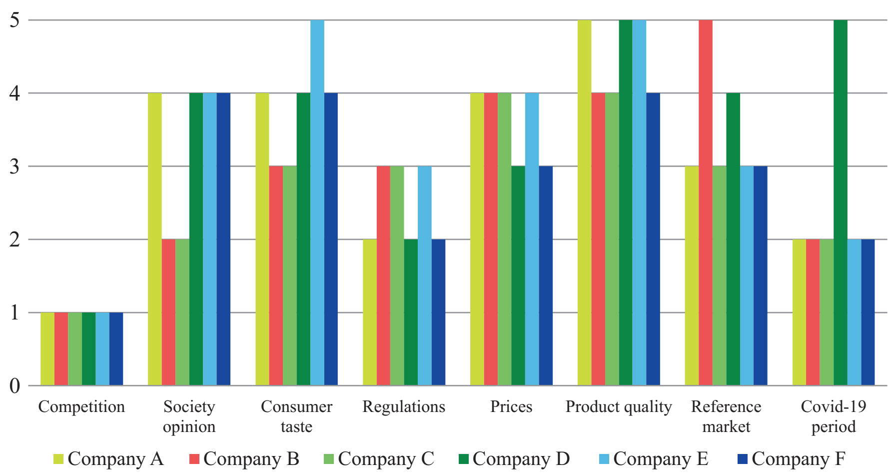

Fig. 29.1 Factors of difficulty in selling honey product

29.3.3 Socioenvironmental Analysis

Regarding the socioenvironmental analysis, the interviews showed the following:

- The communication of their own philosophy to the customer for companies A, D, and E turned out to be of considerable importance. Beekeepers care so much about their product and the way they approach bees that they organize meetings with customers in which they explain their work and participate in regional meetings on topics such as the environment, tradition, and preservation of animal species.
- Attention to environmental issues is a relevant aspect for all companies since the sector in which they trade and survive depends almost in its entirety on the environment and on the bond that the bee has with it. All beekeepers have admitted that the conditions of their production have drastically worsened over the years due to climate change, pollution, and the intensive production of honey by large producers. Mainly beekeepers pay attention to maintaining biodiversity in the natural environment in which they work, reducing waste generation and aiming for the maximum possible circularity in their activities.
- Engagement initiatives are welcome for 50% of companies. The beekeepers of companies A, D, and E are willing to meet people and make their complex little world known; the other three tend to be more reserved and would like that their methods of production are kept and known only in their family business.
- Ethical business gratification is relevant to all businesses. The beekeeper is an ancient profession linked to the environment and therefore rich in ethical and moral values.

29.4 Conclusions and Future Perspectives

The production of honey assumes a qualitative value according to the characteristics of the production area, emphasizing the role of territory in organoleptic and sociocultural issues. The survey provided interesting insights that aim to understand the link between the small local producer and the purchasing behaviour of the customer interested in the consumption of artisanal honey, even if the results obtained cannot be generalized since the sample analysed is small. The extreme territorial fragmentation of beekeepers is generally considered a weakness, but at the same time, it constitutes a strength since the sector uses experiential marketing to expand its clientele. Moreover, beekeeping activity develops in a complementary way to other agricultural activities; in many cases, it represents an integration of agricultural income and not the main activity. This implies greater attention to the coexistence of aspects of environmental protection with cultivation activity.

Referring to the results of the interviews conducted, it emerges that local production is the factor that most influences the decision-making process for purchasing. The study also confirmed that the concept of quality has evolved to include extrinsic attributes that consider, first, the social and environmental impacts of the production process of the products purchased. All this information, together with the preference for localism and direct contact with the seller, contributes to defining effective future marketing strategies for the sector. Implementing the communication process with the average consumer, who, at least for now, is struggling to understand its full value. It would be important for future research to widen the territory to the national context, to understand if the opinion of Abruzzo beekeepers is confirmed at an Italian level, and to compare the Italian situation with the European one to define a European regulation that would help the beekeeping sector.

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Chapter 30
Determination of Bioactive Compounds in Italian Honeydew Honeys

Raffaella Preti and Anna Maria Tarola

Abstract Honey is a natural sweetener produced by bees (*Apis mellifera*) from the nectar of flowers of blossoming plants (blossom honey) or from the secretions of plants or the excretions on plants of plant-sucking insects mostly from the family *Aphididae* (honeydew honey). Characterized by dark colour and by a slightly bitter taste, honeydew honeys show antibacterial and antioxidant properties and values of several physicochemical variables higher than in blossom honeys. Recently, interest in this rare type of honey has increased due to its peculiar sensorial attributes and therapeutic properties. Research reveals that the medicinal properties of honey are related to the high presence of polyphenols, such as flavonoids and phenolic acids, to promote its wide application in the prevention and treatment of many diseases, as well as its use in cosmetology. The aim of this chapter is to determine the antioxidant capacity and phenolic compound content by spectrophotometric assays and the profile of 15 polyphenols by an optimized High Performance Liquid Chromatography with Diode Array Detector (HPLC/DAD) method in commercial samples of Italian honeydew honey. Quality physicochemical parameters were also examined to evaluate the overall quality of the samples and the correspondence to legal requirements.

Keywords Honeydew honey · Antioxidant capacity · Polyphenols · Nutraceutical food

30.1 Introduction

One of the peculiar characteristics of honeydew honey is that it is obtained, in fact, from honeydew and not from nectar. Honeydew is a sugary and sticky substance that is produced by some plant-sucking insects (Hemiptera) from the sap of various

R. Preti (✉) · A. M. Tarola
Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: raffaella.preti@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_30

types of plants. They are, in particular, those of the genera *Cinara, Mindarus, Physokermes, Metcalfe*, and some of the *Coccidae* family. Generally, this is used by bees in periods or in places where the production of nectars is scarce. Honeydew can come from conifers, i.e. fir, pine, and spruce, and from deciduous trees, such as oak, chestnut, birch, willow, and linden (Seraglio et al. 2019).

As reported in the definition of the law (Directive 2014/63/EU), honeydew honey is to all intents and purposes to be considered honey and as such can be indicated on the label even without specifying its origin (or honeydew); moreover, the Italian Ministry of Agricultural, Food and Forestry Policies (MIPAAF) circular no. 03 of 12/07/2007 has made legal the equation forest honey = honeydew honey; therefore, it is possible to define honeydew honey as forest honey. For example, prized black forest honey is a honeydew honey.

Honeydew honey is typical of some mountainous or wooded areas of Italy both in the Alps and in part of the Apennines, where many plants attacked by hemipters (especially conifers and oaks) grow spontaneously. In the rest of Europe, honeydew honey is produced in mountain ranges with similar vegetation (for example, in the Vosges and Jura in France), while moving further north and towards the continental climates of central Europe, this production is always common. Greece, Turkey, some areas of the Balkan Peninsula, the Caucasus, and the Urals are also honeydew-producing countries. In Italy, most of the honeydew honey produced currently derives from the honeydew foraged by bees in hilly environments during the invasions of *Metcalfa puinosa*, which not only produces large quantities of honeydew but also damages the vegetation (Moir et al. 2018).

Honeydew honey has a very dark colour and a particularly dense consistency. It tastes less sweet than honey produced from nectars, with a bitter aftertaste and a hint of bark and earth. Honeydew honey has a lower glycaemic index than other types of honey and most sweeteners, which means that it raises blood sugar at a slower rate, which is a benefit for people with impaired glucose tolerance. It has antibacterial and soothing qualities; it is an excellent natural remedy to calm coughs and soothe other airway disorders. It boasts a nutritional power superior to nectar honey, thanks also to the higher content of mineral salts and trace elements, including iron, manganese, potassium, and magnesium. The presence of oligosaccharides helps the physiological functioning of the gastrointestinal system. It is rich in polyphenols and antioxidant substances that help the body defend itself from oxidative stress at the basis of cellular aging (Pita-Calvo and Vazquez 2018).

Antibacterial properties have attracted particular attention, and recent findings have demonstrated how polyphenolic compounds and their interaction with H_2O_2 are the key factors responsible for the antibacterial activity of honeydew honey (Bucekova et al. 2018).

Compared to blossom honeys, honeydew honeys present higher values of bioactive compounds such as phenolics, with a consequent higher antioxidant activity, which confers this product the properties of functional food. It also presents higher electrical conductivity (EC), pH, acidity and ash content, darker colour, higher oligosaccharide content, and lower content of monosaccharides than blossom honeys (Vasić et al. 2019; Seraglio et al. 2019; Preti and Tarola 2022).

The most abundant polyphenols determined in honeydew honey are ferulic acid, quercetin, kaempferol, and, in particular, p-coumaric acid, with quercetin, naringenin, caffeoylquinic acid, hydroxyphenylacetic acid, apigenin, and genistein, which have been identified as potential markers of the botanical origin of honeydew honey (Recklies et al. 2021). In fact, the profile and content of polyphenols can vary considerably in relation to the botanical and geographical origin of honey (Preti and Tarola 2021).

This chapter aims to characterize the profile and content of 15 polyphenols in samples of Italian honeydew honey and to determine their antioxidant capacity and total phenolic content. Quality parameters were also determined to verify the overall quality of the samples and their correlation to the bioactive compound data.

30.2 Material and Methods

30.2.1 Samples

Ten samples of honeydew honey from different Italian beekeepers were purchased in local markets in Rome in 2021. Five samples were harvested in 2019 and five in 2020 and originated from different geographical regions: Friuli Venezia Giulia, Trentino Alto Adige, Lombardia, and Abruzzo. Samples were stored at room temperature in a dark place until analysis.

30.2.2 Chemicals and Materials

Acetonitrile, methanol (HPLC grade), sodium carbonate, hydrochloric acid, and Folin–Ciocalteu reagent were purchased from Merck (Darmstadt, Germany). 2,2-Azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt (ABTS), potassium persulphate, 2,2-diphenyl-1-picrylhydrazyl (DPPH), cis, trans-abscisic acid standard, flavonoid standards rutin, luteolin, quercetin, apigenin, kaempferol, naringenin, hesperetin and chrysin, phenolic acid standards gallic acid, ellagic acid, syringic acid, caffeic acid, chlorogenic acid, and coumaric acid were all purchased from Sigma–Aldrich (Steinheim, Germany).

30.2.3 Physicochemical Parameters

The pH, total acidities, and hydroxymethylfurfural (HMF) were determined in the honey samples according to the International Honey Commission (IHC) (2009). The colour intensity, defined as the net absorbance at 450 nm and 720 nm, was determined as described by Preti and Tarola (2022). Each chemical parameter was measured in triplicate. The obtained data were expressed as the mean values ± standard deviations.

30.2.4 Determination of Antioxidant Capacity, Total Phenolic Content, and Individual Polyphenols

The determination of all parameters was carried out according to the previously optimized methods described in Preti and Tarola (2022), achieving the same method performances. Each chemical parameter was measured in triplicate. The obtained data were expressed as the mean values ± standard deviations.

30.3 Results and Discussion

The parameters determined to assess the overall quality of the honeydew honeys studied are summarized in Table 30.1. With respect to the legal limits set by EU Directive 63/2014 of 50 meq/kg for free acidity and 40 mg/kg for HMF, no sample exceeded these values, confirming the good conservation status, with no signs of poor storage or overheating. Honeydew honeys usually show a higher mean pH value and acidity than blossom honeys (Pita-Calvo and Vazquez 2018), and the sample objects of the study were in the range of 4.08–4.55, confirming this evidence. The health properties of honeydew honey are linked to its high antioxidant capacity. The results of the present study (Table 30.1) are consistent with those previously published (Preti and Tarola 2022) that compare Italian honeydew honey to other monofloral honeys.

Honeydew honey resulted in the highest antioxidant activity in the DPPH assay together with the other dark honey studied, strawberry tree, chestnut, and eucalyptus honey, and the second most antioxidant, after strawberry tree honey, for the

Table 30.1 Physicochemical parameters of honeydew honey samples analysed (n = 10)

Parameter	Mean	SD	Min	Max
Free acidity (meq/kg)	32.82	4.31	27.64	39.22
Lactone (meq/kg)	9.86	2.01	6.31	13.64
Total acidity (meq/kg)	42.68	4.39	36.46	47.79
pH	4.36	0.13	4.08	4.55
HMF (mg/kg)	14.32	4.91	9.07	21.34
Colour intensity (mAU)	400.79	31.68	327.67	437.26
Antioxidant capacity by DPPH essay (% of inhibition)	71.96	5.29	64.26	80.24
Antioxidant capacity by ABTS essay (% of inhibition)	46.54	4.45	39.98	52.58
Total phenolic content mg GAE/100 g	84.31	9.33	70.39	96.05

ABTS and Total Phenolic Content (TPC) assays. Good correlations between the antioxidant capacity assays with DPPH and ABTS and TPC (r = 0.89 and 0.95, respectively) and with the colour intensity values (r = 0.84 vs TPC and 0.88 vs ABTS) confirmed the well-known assumption that dark honeys have higher bioactive compound levels (Karabagias et al. 2016).

The analysis of individual phenolic compounds was conducted with an optimized SPE extraction and purification method followed by HPLC/DAD analytical determination.

The method was demonstrated to be reliable and efficient for the identification and quantification of the phenolic compounds of interest because no interferent compounds were coeluted (Fig. 30.1) and the sensitivity was high due to the quantification at wavelengths specific for each bioactive compound.

All the studied phenolic compounds were present in all the honeydew samples, except for ellagic acid, which was determined in only three samples, and hesperetin, which was never determined. The results of the individual phenolic compounds determined are displayed in Table 30.2.

The phenolic acid most present was chlorogenic acid, followed by caffeic and syringic acid. Regarding flavonoids, the rank was quercetin > chrysin > kaempferol > apigenin > naringenin > rutin > luteolin. The results are consistent with those reported by other authors, indicating large variability in the phenolic content of honeydew honey (Karabagias et al. 2016; Cheung et al. 2019; Seraglio et al. 2019). The content of phenolics in honeydew honey varies in relation to several factors, such as geographical origin and botanical origin. The samples in the present study were all commercial samples with no indication of origin; in fact, from the data in Table 30.2, great variability among the phenolic contents in the ten samples can be observed. A common trend is the high concentration of coumaric acid, chrysin, and kaempferol, which in a previous study successfully discriminated honeydew honeys from samples of different floral origins (Preti and Tarola 2022) and therefore can be considered a possible marker of this type of honey.

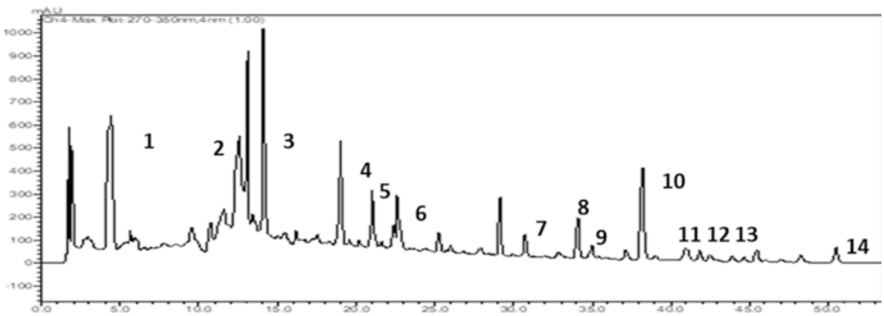

Fig. 30.1 HPLC chromatograms of a honeydew honey sample: 1 gallic acid, 2 caffeic acid, 3 chlorogenic acid, 4 syringic acid, 5 coumaric acid, 6 ellagic acid, 7 rutin, 8 abscisic acid, 9 quercetin, 10 luteolin, 11 naringenin, 12 kaempferol, 13 apigenin, and 14 chrysin

Table 30.2 Polyphenol content in Italian honeydew honey ($n = 10$)

Phenolic compound (mg/kg)	Mean	SD	Min	Max
Gallic acid	5.07	0.82	4.07	6.09
Caffeic acid	6.36	0.54	5.42	7.03
Chlorogenic acid	9.49	1.91	6.94	12.72
Syringic acid	6.27	1.21	4.52	8.06
Coumaric acid	6.03	1.29	4.07	8.21
Ellagic acid	0.24	0.37	nd	0.82
Rutin	0.76	0.22	0.44	1.06
Abscisic acid	2.39	0.61	1.68	3.55
Quercetin	4.19	1.17	2.21	5.82
Luteolin	0.62	0.23	0.28	0.99
Naringenin	0.95	0.41	0.47	1.91
Hesperetin	nd	nd	nd	nd
Kaempferol	2.12	1.20	0.94	4.18
Apigenin	1.29	0.45	0.83	1.94
Chrysin	3.58	0.81	2.64	5.10
TOTAL	49.38	4.47	44.91	58.78

30.4 Conclusions

Honeydew honey is an appreciated type of honey due to its peculiar taste, flavour, and beneficial properties on human health. This study on Italian honeydew honey samples from various geographical and botanical origins confirms its richness in bioactive compounds, determined with a reliable and sensitive analytical method. The data of the antioxidant capacity and total phenolic content assessed by in vitro assays demonstrate how this type of honey can be considered one of the most promising contributors to a diet with an optimum redox balance, especially in the case of diseases and during strong physical exercise. In addition to their important role in human health, the profile and content of polyphenols characterized in this work can be used as a possible marker for honeydew authentication.

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Chapter 31
Comparison of the Carotenoid Content in Durum Wheat Pasta and Whole Wheat Pasta by Multivariate Analysis

Vanessa Giannetti, Maurizio Boccacci Mariani, and Greta Livi

Abstract Whole products have achieved remarkable success over the years due to the growing attention by consumers for the health effects of these foods. In the present study, a multivariate model was developed to characterize durum wheat pasta and whole wheat pasta based on the carotenoid content and to assess the possible influence of the drying process used in pasta manufacturing on the total carotenoid amount. Ninety-six pasta samples were analysed by HPLC-UV/Vis following an accelerated solvent extraction phase (accelerated solvent extraction, ASE) previously optimized using an experimental design approach (central composite design, CCD). A partial least squares-discriminant analysis (PLS-DA) method was used for data processing. The resulting classification model showed excellent results (100% correct classification for both pasta categories) discriminating the samples based on the semolina used for production (refined durum wheat vs whole wheat). The findings also highlighted that lutein was present in much larger amounts compared to the other bioactive components in all investigated samples, suggesting that it might be used as a product marker of total carotenoids in pasta.

Keywords Whole wheat pasta · Carotenoids · Lutein · Central composite design · PLS-DA

31.1 Introduction

According to the International Pasta Organization, Italy confirmed its leadership in the global market in 2021, accounting for approximately a quarter of the entire world's production and 67% of that of Europe. Pasta was also the most exported

V. Giannetti (✉) · M. Boccacci Mariani · G. Livi
Faculty of Economics, Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: vanessa.giannetti@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_31

product during the COVID-19 pandemic in 2020, growing by 16% in the countertrend with Made in Italy overall. In recent years, due to the increasing demand by consumers for foods that contribute to wellness and health via a balanced nutritional composition, whole wheat pasta has gained success on the market. Wholegrain products, in addition to having a lower glycaemic index than their non-wholegrain counterparts, contribute to reducing cardiovascular disease risk, type 2 diabetes (Abdullah et al. 2021), and some types of cancer (Jacobs et al. 1995), as evidenced by numerous scientific studies (Bouchard et al. 2022). According to the Healthgrain Consortium of the European Union, "*whole grains shall consist of the intact, ground, cracked or flaked kernel after the removal of inedible parts such as the hull and husk. The principal anatomical components, the starchy endosperm, germ and bran are present in the same relative proportions as they exist in the intact kernel*." Other definitions were recommended by Regulation (EU) No. 1308/2013; EFSA Panel on Dietetic Products, Nutrition, and Allergies (2010); FDA Consumer Health Information; and various national agencies. Although wholegrain pasta seems to show particular interest for the modern consumer due to its content in fibre and bioactive components with health benefits effects, the different texture, aroma, and colour compared to refined pasta still limit its widespread acceptance. In this context, the current challenge for producers is to manufacture wholegrain products with organoleptic characteristics most acceptable to customers, since their market penetration for nutritional contribution is already widely visible (Liu 2007).

In whole wheat pasta, the bran and germ used for its production are high in fibre, minerals, vitamins, and antioxidant substances such as carotenoids, flavonoids, phenols, and tocols, which have a positive impact on several biological activities (Gardner 1988; Giacco et al. 2016). Among the different classes of bioactive components in pasta, this study focused on carotenoid determination. Carotenoids are yellow–orange pigments classified into two groups (depending on the presence or absence of oxygen in their molecular structure): xanthophylls such as lutein and carotenes (with provitamin A activity) such as beta-carotene. In durum wheat, lutein accounts for 86–94% of the total carotenoids (Panfili et al. 2004; Fratianni et al. 2005).

The carotenoid class continues to receive scientific interest, not only because it contributes to the brilliant yellow colour of pasta (e.g. lutein can be used as an indicator of the quality colour), an aspect widely appreciated by consumers but also because it is an important source of vitamin A. This aspect is particularly significant since vitamin A insufficiency is one of the leading causes of death among children in third-world areas (WHO 2009). In addition, their antioxidant capacity is the most relevant property in terms of human health (Cândido et al. 2022).

Due to their low stability, carotenoids are particularly susceptible to oxidation reactions; however, the presence of proteins in the food matrix increases their stability. This is also true for thermal degradation, as these molecules can undergo degradation to relatively low temperatures (40–50 °C) if isolated (Ornelas-Paz and Yahia 2010). Two competing effects can occur in cereal-based product manufacturing: on the one hand, the mixing phase can lead to the breakdown of the protein–carotenoid complexes, increasing their bioavailability; on the other hand, the drying process temperatures can lead to a decrease in carotenoid levels due to their thermolability. Therefore, in pasta produced with low temperature-long time (LT-Lt) methods, it is possible to expect a decrease in the carotenoid content less than those subjected to the high temperature/very high temperature-short time (HT/VHT-St) methods (more drastic temperature conditions). During pasta manufacturing, physical processes can also affect the total content of carotenoids in the finished product (Behsnilian et al. 2009).

In this study, a multivariate classification model was developed to characterize durum wheat pasta and whole durum wheat pasta based on carotenoid profiles. Particular attention was given to lutein to investigate its potential as a product marker. One further statistical model to assess the possible influence of the temperature used in the pasta drying process on the total carotenoid content was also constructed.

31.2 Analytical Procedure and Statistical Analysis

A set of 96 short pasta samples (64 durum wheat pasta and 32 whole wheat pasta) was analysed. It is well known that the different varieties of wheat (genotype) and harvest years (climate conditions) affect the carotenoid content of the final product; however, in this preliminary research phase, all the pasta samples were collected considering only the package information relating to the whole wheat semolina or refined.

An accelerated solvent extraction (ASE) procedure for carotenoid extraction from the samples was developed. The ASE parameters were optimized using an experimental design, and the optimal conditions obtained were used for the analysis. Five grams of pasta samples were ground and extracted under the following conditions: three static cycles of 6 min each, a temperature of 100 °C, and an extraction mixture of ethanol/acetone/hexane (27.6:22.4:50) $_{v/v/v}$. The extraction pressure was kept constant at 1500 psi, with a flush volume of 60%. A rotary evaporation system kept at 40 °C was employed for extract evaporation. Before HPLC-UV/Vis (high performance liquid chromatography/ultraviolet-visible) analysis, the extracts were dissolved in 1 mL of ethanol. A Kinetex® C18 LC column (5 μm 250 × 4.6 mm ID) maintained at 25 °C was used for chromatographic separation. The mobile phase was a binary solvent system consisting of phase A water/acetonitrile (90:10) $_{v/v}$ and phase B 100% acetonitrile, both containing 0.1% formic acid. The elution gradient was programmed as follows: 2 min at 25% B, 2–12 min at 100% B, 12–22 min at 100% B, and 22–30 min at 25% B. The flow rate was 1 mL/min, and the wavelength was set at 450 nm. Data were collected using the Chromeleon 7 software. To optimize the main ASE parameters used for carotenoid extraction from pasta samples, an experimental design was performed. This statistical approach enables the planning of the minimum number of experiments to be performed, resulting in increased cost-effectiveness of the analysis and lower consumption of solvents. Considering that there might be a nonlinear relationship between the values of the three factors and the response to be optimized, a central composite design (CCD) was used. The discriminant classification method partial least squares-discriminant analysis (PLS-DA) was used for data processing with the goal of characterizing the two pasta typologies (durum wheat pasta and whole wheat pasta) in relation to carotenoid content.

31.3 Results and Discussions

In this study, a three-factor face-centred central composite design (CCD) was performed to optimize the principal ASE parameters: extraction temperature, time of each static cycle, and volume ratio of extraction solvents. The limits of the experimental domain were identified with the following values: 40 and 100 °C for the temperature, 2 and 6 min for static time, and 25:25:50 $_{v/v/v}$ and 33:17:50 $_{v/v/v}$ for the mixture of ethanol/acetone/hexane. Based on these conditions, 15 experiments were required overall from the experimental design. Each experiment was carried out in duplicate to evaluate the accuracy of the measurements and was randomly performed to avoid spurious correlations. The chromatographic data were then imported into MATLAB, pretreated using the iCofish algorithm to eliminate slight peak misalignment, and statistically processed. Two different approaches were performed to define the responses to be optimized: a targeted approach in which the peak areas of lutein (the compound of interest) were assessed and an untargeted approach in which the whole chromatographic profile was considered.

Multiple linear regression was used for the targeted strategy, which showed the best response (highest lutein peak area) for $T = 100$ °C, static time of 6 min, and intermediate ratio for the extraction solvent combination (27.6% ethanol, 22.4% acetone, and 50% hexane). For the untargeted approach, required to evaluate the influence of the various parameters on the total recovery of the compounds of interest, analysis of the main components (principal component analysis, PCA) was performed. The obtained model confirmed that the optimal conditions with this strategy match those obtained with the targeted approach. The 96 samples of pasta were analysed once the conditions that maximized the desired result, i.e. optimal conditions for the extraction of lutein and total carotenoids, were obtained.

For data processing, the PLS-DA method was used to highlight possible differences in terms of carotenoid content between samples of durum wheat pasta and samples of whole wheat pasta. Before the classification model construction, the data were processed with the iCofish algorithm to reduce peak misalignment.

The first classification was focused on the type of durum wheat semolina used in pasta manufacturing (refined and whole wheat). Due to the different number of analysed samples for the two pasta categories (64 conventional and 32 whole wheat), the classification percentage error was previously studied. Despite the disparity in the number of samples between the two classes, the average between the errors made for both classes and the total classification error was almost coincident. The minimum relative error, corresponding to ten latent variables, was 1%; thus, it is reasonable to assume that the two classes are predicted in a comparable way. This preliminary cross-validation output revealed the possibility of carrying out a classification. The classification model was then built and validated with an external set of samples using the Duplex algorithm. The training set used to develop the model was constructed with 60 samples (40 conventional and 20 whole wheat) and the test set (i.e. the validation set with which the predictive power of the model is tested) with 36 samples (24 conventional and 12 whole wheat). The classification error in cross-validation on the training set model with ten latent variables was 1.7%. The model developed using the training set was applied to the missing data, i.e. those in the test set. It was thus feasible to assess its prediction capacity, which was shown to be 100% correct classification for both types of samples, i.e. all traditional pasta samples are included in class 1, and all whole wheat pasta samples are included in class 2.

The second classification, on the other hand, was designed to investigate the temperature (low temperature, LT and high temperature, HT) effect of the drying process on the overall carotenoid content. According to the pack label, 26 of the 96 samples analysed were LT-Lt (class 1) and 70 were HT-St (class 2). The duplex algorithm is also used in this case, including 66 samples in the training set (16 LT-Lt and 50 HT-St) and 30 in the test set (10 LT-Lt and 20 HT-St). Unlike the first classification, this PLS-DA model with eight latent variables (minimal classification error) does not provide excellent results, since the sensitivity for class 1 is 50% and for class 2 is 70% (63.3% accuracy). Nevertheless, a preliminary data analysis suggests that these values may be influenced by the fact that the sample set indiscriminately includes both refined and whole wheat pasta. For this reason, the same classification was performed using only the durum wheat pasta samples to avoid any contributing effects resulting from the different treatments of durum wheat, but the sensitivity of the model stayed at 50% for class 1 and 73% for class 2. However, a more in-depth assessment reveals that the findings of carotenoid chromatographic analysis do not lead to the correct models for this classification for more than one reason. On the one hand, the drying process may have no effect on the carotenoid content in pasta, or the samples analysed are insufficient or unrepresentative of the context in concern. As already reported in the Introduction section, according to several studies, rising temperatures cause the destruction of carotenoids due to their low thermal resistance on the one hand and the release of these substances on the other due to the breakdown of connections between carotenoids and other macronutrients. As a result, it could be reasonable that separation based on carotenoids cannot be performed due to the series of "contrasting" reactions that occur in the matrix during the whole manufacturing process.

Although there are several studies in the literature on the analysis of carotenoids in pasta (Oduro-Obeng et al. 2022; Laus et al. 2017), none have used ASE, a reproducible and automated extraction system with high yields, short extraction times, and low solvent consumption. The optimized procedure in this study could be a useful tool for determining carotenoid content and for providing added value to durum wheat pasta.

31.4 Conclusions and Future Perspectives

The classification based on refined and whole wheat semolina obtained from the 96 pasta samples investigated produced excellent results with a capacity prediction of the model equal to 100%. In consideration of the numerous scientific studies that have amply demonstrated the beneficial effects of carotenoids on human health, it is reasonable to conclude that consuming whole wheat pasta contributes positively to the supply of antioxidant substances to the body. The same can be stated for lutein levels found in whole wheat pasta when compared to refined pasta samples, resulting in a clearly higher antioxidant capacity of the wholemeal product, which is accompanied by a lower loss of nutritional components due to the use of germ and bran during grinding. The results also revealed that lutein was present in significantly higher amounts than any of the other components in all the samples studied and hence might act as a marker product of the total amounts of carotenoids in pasta.

Considering the numerous factors that affect the carotenoid content in the final product, it will be particularly interesting to investigate the various aspects related to the raw material (type of crop, genotype, and environmental conditions) and to the production process (mechanical phases, drying, etc.) to better understand whether the total amount of these substances can be preserved during the entire pasta production and storage cycle.

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Chapter 32
The Likely Effect of the Rise in Global Temperature on Cheese Safety

Gavina Manca, Valentino Tascione, and Fabrizio S. Cordeddu

Abstract Global warming is a current global concern affecting food safety since rising temperatures can influence microbial ecology, resulting in the growth and activity of certain bacterial strains producing toxic substances. Rising temperatures jeopardize the safety of fermented products such as cheese. During cheese ripening, the amino acids liberated through proteolytic phenomena are substrates for secondary catabolic reactions through bacteria, resulting in the release of substances with a potential negative impact on human health, such as biogenic amines. Therefore, this work considers the content of biogenic amines in a sheep's milk cheese produced during the winter and spring period to evaluate the effect of the increment of temperature on the production of these toxic compounds and obtain information on the potential impact of global warming on the safety of cheese. The results showed that spring production had a higher content of biogenic amines than winter production. Given that the lengthening of the warm seasons due to the change in climatic conditions is expected, producers should take action to ensure cheese safety and limit the adverse effect of rising temperatures.

Keywords Global warming · Toxic compounds · Cheese safety

32.1 Introduction

The rise in global temperature poses a risk to the food system. These severe weather conditions threaten food production worldwide with severe effects on food security and food safety. Changes in weather conditions could cause, enhance, or modify the occurrence and intensity of some food-borne diseases since they affect the dominance and persistence of various parasites, fungi, and viruses, which are harmful to

G. Manca (✉) · V. Tascione · F. S. Cordeddu
Department of Economic and Business, University of Sassari, Sassari, Italy
e-mail: gmanca@uniss.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_32

plant and animal health. The increase in temperature can promote the growth and activity of microorganisms or fungi producing toxic substances (Duchenne-Moutien and Neetoo 2021). In this respect, several studies have highlighted that increases in temperature and humidity could favour the production of carcinogenic mycotoxins in cereal crops (Marroquín-Cardona et al. 2014). The change in weather conditions might also pose a risk for fermented foods, such as cheese since the increase in temperature can promote the growth and activity of certain microorganisms producing biogenic amines (Loizzo et al. 2013). Therefore, this research aims to evaluate the variation in the free amino acid and biogenic amine contents in sheep's milk cheese during the winter and spring to provide insight into the effect of the temperature increment on this food.

32.2 Review of the Literature

Biogenic amines at low concentrations are essential for natural metabolic and physiological functions in animals, plants, and microorganisms. Nevertheless, biogenic amine accumulation in food may have a toxicological effect and pose a food safety risk, especially for susceptible consumers. Although biogenic amines are usually detoxified by monoamine oxidase (MAO) and diamine oxidase (DAO) in the small intestine, toxic effects may arise through amine oxidase oversaturation due to high concentrations of biogenic amines or when detoxifying activity is impaired due to the use of monoamine oxidase inhibitors (MAOIs), alcohol consumption, or gastrointestinal disorders. Tyramine, histamine, tryptamine, β-phenylethylamine, putrescine, cadaverine, spermidine, and spermine are the most common biogenic amines in foods. Food rich in tyramine is associated with "cheese syndrome" with symptoms such as hypertension, headaches, migraine, neurological disorders, and gastrointestinal symptoms (Özogul and Özogul 2019). Likewise, consuming food with high histamine content can cause neurological, gastrointestinal, circulatory, respiratory disorders, flushing, rashes, and urticaria. Other amines, such as putrescine and cadaverine, are also precursors of carcinogens, e.g. N-nitrosamine. Biogenic amines could be present at high levels in sheep milk cheeses (Loizzo et al. 2013; Manca et al. 2015; Zazzu et al. 2019). These toxic compounds can be produced in fermented foods mainly by the decarboxylation of amino acids liberated through proteolysis by microorganisms with aminoacyl decarboxylase activity (Linares et al. 2012). In cheese, decarboxylase-producing strains could be provided by milk, some starter cultures, or microbial contamination. Proteolysis, with the consequent release of free amino acid precursors of biogenic amines, is affected by rennet and enzyme activity or microbial fermentation during cheese production and ripening. Storage temperature is a risk factor for the formation and accumulation of biogenic amines in sheep's milk cheese since high temperature can favour the growth and activity of decarboxylase-producing microorganisms and, as a result, the production of biogenic amines (Loizzo et al. 2013).

32.3 Materials and Methods

32.3.1 Sampling

Sheep milk cheese samples were obtained from three farms located in Sardinia (Italy). The samples were collected after 4 months of ripening and produced in the winter and spring period.

32.3.2 Analyses of the Free Amino Acids and Biogenic Amines

The free amino acids and biogenic amines were determined by high-performance liquid chromatography with fluorescence detection (HPLC-FL). The method employed for the extraction and derivatization of the nitrogenous compounds considered as well as the chromatographic conditions utilized were described in previous work (Manca et al. 2020).

32.3.3 Statistical Analysis

Analysis of variance (ANOVA) was used to assess the differences between means in relationship with the season of production. The Pearson correlation test was employed to analyse the correlation between the measured variables ($p = 0.01$).

32.4 Results and Discussion

From winter to spring, the level of the total biogenic amines significantly ($p \leq 0.001$) increased, reaching a mean value (708.9 ± 330.1 mg/kg) almost two times higher in the warm period than in the cold period (Table 32.1).

The weather conditions could favour microbial growth and decarboxylase activity (Renes et al. 2020) during the ripening process. As found in other ewe milk cheeses (Schirone et al. 2012; Manca et al. 2015; Zazzu et al. 2019), tyramine was the main biogenic amine, accounting for 52% and 61% of the total biogenic amines in winter and spring, respectively. Putrescine was the second most represented amine, while cadaverine, β-phenylethylamine, and tryptamine were observed in low concentrations or were not found. Histamine was essentially detected in the samples produced in the warm period. Spermine and spermidine were not detectable in this cheese. Considering that biogenic amines are most often associated with food poisoning, threshold values for their content in food were suggested. Based on the limit of 900 mg/kg proposed by Shalaby (1996) for the total content of biogenic amines

Table 32.1 Content of the biogenic amines and total free amino acids (mg/kg) in cheese produced in winter and spring from three farms

Parameters	Producer	Period of production		ANOVA (p value)
		Winter	Spring	
Tryptamine	A	7.5 ± 10.4	6.7 ± 5.2	
	B	5.5 ± 5.0	8.33 ± 4.1	
	C	21. 7 ± 4.1	18.3 ± 9.8	
	Mean TOT	11.7 ± 10.4	11.1 ± 8.3	0.703
Phenylethylamine	A	5.2 ± 7.6	35.3 ± 35.1	
	B	8.33 ± 7.5	21.67 ± 31.3	
	C	31.7 ± 7.528	23.3 ± 10.3	
	Mean TOT	13.9 ± 14.6	19.4 ± 18.6	0.100
Putrescine	A	70.0 ± 38.2	258.3 ± 123.0	
	B	26.67 ± 15.1	120 ± 32.9	
	C	278.3 ± 82.3	303.3 ± 104.4	
	Mean TOT	129.4 ± 121.2	190.6 ± 124.5	0.063
Cadaverine	A	20.4 ± 16.0	50.0 ± 21.9	
	B	20 ± 6.3	43.3 ± 23.4	
	C	50.0 ± 31.6	50.0 ± 31.6	
	Mean TOT	31.1 ± 24.2	35.0 ± 22.5	0.440
Histamine	B	ND	23.3 ± 57.2	
	B	ND	18.3 ± 29.9	
	C	ND	15.2 ± 32.1	
	Mean TOT	ND	18.9 ± 39.2	0.062
Tyramine	A	227.5 ± 119.9	478.3 ± 214.9	
	B	115.2 ± 65.1	490.3 ± 359.5	
	C	315.0 ± 47.6	315.0 ± 47.6	
	Mean TOT	203.9 ± 109.7	433.9 ± 223.5	0.000
Total BA	A	330.3 ± 100.2	851.7 ± 349.7	
	B	175.2 ± 64.4	701.7 ± 436.7	
	C	696.7 ± 150.5	696.7 ± 150.5	
	Mean TOT	390.0 ± 250.6	708.9 ± 330.1	0.001
Total FAA	A	8135.0 ± 2517.9	10098.3 ± 2417.5	
	B	5093.3 ± 2606.6	12533.3 ± 5494.3	
	C	7088.3 ± 930.3	10668.3 ± 1992.2	
	Mean TOT	6450.0 ± 2119.5	10907.2 ± 3545.4	0.000

ND not detected

in food, the mean levels of total biogenic amines in sheep's milk cheese did not exceed this amount in the winter and spring production. The samples produced during the spring season presented high biogenic amine contents close to the suggested limit.

The total content of free amino acids, considered an index of proteolysis, significantly increased ($p \leq 0.000$) as the seasons changed, reaching a mean value of 10,907.2±3545.4 mg/kg in spring production, one and a half times higher than

Table 32.2 Pearson correlation coefficients among the total free amino acids and biogenic amines measured in sheep's milk cheese

	Tot Total FAA[a]	Total BA[b]	Tryptamine	Phenyl-ethylamine	Putrescine	Cadaverine	Histamine	Tyramine
Total FAA[1]	1	0.807**	0.050	0.465**	0.416**	0.531**	0.573**	0.856**
Total BA[2]	0.807**	1	0.234	0.735**	0.725**	0.587**	0.61**	0.956**
Tryptamine	0.050	0.234	1	0.117	0.497**	0.129	−0.155	0.107
Phenyl-Ethyl amine	0.465**	0.735**	0.117	1	0.428**	0.31*	0.358**	0.737**
Putrescine	0.416**	0.725**	0.497**	0.428**	1	0.373**	0.139	0.533**
Cadaverine	0.531**	0.587**	0.129	0.315*	0.373**	1	0.439**	0.514**
Histamine	0.57**	0.614**	−0.155	0.358**	0.139	0.439**	1	0.600**
Tyramine	0.856**	0.956**	0.107	0.737**	0.533**	0.514**	0.600**	1

** Correlation is significant at $p < 0.01$. * Correlation is significant at $p < 0.05$

[a]Free amino acids

[b]Biogenic amines

that found in winter. Renes et al. (2020) confirmed this behaviour in Spanish sheep milk cheese, in which samples produced in spring after 100 days of ripening presented values of total free amino acids similar to the more mature winter products (180 days). As highlighted through the Pearson correlation test (Table 32.2), the total biogenic amines, as well as the individual biogenic amine content, were significantly correlated with the total free amino acids ($p \leq 0.01$). This result confirmed an interrelationship between the availability of free amino acids and the production of biogenic amines (Loizzo et al. 2013; Manca et al. 2015, 2020). Glutamic acid, leucine, lysine, and valine were the free amino acids most frequently recorded. The free amino acid profile in artisanal sheep's milk cheese was similar to that discovered in other types of ewe's milk cheese (Manca et al. 2015).

32.5 Conclusions and Future Perspectives

During the warm period, proteolysis phenomena and microbial decarboxylase activity were more intense. Consequently, a rise in the biogenic amine content was observed. Considering that global warming is expected to affect the start, duration, and intensity of the warm season, in the future, the weather conditions favourable for the development of biogenic amines in cheese might persist for periods of the year longer than the current ones. Further studies are needed to deepen the understanding of the complex relationship between the intrinsic and extrinsic factors involved in biogenic amine production in cheese. In addition, appropriate technological options to reduce the risk of adverse impacts of changes in weather conditions on the safety of sheep's milk cheese should be proposed. Implementing strict hygienic control of milk and controlling the temperature and humidity during the cheese ripening process, especially in the warmer months, could contribute to limiting biogenic amine production.

Acknowledgements The research was partially funded by the University of Sassari, funding for research 2020.

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Chapter 33
Tomato Supply Chain and Production Quality Control for International Markets

Giancarlo Palumbo, Antonello Senatore, Dario Tuccillo, and Isabella Maria De Clemente

Abstract In addition to being one of the most important Italian horticultural crops, tomato is also one of the most cultivated in the world. Due to its organoleptic and nutritional qualities, it plays a central role in the Mediterranean diet; therefore, the demand is high both from the fresh market and as a raw material for the processing industry. There is a wide range of industrial derivatives, such as peeled tomatoes, purées, concentrates, juices, and, just from the processing of tomatoes, a sector of extreme importance in the Italian manufacturing scene has arisen, the canning sector. Tomato pulp, purée, and peeled tomatoes represent the main categories of industrial derivatives, of which the commercial importance of exports should be noted, both to Europe (Germany, France, and the United Kingdom) and to other countries (Asia, United States, Japan, and Oceania). According to Istituto di Servizi per il Mercato Agricolo Alimentare (ISMEA) data, over 60% of national production is destined abroad, equal to a market share of 13% of world production and 53% of European production. The processed tomato supply chain is controlled, certified, and oriented towards environmental sustainability. Therefore, it is in the interest of companies to enhance both the domestic and foreign markets the quality characteristics of the productions, characteristics linked to a specific territoriality, in order to incentivize the growth of consumption and consolidate the market. Quality productions currently protected include the Pachino Indicazione Geografica protetta (IGP) tomato, a typical fresh variety, as well as the Pomodorino del Piennolo del Vesuvio Dop and the San Marzano dell'Agro Sarnese-Nocerino Dop tomato, which is well suited for industrial processing. In a logic of safeguarding national peculiarities, the national origin of the product and traceability must represent for the canning com-

G. Palumbo · I. M. De Clemente (✉)
Commodity Science Laboratory, Department of Economics, Management, Institutions, University of Naples "Federico II", Naples, Italy
e-mail: gpalumbo@unina.it; isabellamaria.declemente@unina.it

A. Senatore · D. Tuccillo
Commodity Science Laboratory SI Impresa, Naples, Italy
e-mail: direzione@si-impresa.na.camcom.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_33

panies in the sector, as well as a communication and marketing tool, above all a factor of competitiveness on international markets. For this purpose, control parameters are fundamental to discriminate between different cultivars and to enhance their typicality.

Keywords Canning industry · Quality · Territorial specificity

33.1 Introduction

The tomato with its byproducts, as well as other typical Italian food products, represents a true symbol of national identity. In addition to being one of Italy's most important vegetable crops, it is also one of the most cultivated vegetables in the world. Due to its organoleptic and nutritional qualities, it has a central role in the Mediterranean diet: it is rich in antioxidant and anticancer biomolecules such as polyphenols, flavonoids, lycopene, and ascorbic acid and is one of the most interesting plant species due to its nutraceutical and functional properties (Sandei et al. 2017). The demand is high both from the fresh market and as a raw material for the processing industry, so much that the world supply of tomatoes for processing has also grown (+1%), thus reaching 38.7 million tons, driven by the recovery of Italian production but also Spanish and Portuguese. In recent years, other countries, including non-EU countries, have taken a leading role as producers and exporters of tomato products. These are mainly China, which over the years has achieved a considerable position in the global processed tomato market, given its growing exports. Chinese production, oriented towards the production of concentrates and canned food, is in competition with the Italian product, which is intended, instead, mainly for direct consumption and not for the production of semifinished products. According to data from the World Processed Tomato Council (WPTC), California is confirmed as the main production area globally, with more than 9.6 million tons processed in 2021 and a 25% share of total production, followed by Italy (16%), China (12%), Spain (8%), and Turkey (6%). Italy is, therefore, the world's second largest producer of fresh tomatoes for the canning industry. More than 6 MLN tons of tomatoes were produced and processed in our country in 2021, accounting for 52% of European production and 16% of world production (ISMEA 2021).

There are two national tomato production basins: that of the Central South, with the highest concentration of processing companies in Campania, and agricultural production companies in Puglia, and that of the North, concentrated especially in the Emilia Romagna region. Production is mostly equally divided between the two production basins, although a different specialization between the two districts should be highlighted: in the North, pulps (36.6%), concentrates (32.5%), passata (28.6%), and sauces (1.9%) are mainly produced (OI Nord Italia 2018); on the other hand, the Center-South is a leader in the production of peeled tomatoes, pulps, passata, and cherry tomatoes (ISMEA 2019). The balance of the 2021 harvest year was more than satisfactory in both basins both in terms of quantity harvested and the excellent quality of fresh tomatoes, which also resulted in good yields at the processing stage. Certainly, favourable climatic conditions, such as the absence of rain and high temperatures, which accelerated the ripening of the berries and facilitated their harvesting activity, had a decisive impact on the result, bringing daily deliveries to record levels and making Italy's position among the largest producers globally even more solid, right after California (Marzialetti 2021). The increase (+8.5%) in the areas involved compared to the previous year and the improved agricultural yield (more than 85 tons per hectare) also contributed to this result. In particular, in the Northern Italian production basin, the area invested in tomatoes grew by 4.2%, while in the Center-South, there was an increase of 14% (Pascale 2021). In our country, the industrial turnover of the sector worth 3.7 billion euros, 1.9 of which comes from exports, more than 60% of national production is destined for foreign countries, with a market share of 13% of world production and 53% of European production. However, despite the positive results of the last campaign, the consequences of the recent war events will not be long in making themselves felt in this sector as well, where at least 10% loss is estimated, due not only to energy price rises and their consequences but also to the adverse weather conditions that have mainly affected the production district in Northern Italy.

Wide is the range of industrial derivatives such as peeled tomatoes, purées, concentrates, juices, and just from the processing of tomatoes has arisen a sector, the canning sector, of extreme importance in the Italian manufacturing scene so much to baptize the tomato with the appellation of "Red Gold." It is a sector that employs more than 30,000 workers, of whom approximately 10,000 are permanent and 25,000 seasonal, to which must be added the labour employed in the allied industries. In addition to meeting domestic needs (35 kg per capita/year), more than 50% of production is for export to markets in EU countries, especially Germany and France but also the United Kingdom. Outside European borders, the flow of processed tomatoes involves a growing number of countries, such as Asia, the USA, Japan, and Oceania, with an export share of more than 1.9 billion euros.

Tomato purée, tomato pulp, and peeled tomatoes represent the main categories of industrial derivatives, whose export trade importance should be noted. At the national level, in 2021, passata (60.4%) was the most sold in the retail channel, followed by pulp (22.2%), peeled tomatoes (11.8%), cherry tomatoes (3.9%), and concentrate and others (1.7%). While 30% of the entire sector's turnover is accounted for by the Ho.Re.Ca. out-of-home consumption channel (bars, restaurants, food service) (ANICAV n.d.).

The processed tomato supply chain is controlled, certified, and oriented toward environmental sustainability. Therefore, it is in the interest of companies to enhance both in the domestic and foreign markets the quality characteristics of the productions, characteristics linked to a specific territoriality, to stimulate the growth of consumption and consolidate the market. Quality productions that are currently protected include the Pachino Tomato IGP, a typical fresh species, as well as the Pomodorino del Piennolo del Vesuvio Dop and the San Marzano Pomodoro dell'Agro Sarnese-Nocerino Dop, which is well suited for industrial processing. San Marzano is undeniably one of the symbols of the Italian canning industry, known and appreciated worldwide for its special quality characteristics (Nomisma 2017).

In a logic of safeguarding national peculiarities, the national origin of the product and traceability must represent for canning companies in the sector not only a communication and marketing tool but above all also a factor of competitiveness in international markets.

In particular, Regulation (EU) No. 1151/2012 "on quality schemes for agricultural products and foodstuffs" requires that agri-food products benefiting from a Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI) be obtained in accordance with the relevant specification and that verification of compliance with the regulated requirements be carried out by competent authorities and/or control bodies, authorized by Member States.

Fundamental to this are, therefore, the control parameters that should be more discriminating and enhance typicality. This chapter therefore emphasizes the need to develop a more integrated control system that, through the use of specific analytical techniques and possibly automatic ones to reduce execution times, is capable of certifying the quality characteristics of the productions and, in particular, the characteristics linked to a specific territoriality to stimulate the growth of consumption and consolidate the market.

33.2 Material and Methods

Peeled tomatoes are the type of tomato conserve that allows the raw material to be more highly valued because the whole fruit with its original characteristics is clearly visible in the finished product, and this obviously requires higher costs for the sorting and processing stages. In other words, it is not a simple commodity but a specific canned food product with even higher production costs. For the quality of the product, the raw material must, in fact, be processed as quickly as possible, i.e. within 24/36 hours of harvesting. Fresh tomatoes are therefore necessarily made in Italy, as sourcing them from abroad is uneconomical. Given the healthy potential of tomatoes, the valuing of production in relation to the territory of origin is now more important than ever. As part of this research, more than 300 commercial samples of canned peeled tomatoes supplied directly by the companies involved were analysed during the 2020–2021 period, particularly samples of canned San Marzano dell'Agro Sarnese-Nocerino DOP tomatoes destined for foreign markets. Both chemical–physical and organoleptic analyses were carried out on these samples to verify their compliance with the requirements set out in the current Production Regulations of the Protected Designation of Origin (*Disciplinare di produzione della denominazione di origine protetta "Pomodoro San Marzano dell'Agro Sarnese-Nocerino*"). In particular, the checks concerned the following parameters:

- Colour (red typical of the variety)
- Smell and taste
- Visual inspection for changes of a parasitic nature and stylar rot

- Drained weight expressed as % of net weight (DM 03/02/1989 SO GU n. 168 del 27/7/1989 Titolo II Met 4)
- pH (DM 03/02/1989 SO GU n. 168 del 27/7/1989 Titolo II Met 17)
- Wholeness (DM 25/03/1961 GU n.105 del 29/4/1961 Tit III Met 4)
- Total D and L lactic acid content (UNI EN 12631:2000)
- Determination of added salt (MIP 04 rev3–2021)
- Refractometric optical residue (digital refractometer Ohaus dbr 95)

33.3 Results and Discussions

The data obtained from the chemical–physical analyses carried out (Table 33.1) show that the products comply with normal commercial standards, as is also evident from the graphs, of which only those relating to the determination of sodium chloride and lactic acid are given as examples (Figs. 33.1 and 33.2).

Table 33.1 Statistical summary of analytical data of San Marzano peeled tomato samples for 2020–2021

Samples year 2020	Wholeness %	Drained weight%	pH	D/L lactic acid g/kg	NaCl %	RO %
160	*>60*	*>60*	*4.2–4.5*	*<0.4*		*>4*
Average	86.6	72.0	4.32	0.19	0.09	6.8
Deviation	4.74	9.12	0.09	0.13	0.03	0.65
Dev %	5.48	12.67	1.98	69.93	34.46	9.57
Samples year 2021	Wholeness %	Drained weight %	pH	D/L lactic acid g/kg	NaCl %	RO %
160	>60	>60	4.2–4.5	<0.4		>4
Average	85.0	70.6	4.27	0.20	0.15	6.3
Deviation	7.65	6.97	0.08	0.15	0.07	0.50
Dev %	9.01	9.88	1.84	75.64	47.01	8.07

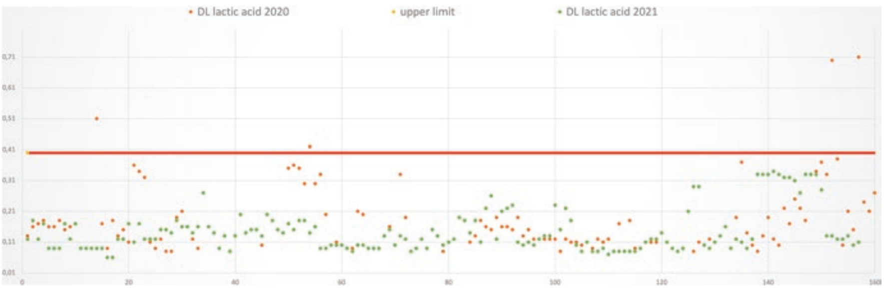

Fig. 33.1 D and L lactic acid content (g/kg) vs sample number analysed in 2020–2021

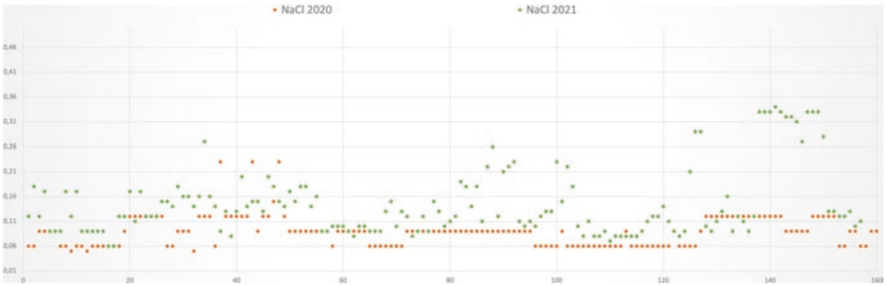

Fig. 33.2 NaCl % vs sample number analysed in 2020–2021

All of the samples analysed substantially fall within the limits of the parameters set out in the specifications, parameters which, however, are not particularly discriminating for the peculiarities of products with protection marks.

33.4 Conclusions and Future Perspectives

In an era of globalization where Italian companies find it difficult to emerge, quality certifications become more important than ever. To be effective without being just a cost for companies, they must be adapted to the product and the historical reference period. In general, production specifications and analysis protocols for the certification of PDO products are drawn up at the same time as the historical reference period. However, the natural evolution of technology positively influences the quality of the finished product, hence the need to reconsider the chemical–merceological parameters. Hence, there is a need to update the analyses required for certification.

In particular, for PDO San Marzano dell'Agro-Sarnese-Nocerino, it is considered appropriate to propose the exclusion from routine analyses of both the determination of added salt and the Howard mould count, which is the most commonly used method for determining the microbiological quality of the raw material. In fact, both of these analyses are better suited to tomato quality control in general, as they do not highlight any particular peculiarities of the quality of PDO San Marzano dell'Agro-Sarnese-Nocerino. Specifically, the determination of added salt is performed to correct the value of the optical residue, expressed in degrees Brix, which would be altered by the possible addition of salt. However, all the samples analysed show values of added salt close to zero or with values that are in any case negligible, confirming the possibility of excluding this determination from routine ones. Mould control is also a parameter related to the hygienic-sanitary conditions of the raw material and the plant, conditions that are already monitored as part of the company's self-control. Today, plants are more advanced than in the past, and product quality can be controlled with more sensitive and fast analysis, including the determination of D and L lactic acids as an indicator of microbiological alteration.

Given the experience with extra virgin olive oil, where for the various PDOs not all the analyses required by Regulation (EEC) No 2568/91 are carried out but only those that best characterize the product, it would be desirable to take the same path. Exclusion of the above-mentioned two parameters from the list of those normally provided would meet the needs of the San Marzano Tomato Protection Consortium to reduce the costs and time required for analysis, while more effective analyses could be introduced for PDO qualification. In particular, it might be useful to define sensory parameters to be used in a possible panel test, which, as in the case of extra virgin olive oil, could prove useful in highlighting the quality of the product.

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Chapter 34
Sustainability of Rural Supply Chains in Nepal: Selection, Characterization, and Labelling of Spices for the Local Market

Patrizia Pinelli, Daniela Tacconi, Vittoria Vineis, and Leonardo Borsacchi

Abstract The agricultural sector plays a major role in Nepal's economy, contributing approximately one third of the country's gross domestic product. Although subsistence farming still dominates agricultural production, the proportion of farmland used for the production of high-value crops such as spices increased by 24% in this last decade. However, Nepal has not yet been able to establish direct trade relationships with buyers in potential destination markets. This chapter focuses on the project "Spices and sEEDs value chain improvement for rural development in Nepal, enhancing women and youth empowerment," implemented by the ASIA non-governmental organization (NGO) and funded by AICS. The project aims to support small-scale farmers by improving agricultural production and the sale of seeds and spices of high commercial value. The work focuses on the sustainability of the rural supply chain of Nepali spices, and the actions carried out aim to describe the action research carried out by ARCO PIN-Unifi to introduce upgrading in the processes of selection, preservation, and packaging/labelling of the selected spices. Spectrophotometric analysis is also carried out for the evaluation of polyphenols, flavonoids, and antioxidant activity to enhance the functional value of spices and for the preparation of data sheets, which are also useful for the possible export of the product.

Keywords Ginger · Turmeric · Cardamom · Sustainability · Supply chains · High-value crops · Bioactive compounds

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P. Pinelli
Department of Statistics, Computer Science, Applications "Giuseppe Parenti" (DiSIA), University of Florence, Florence, Italy
e-mail: patrizia.pinelli@unifi.it

D. Tacconi · V. Vineis · L. Borsacchi (✉)
Action research for CO-development (ARCO) – PIN, University of Florence, Prato, Italy
e-mail: daniela.tacconi@arcolab.org; vittoria.vineis@arcolab.org; leonardo.borsacchi@pin.unifi.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_34

34.1 Introduction

The agricultural sector is central to the national economy of Nepal. According to the International Labour Organization, agriculture provides livelihoods for 68% of Nepal's population, contributing approximately one third of the gross domestic product (USAID 2022). Subsistence farming still dominates agricultural production, and economic well-being is very closely bound to natural resources, particularly in hilly regions where people depend on agriculture for their food source, income, and livelihood. Most of the farmers of Nepal are smallholder farmers, with 52.7% of households having less than 0.5 hectares of landholding, and approximately 70 percent of landholdings are less than 1.0 ha in size (FAO 2022). Nevertheless, people depending on agriculture and the sectorial contribution to the economy have been shrinking over the years (Thapa et al. 2017). Despite the slump in the agriculture sector's share in GDP, the agriculture sector in Nepal is characterized by rapid growth in the production of high-value crops. Due to the increasing demand in domestic and foreign markets, the farming and production of high-value products such as spices have increased by 25% in the past 10 years (Acharya et al. 2021).

On the one hand, this shift could have positive implications in terms of the livelihood of farmers and the farming system; at the same time, the sector is still affected by poor access to market infrastructure, weak institutions, poor competitive capacity of farmers, and heavy price fluctuations. In particular, Nepal has not yet been able to establish direct trade relationships with buyers in potential destination markets due to an underdeveloped and highly fragmented supply chain.

This chapter took place within the project *"SPEED for Life: SPices and sEEDs value chain improvement for rural development in Nepal, enhancing women and youth empowerment"* (hereafter SPEED Project), implemented from 2020 to 2022 by the ASIA non-governmental organization (NGO) and funded by AICS, the Italian Agency for Development Cooperation. The main objective of the project is to support the livelihood of small-scale farmers in the central region of Nepal by improving the agricultural production of microenterprises and strengthening the whole value chains of seeds and spices of high commercial value. This chapter presents the results of action research conducted by ARCO, a university action research centre founded in 2008 at PIN S.c.r.l. (Polo Universitario "Città di Prato") – University of Florence. In this context, the activities carried out by ARCO focus on the analysis of the sustainability of the value chains of local spices destined to the local market, with the purpose of introducing upgrading in the processes of selection, preservation, and packaging/labelling of the selected spices. Within a perspective of local development based on the whole valorization of local productions, this research has focused in particular on the following specific objectives: (1) to understand more about the existing procedures adopted by a sample of selected local farmers and local sellers to elaborate a value chain analysis and (2) to prepare technical specifications sheets and labels for the domestic market. The final common aim is to investigate and enhance the supply chains from a quality perspective for specifically selected spices, creating new business potential opportunities.

34.2 Materials and Methods

To achieve the above-mentioned objectives, this action research study has adopted a methodology based on the active involvement of the project stakeholders in the districts of Kavrepalanchowk and Sindhupalchowk (Katmandu, Nepal). In particular, the activities were carried out before and during a field mission: (1) desk-based analysis of internal reports (e.g. previous field mission reports by project partners) and literature and (2) conduction of semistructured interviews and on-field visits. It should be noted that, following the pandemic emergency, part of the activities have been conducted remote (i.e. online interviews and online evaluation of production sites), with a final field mission in the target areas in Nepal in April 2022. The elaboration of a value chain analysis and the preparation of the technical specification sheets were generally based on local field data through the conduction of semistructured interviews and focus groups with farmers and cooperatives. Within the framework of the project, samples of fresh ginger, turmeric powder, and cardamom were also analysed and characterized by spectrophotometric methods to identify and quantify secondary bioactive compounds. Hence, polyphenols, flavonoids, antioxidant, and radical scavenging activities were evaluated for each sample using in vitro methods of Folin-Ciocalteu and stable radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) and then compared with literature data to identify the compounds or subclasses responsible for biological activities. The results on the functional value of spices have been used in the elaboration of technical specifications sheets, envisioning further market opportunities both locally and internationally.

34.3 Results and Discussions

The main key players of the value chain have been identified, providing a framework on the role of farmers, middlemen, and retailers and outlining the mechanism of the chains. Figure 34.1 shows the different channels of the value chains.

Some farmers in Kavrepalanchowk and Sindhupalchowk sell their products in the local market without using intermediaries (middlemen), either directly to consumers or by delivering products to local retailers. Most of the farmers disposed of their products at the nearest road-head point to the traders. Such products are then delivered to wholesale markets or sold to retailers and consumers directly by middlemen. A limited number of farmers place their productions in Kathmandu markets directly via wholesalers: A major part of the road-head collection is canalized to Kathmandu through the middlemen. Because of the perishable nature of vegetables and lack of safe storage, farmers, due to their weak negotiation power, have to accept the prices offered by middlemen. The analysis shows that the demand exceeds the supply in the local and regional markets and sometimes in the national market. Farmers' offer is often much lower compared to middlemen and retailers' offers. Low-quality infrastructure, weak market orientation of smallholder farmers,

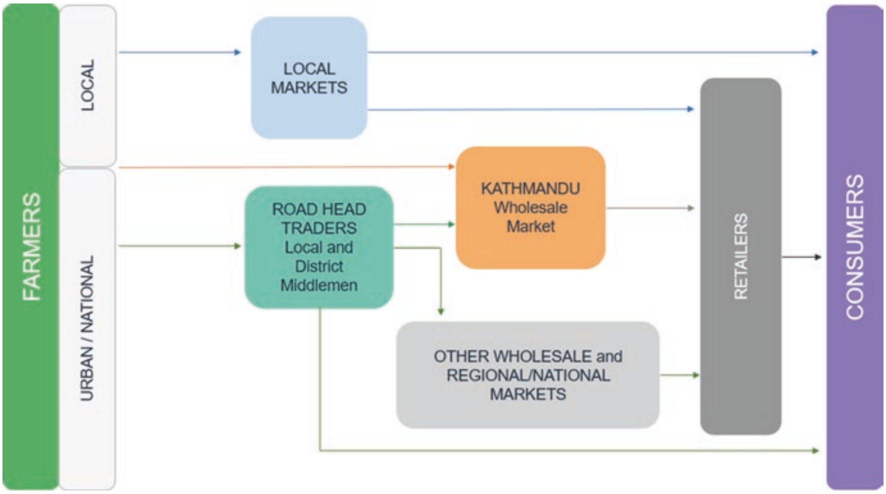

Fig. 34.1 The different channels of the value chain for the selected products in Kavrepalanchowk and Sindhupalchowk

poor market access, low productivity, and high postharvest losses impose relevant issues for the supply chain, generating an inconsistent supply of products from farmers. This situation results in an increase in imports, often leading to a market paradox within the market, as is the case for ginger, which is exported fresh at low prices to the Indian market and reimported in the form of ginger powder at higher prices to individual customers. This mechanism generates a consistent "loss of value" along the entire supply chain. Process and storage facilities appear to be weaker links, together with high-quality and hygienic requirements to access national and international markets and the high price competitiveness of imported products. Technical specification sheets have been elaborated for the three selected products, chosen both for their commercial interest (current and potential) and by their commodity profile. By preparing these documents, the aim is to provide the social enterprise/cooperative a useful tool, both for commercial and for marketing purposes. Each technical specifications sheet outlines relevant information according to the following scheme:

- General information, with composition and place of origin.
- Processing, with the details of the production process.
- Properties outline information about the functional properties of the product. According to studies and scientific literature, functional activities have been described based on the different bioactive compounds that characterize single species.
- Packaging and storage description.
- Organoleptic properties.
- Microbiological parameters (i.e. bacteria and mould limits according to EU standards) (Table 34.1).

Table 34.1 Summary of technical specifications sheets of the target species

	Fresh ginger	Turmeric powder	Cardamom
	Zingiber officinale	*Curcuma longa*	*Amomum subulatum Roxb.*
Origin	Produced in Melanchi in compliance with cultural heritage and territorial systems		
Processing	Harvesting. Transport to Melanchi. Cleaning. Sorting and grading. Visual inspection. Packaging	Harvesting. Transport to Melanchi. Washing. Sorting. Peeling and cutting into slices. Drying. Grinding. Visual inspection. Packaging	Harvesting of capsules and storage for 2–3 days. Capsules separation. Cleaning. Drying. Grading. Visual inspection. Packaging
Properties	Very high levels of phenolic compounds and total flavonoid with important antiradical capacity in ginger from Melanchi	Very interesting content of polyphenols and flavonoids with a good antiradical power evaluated by DPPH test	Very interesting content of antioxidants and flavonoids. Modest antiradical power, which is in contrast with literature data
Packaging	25 kg sales unit. Plastic bag	100 g sales unit. Clear plastic bag	5 kg, 10 kg, and 20 kg sales unit. Plastic bag (polyester fibre)
Organoleptic properties	In the form of hand and fingers, sour and spicy taste, yellow–white colour	Soft and fine powder, with bright yellow–orange in colour. Pungent, bitter flavour	Spindle-shaped pods that are light to dark brown in colour. Warm, slightly pungent, sweet, smoky, and citrus aroma
Microbiological parameters	TBC: $\leq 1 \times 10^6$ cfu/g Moulds: $\leq 1 \times 10^4$ cfu/g	TBC: $\leq 1 \times 10^5$ cfu/g Moulds: $\leq 1 \times 10^4$ cfu/g	TBC: $\leq 1 \times 10^6$ cfu/g Moulds: $\leq 1 \times 10^4$ cfu/g

Regarding the chemical characterization of the selected species in terms of functional molecules, an interesting presence of bioactive compounds in the ginger sample should be noted (Amma et al. 2010). In particular, fresh ginger sampled in Melanchi had a very interesting total phenolic content (TPC) (141.20 mg GAE/g), which was higher than that of samples reported in the literature (Ahmed Hassan El-Ghorab et al. 2010) on Pakistani ginger evaluated with the same test (95.2 mg GAE/g). Another research paper (Shirin Adel and Prakash 2011) shows a very high TPC value (840 and 830 mg/g), presumably because, despite using the same test (Folin-Ciocalteau), tannic acid is used instead of gallic acid as a standard compound. Moreover, fresh ginger from Melanchi has an important total content of flavonoids – TFC (56.36 mg QE/g) with respect to the already reported paper about Pakistane ginger (6.85 mg QE/g) evaluated with the same test and using quercetin as standard. In Malaysian ginger (Mojani et al. 2014), flavonoid and phenolic contents were reported to be 3.66 ± 0.45 mg gallic acid/g and 10.22 ± 0.87 mg quercetin/g of dry weight basis of rhizome. Finally, the antiradical activity of the

Table 34.2 TPC, TFC, and antiradical assay (by DPPH test) of ginger extracts

Total phenolic content (TPC)			
Conc.(μg/mL)	OD sample	OD control	OD value
1000	0.716	0.109	0.607
TPC = 151.205 mg GAE/gm			
Total flavonoid content (TFC)			
Conc.(μg/mL)	OD sample	OD control	OD value
1000	0.439	0.047	0.391
TFC = 56.362 mg QE/gm			
DPPH (antioxidant assay)			
Conc.(μg/mL)	OD sample	OD control	Inhibition %
62.5	0.400	0.650	38.461
125	0.318	0.650	51.076
250	0.200	0.650	69.230
500	0.091	0.650	85.897
IC_{50}		127.188 μg/mL	

Melanchi sample (DPPH test) was calculated as IC_{50} (102.2 μg/mL). According to a recent work (Mošovská et al. 2015), the evaluation of the antioxidant activity of extracts from *Zingiber officinale* reported TPC = 181.41 mg GAE/g, from which flavonoids contributed 7.8% (14.15 mg QE/g). In the same paper, ginger extract showed an antioxidant effect in inhibiting DPPH radicals, and the IC50 was 4.25 mg/mL. The Melanchi sample, with an IC50 of 127.19 μg/mL, seemed highly more active (see Table 34.2). Hence, the ginger rhizome originating from Melanchi may exhibit antioxidative and anti-inflammatory potential due to high levels of phenolic compounds and total flavonoids with important antiradical capacity.

34.4 Conclusions

This work focuses on improving the sustainability of the value chains of ginger, turmeric, and cardamom in Nepal, introducing upgrading in the processes of selection, preservation, and packaging/labelling. Microbiological analyses carried out on samples of target spices demonstrated a high number of bacteria and the presence of moulds (probably due to a lack of adoption of good manufacturing practices (GMP) in processing and storage phases), and they are not suitable for European market. Both value chain and analytical evidence suggest further investigation with a more significant number of samples to confirm that profile. If confirmed, ginger in particular could potentially be increasing its value.

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Chapter 35
Carob Leaf Extracts as New Ingredients in the Food Field: Extraction, Characterization, and Antioxidant Features

Donatella Restuccia, U. Gianfranco Spizzirri, Filomena Corbo, Maria Lisa Clodoveo, Pasquale Crupi, Marilena Muraglia, Paolino Caputo, Cesare Oliviero Rossi, and Francesca Aiello

Abstract The leaves of two Apulian carob cultivars (Selvatica and Amele) were investigated in terms of their phytochemical profiles. Ultrasound assisted extraction (UAE) proved to be effective in the recovery of bioactive compounds in comparison with classical methods. When equal to the solvent, the Selvatica leaf extracts showed higher contents of antioxidants, and among solvents, water was shown to possess the most effective extraction capacity, leading to the highest yield. Liquid chromatography–diode array detection (LC-DAD) analyses revealed remarkable amounts of antioxidants in carob leaf extracts, as confirmed by different colorimetric assays. Myricitrin and 4- hydroxy-benzoic acid (HBA) were shown to be the most abundant compounds in all samples, containing simple phenols, polyphenols, and flavanols. The obtained data demonstrated the suitability of carob leaf extracts as a promising ingredient during functional food formulation.

D. Restuccia (✉) · U. G. Spizzirri · F. Aiello
Department of Pharmacy, Health and Nutritional Sciences, Department of Excellence 2018-2022, Edificio Polifunzionale, University of Calabria, Arcavacata, Italy
e-mail: donatella.restuccia@unical.it; g.spizzirri@unical.it; francesca.aiello@unical.it

F. Corbo · M. Muraglia
Department of Pharmacy-Drug Sciences, University of Bari Aldo Moro, Bari, Italy
e-mail: filomena.corbo@uniba.it; marilena.muraglia@uniba.it

M. L. Clodoveo · P. Crupi
Interdisciplinary Department of Medicine, School of Medicine, University of Bari Aldo Moro, Bari, Italy
e-mail: marialisa.clodoveo@uniba.it; pasquale.crupi@crea.gov.it

P. Caputo · C. O. Rossi
Department of Chemistry and Chemical Technologies, University of Calabria, Arcavacata, Italy
e-mail: paolino.caputo@unical.it; cesare.oliviero@unical.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_35

Keywords Carob leaves · Extraction · Antioxidants · Functional foods · Circular economy

35.1 Introduction

Increased consumer awareness of the importance of a healthy diet in preventing illness and diseases led to the development of a healthier food industry, prompting the market for functional foods and gluten-free products. However, a proper formulation of this kind of product poses many issues to be faced, including extraction, analysis, and technology parameters as well as bioavailability, biological activity, sensory features, and legal constraints (Banwo et al. 2021). It follows that the design and formulation of such a product must be carefully evaluated by choosing proper matrices as ingredients to confer novel food acceptable/improved nutritional, technological, and organoleptic characteristics (Galanakis 2017).

In this regard, many efforts have been devoted during the last decades by researchers, and a great number of novel foods are now available on the market. Among all possible exploitable bioactive compounds to obtain fortified foods, antioxidant molecules surely play a major role in their established health-promoting effects (Koch 2019). Byproducts of fruits and vegetables have been proven to be a valuable source of these molecules (Ramírez-Pulido et al. 2021). Their exploitation was shown to be particularly convenient for minimizing waste and reintroducing it into the production chain. In this sense, lowering agri-food wastes and byproducts to develop functional foods could limit resource depletion, economic loss, and environmental impact in a circular economy approach.

When considering fortified foods, many aspects need to be addressed, and the new ingredient must be carefully evaluated to clearly elucidate the composition in relation to the desired activity to be conferred. In this context, the research focused on the extraction and characterization of different carob leaf extracts from Selvatica and Amele cultivars. Carob leaves have been selected because they represent a byproduct of ancient cultivation in the Mediterranean basin and show great food potential (Brassesco et al. 2021). Several extracts were obtained using different extraction techniques and solvents. A complete characterization of each extract by liquid chromatography–diode array detection (LC-DAD) and colorimetric assays was then carried out to evaluate the suitability of the functional ingredient to be possibly included in a fortified food formulation.

35.2 Material and Methods

35.2.1 Chemicals and Reagents

Chlorogenic acid (CHA) was purchased from Phytolab (Aprilia, Italy). Gallic acid (GA), 4-hydroxy-benzoic acid (HBA), ferulic acid (FA), 4-hydroxy-coumaric acid (HCA), caffeic acid (CA), syringic acid (SA), catechin (CT), epigallocatechin

(EGC), epicatechin gallate (ECG), epigallocatechin gallate (EGCG), quercitrin (QU), myricitrin (MY), and rutin (RU) were purchased from Extrasynthese (Genay, France) and used as HPLC reference standards. Other chemicals and reagents were purchased from Merck (Darmstadt, Germany) and VWR International (Milan, Italy). Formic acid, ethanol, HPLC grade water, and acetonitrile were supplied by Merck Life Science S.r.l. (Milan, Italy). Other solvents and standards were purchased from Merck (Darmstadt, Germany).

35.2.2 Carob Leaf Extraction

The leaves of two carob cultivars, i.e. Selvatica (CS) and Amele (CA), were analysed. The extracts obtained using the ultrasound-assisted method (UAE) are labelled Carob Selvatica ultrasound assisted extraction (CSU) and Carob Amèle ultrasound assisted extraction (CAU), and those obtained using the Soxhlet CSS and CAS. Five solvents, absolute ethanol, water, acetone, ethyl acetate, and dichloromethane, were employed. One gram of freeze-dried CS and CA in 50 mL of solvent was sonicated for 30 min at 40 °C. The extracts were filtered on Whatman paper N°3 and freeze-dried (CSU5, CAU5) or under vacuum (CSU1–4, CAU1–4). CS and CA (1.0 g) in 100 mL of solvent were refluxed in a Soxhlet apparatus for 5 h. The extracts were filtered on Whatman paper N° 3, dried under vacuum, and stored at −20 °C before use.

35.2.3 Chemical Composition and Antioxidant Performances of the Extracts

35.2.3.1 Characterization of the Extracts by High Performance Liquid Chromatography–Diode Array Detection (HPLC-DAD)

HPLC 1260 (Agilent Technologies, Palo Alto, USA), with a degasser, quaternary pump solvent delivery, thermostated column compartment, and diode array detector, was exploited for polyphenol determination. The extracts (3 μL) were injected onto a reversed stationary phase column, Zorbax SB-C_{18} (Agilent Technologies, Palo Alto, USA) 3.5 μm (150 × 4.6 mm i.d.), protected by a precolumn, Gemini C_{18} (Phenomenex, Torrance, CA, USA) 5 μm (4 × 2 mm i.d.) and (maintained at 40 °C. Water/formic acid (99.9:0.1, v/v) (solvent A) and acetonitrile (solvent B) were adopted as mobile phases through a binary gradient with a total run time of 35 min. Five minutes were added to restore the starting conditions. The flow was maintained at 0.8 mL/min. DAD was between 190 and 400 nm, and absorbance was recorded at 360, 330, and 280 nm. Positions of absorption maxima ($\lambda_{max.}$), absorption spectra profile, and retention times (RTs) were matched with those of pure standards for identification. External calibration was carried out for quantification. The method was validated in terms of usual figures of merit (limit of detection

(LOD), limit of quantification (LOQ), linearity, precision, and analytical sensitivity).

35.2.3.2 Polyphenol Total Content and Antioxidant Performance

The total phenolic content (TPC), expressed in milligrams of gallic acid (GA) per gram of sample (mg GA/g sample), was determined using the Folin–Ciocalteu assay (Restuccia et al. 2019). The free radical scavenging properties of the extracts were estimated towards 2,2-diphenyl-1-picrylhydrazyl (DPPH) and (2,20-azinobis (3-ethylbenzothiazoline-6-sulphonic acid)) (ABTS) radicals and expressed in terms of IC_{50} (Restuccia et al. 2019).

35.3 Results and Discussion

35.3.1 Extraction Techniques and Parameters

It is now well established that the extraction technique applied for bioactive compound recovery from plant matrices is a crucial step for further analysis and characterization. In Tables 35.1 and 35.2, the analytical parameters related to UAE and Soxhlet extraction are reported. The classical method generally offers higher yields; however, the Soxhlet procedure is time-consuming and requires relatively large quantities of solvents, and the examined active components may degrade or oxidize due to the long processing times and high temperatures used.

In contrast, UAE is a simple, efficient, inexpensive, and environmentally friendly method of extraction. In this case, the disruption of the cell walls and the mass

Table 35.1 Ultrasound-assisted extraction of Carob Selvatica (S) and Amele (A) carob leaves

Samples		Extraction conditions				Yield	
Label	Amount (g)	Solvent	Volume (mL)	T (°C)	t (h)	w (g)	%
CSU1	1.0	Ethanol	50	40	0.5	0.070	7.0
CSU2	1.0	Acetone	50	40	0.5	0.040	4.0
CSU3	1.0	Ethyl acetate	50	40	0.5	0.034	3.4
CSU4	1.0	Dichloromethane	50	40	0.5	0.034	3.4
CSU5	1.0	Water	50	40	0.5	0.302	30.2
CAU1	1.0	Ethanol	50	40	0.5	0.147	14.7
CAU2	1.0	Acetone	50	40	0.5	0.112	11.2
CAU3	1.0	Ethyl acetate	50	40	0.5	0.038	3.8
CAU4	1.0	Dichloromethane	50	40	0.5	0.014	1.4
CAU5	1.0	Water	50	40	0.5	0.024	2.4

Table 35.2 Extraction process by Soxhlet of Selvatica (S) and Amele (A) carob leaves

Samples		Extraction conditions				Yield	
Label	Amount (g)	Solvent	Volume (mL)	T (°C)	t (h)	w (g)	%
CSS1	1.0	Ethanol	100	70	5	0.132	13.2
CSS2	1.0	Acetone	100	50	5	0.175	17.5
CSS3	1.0	Ethyl acetate	100	70	5	0.105	10.5
CSS4	1.0	Dichloromethane	100	30	5	0.098	9.8
CAS1	1.0	Ethanol	100	70	5	0.177	17.7
CAS2	1.0	Acetone	100	50	5	0.109	10.9
CAS3	1.0	Ethyl acetate	100	70	5	0.074	7.4
CAS4	1.0	Dichloromethane	100	30	5	0.038	3.8

transfer are linked to acoustic cavitation leading to both thermal and mechanical effects (Stavrou et al. 2018). Overall, UAE shows good extraction yields, significantly reduced processing times and lower temperatures, representing a convenient alternative for the extraction of thermally unstable molecules.

Considering the food application of the extract and the data evaluation, CSU5 seemed the best extract to be considered for new ingredient design and application. This choice, made because of the highest extraction yield, had to be confirmed by the total phenolic content and the antioxidant properties of each extract as obtained by colorimetric assays (Table 35.3).

As seen, being equal to the solvent, Selvatica-derived extracts showed better performances compared to Amele *cv* extracts, whereas among solvents, water showed the highest TPC and good IC_{50} values. Poor values for each experiment were recorded using dichloromethane, which was not exploited any further. All considered, antioxidant data confirmed CSU5 as the better extract to apply, as already hypothesized by previous data.

In this regard, LC-DAD data further confirmed the choice of CSU5 as the best extract to be used as a functional ingredient (Table 35.4). The results of this study showed that carob leaves contain varieties of individual components from several classes: simple phenols, polyphenols, free flavonoids, and glycosylated flavonoids (Stavrou et al. 2018).

Among them, the most abundant was the flavonol glycoside myricitrin (3-O-α-L-rhamnopyranoside of myricetin), claimed to exert antiallergic, anti-inflammatory, antioxidant, antifibrotic, and antiatherogenic effects as well as anti-obesity activity (Semwal et al. 2016). High concentrations of 4-HBA were also found in carob leaf extracts. This molecule has been proven to be highly effective as an antimicrobial, antialgal, anti-inflammatory, antiviral, and antioxidant agent widely exploited as a preservative in many drugs, cosmetic products, pharmaceuticals, food, and beverages (Banwo et al. 2021).

Table 35.3 Antioxidant features of Selvatica (S) and Amele (A) carob leaf extracts

Sample	TPC (mg AG/g extract)	IC_{50} (mg mL^{-1})	
		DPPH	ABTS
CSS1	60.0 ± 0.4	0.0138 ± 0.0006	0.0050 ± 0.0001
CSS2	67.1 ± 0.3	0.0180 ± 0.0007	0.0037 ± 0.0001
CSS3	37.4 ± 0.2	0.0179 ± 0.0007	0.0034 ± 0.0001
CSS4	14.3 ± 0.2	0.2510 ± 0.0074	0.1610 ± 0.0054
CAS1	61.9 ± 0.3	0.0132 ± 0.0005	0.0018 ± 0.0001
CAS2	69.0 ± 0.4	0.0170 ± 0.0007	0.0023 ± 0.0001
CAS3	26.8 ± 0.2	0.0510 ± 0.0006	0.0210 ± 0.0007
CAS4	5.3 ± 0.1	0.2010 ± 0.0061	0.1110 ± 0.0051
CSU 1	29.2 ± 0.2	0.0330 ± 0.0001	0.0037 ± 0.0001
CSU 2	28.1 ± 0.2	0.0372 ± 0.0001	0.0046 ± 0.0015
CSU 3	42.5 ± 0.3	0.0440 ± 0.0001	0.0106 ± 0.0007
CSU 4	18.0 ± 0.1	0.0904 ± 0.0016	0.0530 ± 0.0006
CSU 5	313.0 ± 0.4	0.0420 ± 0.0014	0.0072 ± 0.0002
CAU 1	58.7 ± 0.3	0.0160 ± 0.0007	0.0080 ± 0.0001
CAU 2	23.0 ± 0.2	0.0405 ± 0.0014	0.0125 ± 0.0007
CAU 3	15.2 ± 0.1	0.0720[a] ± 0.0015	0.0355 ± 0.0013
CAU 4	12.4 ± 0.1	0.0780 ± 0.0016	0.0380 ± 0.0016
CAU 5	174.4 ± 0.4	0.0180 ± 0.0006	0.0039 ± 0.0006

[a] IC_{30}

35.4 Conclusions and Future Perspectives

The agri-food sector originates throughout the whole food supply chain with many byproducts and wastes needing proper handling and disposal within the current bio-economy and sustainability framework. In this regard, the recovery of bioactive molecules from carob leaves represents a very challenging task from analytical and technological perspectives. In particular, the lack of a standardized extraction method underlines the importance of a proper choice of the extraction solvent and the applied temperature. In this sense, data collected in this study indicated that water was the most efficient solvent. At the same time, ultrasound-assisted extraction, avoiding extreme conditions, demonstrated more representative results. Owing to its composition and antioxidant features, the extract of Selvatica carob leaves (CSU5) represents a promising ingredient to be added during food production in relation to the many carob-related health-promoting effects (Rtibi et al. 2017). However, the sensory quality of enriched food products must be investigated since the addition could lower the product's sensory features and consumer acceptance. Moreover, the bioaccessibility and bioavailability of bioactive compounds should be assessed to estimate the nutraceutical potential of enriched products.

Table 35.4 Concentration (mg/g) of polyphenols in carob leaf extracts

Label	CSU1	CSU2	CSU3	CSU5	CSS1	CSS2	CSS3	CAU1	CAU2	CAU3	CAU5	CAS1	CAS2	CAS3
GA	0.67	2.09	0.023	2.46	2.27	1.16	0.085	0.95	1.63	tr	1.28	2.36	1.20	0.083
EGC	0.40	0.26	n.d.	1.04	0.87	1.00	n.d.	0.58	0.20	n.d.	0.59	0.90	1.03	n.d.
CHA	n.d.	n.d.	n.d.	0.023	n.d.	0.014	n.d.	tr	n.d.	n.d.	0.013	n.d.	0.014	n.d.
CT	0.44	n.d.	0.033	0.025	0.89	0.49	n.d.	0.64	n.d.	0.013	0.013	0.92	0.50	n.d.
HBA	27.15	27.61	2.96	35.34	30.50	18.12	6.96	29.91	20.71	1.2	20.14	42.20	19.47	6.74
EGCG	0.058	0.038	n.d.	0.39	0.058	0.028	n.d.	0.084	0.029	n.d.	0.21	0.060	0.029	n.d.
SA	0.066	0.066	n.d.	0.59	0.079	0.27	n.d.	0.095	0.050	n.d.	0.34	0.082	0.28	n.d.
HCA	tr	0.010	n.d.	0.054	0.039	0.11	n.d.	0.031	tr	n.d.	0.030	0.040	0.11	n.d.
RU	0.23	0.15	0.041	0.82	0.43	1.49	0.32	0.33	0.11	0.018	0.48	0.45	1.54	0.31
MY	11.38	8.50	1.66	37.80	10.80	24.16	23.65	6.39	6.38	0.71	20.79	21.51	25.68	22.89
ECG	0.38	0.35	n.d.	0.60	0.29	0.27	n.d.	0.55	0.26	n.d.	0.34	0.30	0.28	n.d.
FA	tr	tr	n.d.	tr	tr	0.015	n.d.	0.014	n.d.	n.d.	n.d.	tr	0.015	n.d.
QU	1.59	1.72	0.38	6.99	3.01	1.59	6.53	2.29	1.29	0.16	4.05	3.13	1.91	6.35

CHA Chlorogenic acid, *GA* gallic acid, *HBA* 4-hydroxybenzoic acid, *FA* ferulic acid, *HCA* 4-hydroxy-coumaric acid, *CA* caffeic acid, *SA* syringic acid, *CT* catechin, *EGC* epigallocatechin, *ECG* epicatechin gallate, *EGCG* epigallocatechin gallate, *QU* quercitrin, *MY* myricitrin, *RU* rutin

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Chapter 36
Carob Pods as a Source of Bioactive Molecules in the Preparation of Functional Jelly

Umile Gianfranco Spizzirri, Donatella Restuccia, Pasquale Crupi, Paolino Caputo, Marilena Muraglia, Filomena Corbo, Cesare Oliviero Rossi, Maria Lisa Clodoveo, and Francesca Aiello

Abstract The aim of this research was to employ the unripped pod of the carob tree (*Ceratonia siliqua L.*) as a source of molecules with remarkable health and nutraceutical properties. The extractions were carried out by the ultrasound extraction method, an eco-friendly procedure that, employing low temperatures, preserves bioactive molecules. The optimization of the extraction methods performed on *Selvatica* cultivar pods allowed the recovery of several fractions with different polyphenolic contents, deeply characterized in terms of antioxidant properties, as well as chemical composition. The extract that provided the best performance was involved in a radical reaction on the gelatin backbone, a natural polymeric matrix widely employed as a food ingredient. The grafting reaction was performed by a totally eco-friendly synthetic methodology involving ascorbic acid and hydrogen peroxide as initiator systems. The polymeric conjugate, showing remarkable antioxidant features, can potentially be used as a gelling agent in the preparation of jellies and/or candies with an added nutritional value, as well as prolonged shelf life compared to

U. G. Spizzirri (✉) · D. Restuccia · F. Aiello
Department of Pharmacy, Health and Nutritional Sciences, Department of Excellence 2018-2022, Edificio Polifunzionale, University of Calabria, Arcavacata, Italy
e-mail: g.spizzirri@unical.it; donatella.restuccia@unical.it; francesca.aiello@unical.it

P. Crupi · F. Corbo · M. L. Clodoveo
Interdisciplinary Department of Medicine, School of Medicine, University of Bari Aldo Moro, Bari, Italy
e-mail: pasquale.crupi@crea.gov.it; filomena.corbo@uniba.it; marialisa.clodoveo@uniba.it

P. Caputo · C. O. Rossi
Department of Chemistry and Chemical Technologies, Edificio Polifunzionale, University of Calabria, Arcavacata, Italy
e-mail: paolino.caputo@unical.it; cesare.oliviero@unical.it

M. Muraglia
Department of Pharmacy-Drug Sciences, University of Bari Aldo Moro, Bari, Italy
e-mail: marilena.muraglia@uniba.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_36

the conventional one, mainly attributable to the bioactive molecules coming from the carob pod extract.

Keywords Carob pod · Eco-friendly extraction · Antioxidant properties · Gelatin conjugate

36.1 Introduction

The carob tree is generally grown and evergreen on the coastline of the Mediterranean region (Stavrou et al. 2018). The average world production of carob from 2010 was variable, and in recent years, it underwent a significant decrease (Fig. 36.1a), ranging from 127,998 (2010) to 49,943 (2020) tonnes (FAOSTAT 2021).

The main producers are Portugal (29.8%), Italy (20.8%), Morocco (15.9%), Turkey (10.8%), Greece (8.9%), and Cyprus (5.4%) (FAOSTAT 2021) (Fig. 36.1b). According to the literature data, Italy is one of the major producers of carob in the world both for total production (28,910 tonnes) and harvested area (5576 ha), with a yield of 51,847 hg/ha. The carob is mainly widespread in the southern regions, mostly in Sicily and Apulia. The carob pod can be classified into two parts: kibble (80–90% w/w) and seeds (10–20% w/w) (Oziyci et al. 2014). The seeds are generally used to produce locust bean gum, which is a special gum for food and other industries. The kibbled pod is mainly used to produce carob powder by roasting and milling processes. Carob powder is generally employed as a substitute for cocoa because of its rich nutritional content (Yousif and Alghzawi 2000). Carob pods represent a valuable source of bioactive molecules that are potentially useful for the preparation of functional food. In this regard, eco-friendly extraction procedures were exploited to achieve extracts with remarkable antioxidant properties. Active compounds were then involved in a green radical process for the synthesis of a macromolecular conjugate able to be employed as an additive in the food industry. Gelatin was chosen as the polymeric system that was conveniently functionalized with the polyphenol moieties of the extracts, carrying on to a high-molecular-weight conjugate with significant antioxidant features.

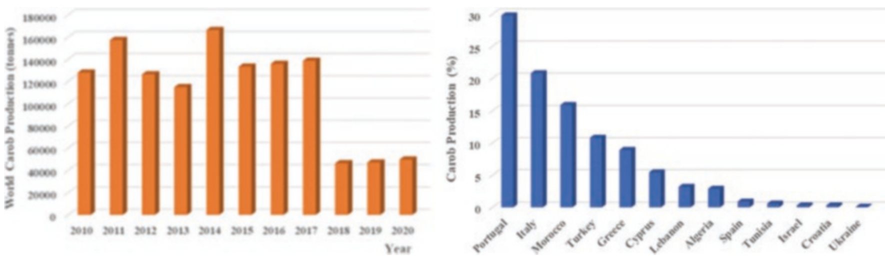

Fig. 36.1 Trend of the world production of carob from 2010 to 2020 (**a**) and production of carob by country (year 2017) (**b**)

36.2 Materials and Methods

36.2.1 Carob Pod Extraction

The pods used in this study were from the *Selvatica* carob tree (SCP). The extractions were performed by the ultrasound-assisted method (UAE), employing (1) water, (2) water/acetone (50/50 v/v), and (3) water/ethanol (50/50 v/v) as extraction solvents, to produce three different extracts, labelled CP1, CP2 and CP3, respectively (Table 36.1).

In a standard procedure, 1.0 g of freeze-dried SPC was suspended in 100 mL of solvent and sonicated for 30 min at 40 kHz and 40 °C. The extracts were filtered and freeze-dried until constant weight. Each extraction was performed in triplicate, and the data are expressed as the means (±SD). All the extracts were stored at −20 °C before the analysis.

36.2.2 Characterization of the Extracts by HPLC-DAD

Polyphenol analysis was carried out by HPLC-DAD (High Performance Liquid Chromatography-Diode Array Detector) at 360, 330, and 280 nm. The extracts (3 μL) were injected onto a reversed stationary phase column, Zorbax SB-C_{18} (3.5 μm; 150 × 4.6 mm i.d.), protected by a precolumn at 40 °C. Water/formic acid (99.9:0.1, v/v) and acetonitrile were adopted as mobile phases through a binary gradient (Clodoveo et al. 2022). Stop time was set at 35 min. The flow was maintained at 0.8 mL min^{-1}. Positions of absorption maxima (λ_{max}), absorption spectra profile, and retention times (RT) were matched with pure standards: gallic acid, 4-hydroxycoumaric acid, procyanidin B1, procianidin B2, quercetin, and myricitrin (Table 36.2).

Table 36.1 Ultrasound-assisted extraction of Selvatica unripped carob pods

Samples		Extraction condition				Yield	
Code	SPC (g)	Solvent	Volume (mL)	T (°C)	t (min)	Mass (g)	%
CP1	1.0	Water	100	40	30	0.38 ± 0.02	38 ± 2
CP2	1.0	Water/acetone	100	40	30	0.37 ± 0.02	37 ± 1
CP3	1.0	Water/ethanol	100	40	30	0.16 ± 0.01	16 ± 1

SPC Selvatica carob tree, *CP1* pod of *Selvatica* carob in water, *CP2* pod of *Selvatica* carob in water/acetone 50/50 (v/v), *CP3* pod of *Selvatica* carob in water/ethanol 50/50 (v/v)

Table 36.2 Chemical characterization of the extracts by HPLD-DAD

Compound	CP1	CP2	CP3
Gallic acid	3.30 ± 0.16	3.35 ± 0.02	3.58 ± 0.18
Procianidin B1	1.25 ± 0.06	1.19 ± 0.02	1.53 ± 0.08
Procianidin B2	0.72 ± 0.09	0.11 ± 0.02	0.90 ± 0.07
Myricitrin	0.53 ± 0.06	0.11 ± 0.02	0.57 ± 0.07
Quercetrin	1.24 ± 0.06	1.29 ± 0.03	1.60 ± 0.08

CP1 pod of *Selvatica* carob in water, *CP2* pod of *Selvatica* carob in water/acetone, *CP3* pod of *Selvatica* carob in water/ethanol

Table 36.3 Total phenolic content and antioxidant activity of the extracts from *Selvatica* carob pods

Samples	TPC (mg CT g^{-1} extract)	ABTS radical IC_{50} (mg mL^{-1})
CP1	185.2 ± 2.5	0.0136 ± 0.0011
CP2	311.5 ± 3.0	0.0094 ± 0.0003
CP3	275.6 ± 2.4	0.0420 ± 0.0011

CP1 pod of *Selvatica* carob in water, *CP2* pod of *Selvatica* carob in water/acetone, *CP3* pod of *Selvatica* carob in water/ethanol, *TPC* total phenolic content, *CT* catechin, *ABTS* (2,2′-azinobis (3-ethylbenzothiazoline-6-sulphonic acid))

36.2.3 Polyphenol Total Content

The total phenolic content (TPC) in the extracts, expressed in milligrams of catechin (CT) per gram of extract (mg CT/g extract), was determined using the Folin–Ciocalteu reagent by following literature protocols with some changes (Spizzirri et al. 2021) (Table 36.3).

36.2.4 Antioxidant Performances

The free radical scavenging properties of the extracts were estimated towards (2,20-azinobis (3-ethylbenzothiazoline-6-sulphonic acid)) (ABTS) radicals by following literature protocols with some changes (Carullo et al. 2020). The scavenging activity was expressed in terms of IC_{50} (Table 36.3).

36.2.5 Synthesis of the Conjugate

The synthesis of the gelatin conjugate was assessed following the general procedure according to a literature method, with some modifications (Spizzirri et al. 2021). Briefly, 500 mg of gelatine reacted with an amount of CP2 equivalent to 70 mg of catechin (CT), providing the macromolecular conjugate GCP2 (Conjugate of gelatin and extract of water/acetone *Selvatica* carob pod) . Additionally, blank gelatin (BG), exploited as a control, was prepared when the grafting process was carried out in the absence of the extracts.

36.2.6 Characterization of Gelatine-Based Polymers

The TPC and scavenger activity against ABTS radicals of GCP2, BG, and commercial gelatine (CG) were evaluated by following literature protocols with some changes (Restuccia et al. 2019), and the results are shown in Table 36.4.

36.3 Results and Discussion

Selvatica unripped carob pods underwent eco-friendly extraction processes based on the use of environmentally sustainable solvent mixtures, consisting of ethanol/water, acetone/water, and water, as reported in Table 36.1. To avoid the employment of high temperatures, the extraction procedures were assisted by ultrasounds. In a liquid medium, the collapse of the bubbles generated by ultrasounds has a strong impact on the solid surface and causes penetration of the solvent, thus triggering the release of bioactive molecules (Arun et al. 2020). The yields of the extractions appear quite similar by employing water or acetone/water as solvents (approximately 37% w/w), while the performance of the mixture water/ethanol is significantly reduced (16% w/w). A more detailed characterization of the extracts was performed by HPLC-DAD and by evaluation of the total phenolic content (TPC) and antioxidant performances (scavenger activity against ABTS radical).

HPLC-DAD analyses (Table 36.2) displayed relevant amounts of gallic acid and quercetin, while procyanidins B1 and B2 and myricitrin were also detected. The amounts of these compounds were quite similar in all the extracts, while gallic acid was the most abundant molecule.

The TPC values of carob pod extracts are reported in Table 36.3, and the CP2 extract displayed the highest amount (311 mg of CT per gram of extract) with respect to CP3 and CP1. These data were confirmed by experiments performed to

Table 36.4 Total phenolic and antioxidant activity of gelatine-based polymers

		IC_{50} (mg mL^{-1})
Code	TPC (mg CT g^{-1} polymer)	*ABTS radical*
GCP2	36.02 ± 2.11	0.0212 ± 0.0190
BG	5.53 ± 0.19	–
CG	2.36 ± 0.94	–

GCP2 conjugate of gelatin and pod of *Selvatica* carob in water/acetone, *BG* blank gelatine, *CG* commercial gelatine, *TPC* total phenolic content, *CT* catechin, *ABTS* (2,2′-azinobis (3-ethylbenzo thiazoline-6-sulphonic acid)). (−) Not detected or under the LOQ of the assay

determine the scavenger activity against hydrophilic ABTS radicals. Specifically, a significant reduction in the IC_{50} value was recorded for CP2, highlighting the remarkable antioxidant performance of this extract in an aqueous medium (Fig. 36.2).

This feature can be usefully exploited to perform the chemical conjugation of active molecules in the extract on a suitable macromolecular system. In this regard, gelatin was chosen as the polymeric backbone, and the grafting reaction was performed by an eco-friendly synthetic procedure (Spizzirri et al. 2009). Antioxidant conjugates are systems with remarkable chemical stability and a lower degradation rate compared to lower molecular weight molecules (Kurisawa et al. 2003) and therefore are very suitable for biomedical, cosmetic, and food applications. Specifically, to synthesize polypeptide conjugates with antioxidant activity, the reactive species present in the extract were linked to the gelatin chains using a water-soluble and biocompatible redox pair (H_2O_2/ascorbic acid) as the initiator system, showing several advantages, including the possibility of inducing polymerization processes at lower temperatures, thus reducing the risks of degradation of phenolic compounds and avoiding the generation of any type of toxic reaction product (Toti and Aminabhavi 2004). A specific CP2/polypeptide weight ratio was used in the polymerization mixture. A quantity of CP2 equivalent to 70 mg of catechin (calculated by TPC value) for each gram of gelatin was employed. Two polymers were thus synthesized: GCP2, obtained using the CP2 extract, and a control polymer (BG), prepared under the same conditions but in the absence of the extract. TPC and scavenger activity against ABTS radicals were evaluated, and the results are reported in Table 36.4. GCP2 showed a remarkable amount of disposable phenolic groups (36 mg of CT per gram of polymer) able to confer significant antioxidant performance (IC_{50} value equal to 0.0212 mg mL^{-1}). This activity was not recorded in BG or in the commercial gelatine (CG).

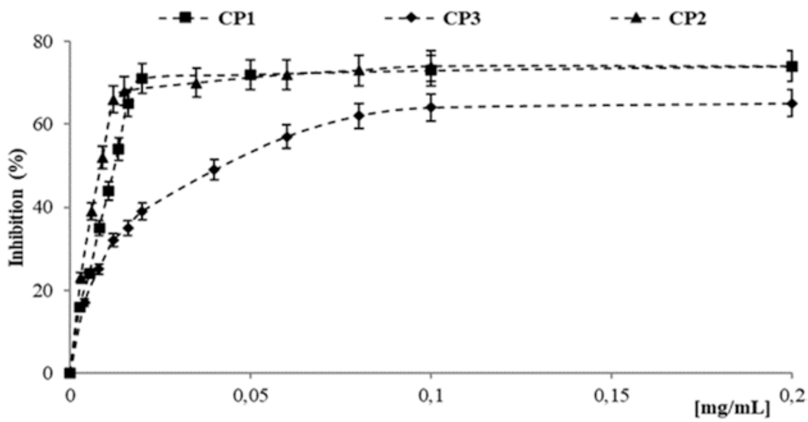

Fig. 36.2 Scavenger activity against ABTS radical of *Selvatica* carob pod extracts

36.4 Conclusions and Future Perspectives

Sustainable exploitation of unripped *Selvatica* carob pods can represent a viable system to reduce the environmental impact of the entire production process, as well as a significant starting point for increasing the economic value of this product. The proposed eco-friendly extraction procedure allowed us to obtain phenolic fractions displaying remarkable antioxidant activities in an aqueous environment, thus offering new horizons for the implementation of industrial food production. The conjugation of the phenolic compounds of the extracts into the gelatin chains was a valuable strategy for developing a high-quality product suitable for the organoleptic standards required by the consumer. Gelatin acts as an eco-sustainable macromolecular system and was involved in a grafting process with the pod extracts. Antioxidant assays of the conjugate highlighted its biological properties, confirming that the synthetic strategy allows improvement of the properties of the natural polymer, introducing new features into the protein for specific applications in the food industry. Our challenge will be to employ this functional polymer as a starting material for the preparation of jellies with significant chemical–physical, nutraceutical, and biological features. The substantial gap in terms of antioxidant activity between enriched jellies and conventional jellies should confer considerable added value to the functional product to make it immediately placed on the market.

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Chapter 37
Crocus sativus L. Flower's Valorization as Sources of Bioactive Compounds

Pamela Vignolini, Chiara Vita, Margherita Campo, Francesca Ieri, Arianna Bettiga, Riccardo Vago, Francesco Trevisani, and Annalisa Romani

Abstract The application of circular economy principles is of particular interest to the agricultural and agri-food sectors, given the large amount of waste matrix of some plant species. In recent decades, attention that has been given to the cultivation of saffron (*Crocus sativus* L.) has been rediscovered. The saffron produced from dried stigmas of *Crocus sativus* L. has been known since ancient times for its numerous therapeutic properties. The spice is obtained from the stigmas of the flowers, while petals and stamens are 90% waste material.

The recovery of the flowers, considering the considerable amount of polyphenols with high antioxidant activity present in this matrix (kaempferol and quercetin glycosides), allows its use for innovative purposes in different product sectors, such as foods, cosmetics, and biomedical applications. In this context, this work evaluated that the polyphenol content in flowers of *C. sativus* grown in Tuscanyto

Annalisa Romani died before publication of this work was completed.

P. Vignolini (✉) · M. Campo · A. Romani (deceased)
Laboratorio PHYTOLAB – DiSIA – University of Florence, Florence, Italy
e-mail: pamela.vignolini@unifi.it

C. Vita
PIN-QuMAP – Polo Universitario di Prato, Prato, Italy

F. Ieri
Laboratorio PHYTOLAB – DiSIA – University of Florence, Florence, Italy

INSTM – National Interuniversity Consortium of Materials Science and Technology, Florence, Italy

A. Bettiga · R. Vago · F. Trevisani
Urological Research Institute (URI), Division of Experimental Oncology, IRCCS San Raffaele Scientific Institute, Milan, Italy

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_37

characterizes this product from a qualitative–quantitative point of view for various product sectors. The quali-quantitative analysis of the extracts was carried out by HPLC/DAD/MS (high performance liquid cromatography coupled with diode array and mass specrometer) analysis. Given the potential of this matrix, another aspect of the research consists of evaluating the possible tumour growth inhibition activity on kidney and bladder cancer cell lines by the extracts of petals.

Keywords Circular economy · HPLC/DAD/MS · Saffron · By products · Biological activity

37.1 Introduction

Saffron (*Crocus sativus* L.) is known throughout the world for the expensive spice obtained from dried stigmas. In addition to its organoleptic properties, saffron spice is known for its therapeutic applications in many diseases, and its potential derives from the antioxidant and anti-inflammatory properties of its components, such as carotenoid pigments and their derivatives (Shahi et al. 2016; Cardone et al. 2020). In recent decades, the cultivation of saffron in Italy has received renewed attention, and total cultivation is increasing. However, saffron is characterized by an enormous amount of manual work, which is the main factor influencing the final cost (Alonso et al. 2012). Given the high cost of saffron spice, interest in possible alternative uses of waste matrices, including flowers and petals, is growing. Compared to stigmas, saffron produces a large amount of biomass given by flower byproducts: based on agronomic measurements, flower byproducts represent approximately 90%. In addition to stigmas, saffron petals have also been shown to have some bioactive compounds (Zeka et al. 2015). Saffron flowers are rich in phenolic compounds, such as kaempferol derivatives, which show interesting antioxidant, antimicrobial, and anti-inflammatory activities. Kaempferol derivatives are flavonols present in different plant species (fruit and vegetables) with antioxidant and anti-inflammatory activity with beneficial effects in reducing the risk of chronic diseases, especially cancer (Chen and Chen 2013; Devi et al. 2015). The pharmacological properties of saffron petals include antibacterial, antispasmodic, immunomodulatory, antitussive, antidepressant, and antinociceptive activities (Shahi et al. 2016; Hosseini et al. 2018).

Considering these results, in this study, we aimed to further characterize saffron byproducts from a phytochemical point of view. In particular, analyses were carried out to evaluate the phenolic content, and given the potential of this matrix, a further aspect of the research was to evaluate the possible activity of tumour growth inhibition on kidney and bladder cancer cell lines by the extracts of the characterized flowers.

37.2 Material and Methods

The plant material was kindly provided by a local farmer from Montalcino (SI) (Azienda Pura Crocus) in 2019 and 2021. The collection of saffron flowers is handmade. The flowers are harvested in October in the early morning, and the stigmas are separated from the other parts of the flower. Saffron flowers were dried at 40 °C, and 300 mg of dried flowers was extracted with 15 mL of 70% ethanol (pH 3.2 for HCOOH) for one night and then filtered to eliminate plant residues.

These extracts were analysed by HPLC/DAD/MS for the determination of phenolic compounds. An authentic standard of safranal was purchased from Sigma-Aldrich (St. Louis, USA), and pOH benzoic acid, kaempferol 3 glucoside, quercetin 3-glucoside, and curcumin were purchased from Extrasynthèse S.A. (Lyon, France). All solvents were of HPLC grade purity (BDH Laboratory Supplies, United Kingdom).

37.2.1 Phytochemical Analysis

37.2.1.1 HPLC/DAD/MS Analysis

The analysis of polyphenols was carried out using an HP 1260 liquid chromatograph equipped with a DAD detector and an API (atmospheric pressure ionization)/electrospray interface (Agilent Technologies, Palo Alto, CA, USA), and polyphenols were separated by using a 250 ∗ 4.6 mm i.d. 5 μm Luna C18 column (Phenomenex) operating at 25 °C. UV/Vis spectra were recorded in the 190–600 nm range, and chromatograms were acquired at 280, 330, 350, and 440 nm. The mobile phase was a two-step linear solvent gradient system, starting from 90% H_2O (adjusted to pH 3.2 by HCOOH) up to 100% CH_3CN during a 40-min period, flow 0.8 mL min^{-1}.

The MS analyses were conducted with the following ESI parameters: nitrogen flow rate 10.5 L/min, drying gas temperature 350 °C; nebulizer pressure, 1811 Torr; and capillary voltage, 3500 V. The experiments were carried out in positive and negative ionization mode.

Quantification of individual compounds was directly performed by HPLC/DAD using a five-point regression curve (r^2 = 0.998) in the range 0–30 μg on the basis of authentic standards. In particular, kaempferol and quercetin derivatives were determined at 350 nm using kaempferol 3-glucoside and quercetin 3-glucoside as reference compounds, respectively, and crocetin derivatives were determined at 440 nm using curcumin as a reference compound. In all cases, actual concentrations of the derivatives were calculated after applying, where possible, corrections for differences in molecular weight. The identity of polyphenols was ascertained using data from HPLC/DAD/MS analyses by comparison and combination of their retention times, UV/Vis and MS spectra with those of authentic standards and previously reported data (Vignolini et al. 2008).

37.2.2 Pharmacological Studies

37.2.2.1 Cell Culture

RT4 and RT112 human bladder cancer cells were maintained in RPMI 1640 medium supplemented with 10% foetal calf serum (FCS), 2 mM L-glutamine, and antibiotics (100 U/mL penicillin and 100 μg/mL streptomycin) at 37 °C with 5% CO_2.

37.2.2.2 MTT Viability Assay

Cultured cell lines (5 × 103 cells/well) were seeded in 96-well plates and incubated for 72 h with serial logarithmic concentrations ranking from to μM of kaempferol or flower extract at 37 °C, 5%. Cell viability was then quantified by 3-(4,5-dimethy lthiazol-2-yl)-2,5-diphenyltetrazolium bromide staining (MTT) (working solution 0.5 μg/mL). After 1 h of incubation, the supernatants were removed, the formazan crystals were dissolved in dimethyl sulphoxide, and the absorbance at 570 nm was measured using a microtiter plate reader.

37.3 Results and Discussion

37.3.1 Saffron Byproduct Characterization

The application of circular economy principles is of particular interest to the agricultural and agri-food sectors, given the large amount of waste matrices. Among these, the rediscovery of saffron cultivation in recent decades has also led to the production of high quantities of waste matrix. This spice is considered the most expensive in the world, but it is obtained only from the stigmas of the plant, and flowers (petals and stamen) represent a percentage greater than 90%. To enhance the waste matrices of saffron, the first step is to analyse and characterize the tissues to evaluate the presence of bioactive compounds. The flower extracts harvested in 2019 and in 2021 were analysed. The characterization of secondary metabolites was performed by HPLC/DAD/MS analysis. This technique allows us to acquire chromatograms at different wavelengths, obtain information on the retention times and UV/Vis spectra of each component present, and compare them with those of similar substances and/or known standards for injection under the same analytical conditions. In Table 37.1, we report the qualitative and quantitative analysis of the extract analysed.

In particular, we confirmed the presence of flavonols (kaempferol and quercetin derivatives), which represented approximately 79%, and crocins (20%); the percentage was comparable in the 2 years, even if the total amount was higher in the 2021 sample. In particular, kaempferol derivatives are the main compounds present,

Table 37.1 Polyphenol content of saffron flowers, years 2019–2021. Data are expressed as mg/g dry sample. Data are the mean of three determinations (standard deviation <5%)

	2019	2021
	mg/g DW	mg/g DW
FLAVONOLS		
k 3 sophoroside 7 glucoside	7.89	8.06
k diglucoside	0.12	0.09
q diglucoside	1.31	1.46
q diglucoside	0.05	0.66
Methyl q diglucoisde	1.54	1.76
k 3 sophoroside	56.40	62.52
k sinapoyl glucoside	1.05	1.47
k glucoside	1.20	1.86
k cumaroylglucoside	0.17	0.28
q cumaroylglucoside	0.03	0.05
Quercetin	0.05	0.03
Kaempferol	1.54	1.66
Myricetin	0.80	0.13
q derivatives	0.98	0.80
k derivatives	1.50	5.37
CROCINS	19.45	23.56
TOTAL	94.08	109.75

q=quercetin, *k*=kaempferol

and kaempferol 3-sophoroside is the principal compound, as reported in a previous work (Vignolini et al. 2008), representing approximately 58% of total polyphenols. Due to the reported data on antioxidant and anti-inflammatory activity with beneficial effects in reducing the risk of chronic diseases, in particular cancer (Chen and Chen 2013; Devi et al. 2015), studies were performed to evaluate the possible tumour growth inhibition activity of flower extracts on the kidney and bladder cancer cell lines.

37.3.2 Effect of Crocus Sativus Flower Extract on Bladder Cancer Cell Viability

The following are the preliminary results of the studies conducted by the Urological Research Institute (URI) on the effect of *Crocus sativus* flower extract on bladder cancer cell viability. The RT4 and RT112 bladder cancer cell lines were used to determine the activity of *Crocus sativus* flower extract. Cells were incubated with scalar concentrations of kaempferol 3-glucoside as a standard and with the extract, and then the cell viability was measured (Fig. 37.1). Kaempferol 3-glucoside did not exert any toxic effect on cells at any of the tested concentrations. On the other hand, the extract was toxic to both cancer cell lines, although to different extents.

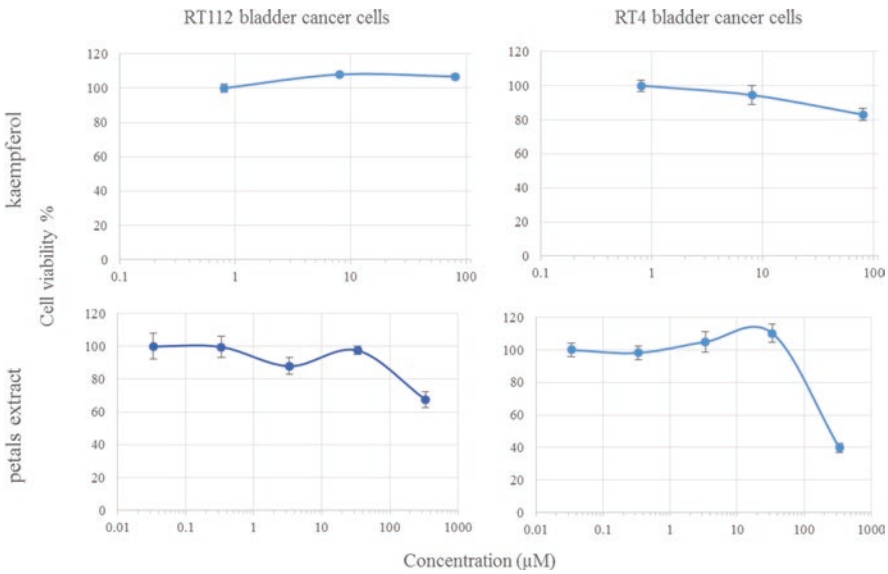

Fig. 37.1 Detection of cell viability of RT112 (left) and RT4 (right) bladder cancer cells incubated with increasing amounts of kaempferol 3-glucoside (top) or *Crocus sativus* petal extract (bottom) for 72 h. Reported values correspond to the mean of cell viability with standard deviation

This result suggests that the activity of the extract is unlikely due to kaempferol 3-glucoside at least alone but to the phytocomplex that contains it together with other flavonol derivatives, in particular kaempferol 3-sophoroside, which is the principal compound of the flower extract.

It is therefore clear that kaempferol derivatives, in particular kaempferol 3-sophoroside, are worthy of further studies to evaluate their activity.

37.4 Conclusions

The valorization of waste and secondary products has always been an important aspect of the agricultural sector, as well as a key element for the development of the circular economy in the agricultural context. Currently, the stigmas of saffron are used not only in the food sector but also in the cosmetic and phytotherapeutic sectors. Considering the tests and preliminary scientific tests, the evaluation of the use of the saffron flowers in the phytotherapeutic field could make it possible to use the entire flower for innovative production. The assessment of the therapeutic functionality of saffron waste tissues will allow an increase in the added value of saffron production itself.

Acknowledgements The authors wish to express their sincere gratitude to SaffronNutraMed-PEI-AGRI, PS-GO sottomisura 16.2 – PSR Toscana 2014-2020. We express sincere thanks to Azienda Pura Crocus ssa (Montalcino, SI) for the supply of saffron samples.

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Part IV
Consumers' Awareness and Behaviours: Circular Economy and Sustainability

Chapter 38
An Empirical Study to Understand Whether Sustainable Consumers Have Sustainable Behaviours

Tommaso Gallo, Francesco Pacchera, Cecilia Silvestri, Stefano Poponi, and Alessandro Ruggieri

Abstract Sustainability and the circular economy (CE) are issues of increasing interest to governments, investors, industry, and civil society, and for this reason, the implementation of a business model for circularity and/or sustainability is becoming crucial for achieving and maintaining a competitive advantage for various organizations. In this context, consumers play a crucial role in reducing the environmental impact of business processes through their choices and behaviours (van Bussel et al, J Clean Prod 341:130904, 2022). However, even though sustainability issues and the circular economy have now widely involved consumers, making them seemingly well aware of how their behavior can have a direct impact on the environment, the percentage of people who accompany this awareness with truly sustainable behaviour and who are therefore willing to embrace the goal of "saving the planet" is small (D'Arco, Marino, Transform Gov 16:185–202, 2022). Through an empirical survey, the research aims to understand the actual level of consumer awareness of sustainability issues, with a focus on the environmental dimension, and to analyse the main characteristics that distinguish a genuinely sustainable consumer, through his behaviour, from a less sustainable consumer.

Keywords Sustainability · Sustainable consumer · Sustainable behavior · Cluster analysis

T. Gallo (✉) · F. Pacchera · C. Silvestri · S. Poponi · A. Ruggieri
Department of Economics, Engineering, Society and Business Organization (DEIM), University of Tuscia, Viterbo, Italy
e-mail: tommaso.gallo@unitus.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_38

38.1 Introduction

Sustainability and circular economy (CE) are topics of increasing interest to governments, investors, industry, and civil society. For this reason, implementing a business model for circularity and/or sustainability is becoming critical to achieving and maintaining a competitive advantage for various organizations. It is not a coincidence that several approaches to innovation in business models have been proposed to meet the principles of circular economy or sustainability (Pieroni et al. 2019). In addition, with the growth of conscious consumers and the intention to make green and ethical purchasing decisions, companies must integrate sustainability and CE at the core of their business and look for new ways to grow by improving purchasing efficiency and meeting the rapidly evolving needs of consumers, although they must also build a value-sharing relationship with them (Purcărea et al. 2022). However, although consumers exhibit positive attitudes, they fail to put these attitudes into practice by engaging in responsible behaviour. In fact, despite policy pushes and initiatives, guiding consumer behaviour towards sustainable consumption is a challenging task (Francis and Sarangi 2022).

The purpose of this article is to understand, through an empirical investigation, the fundamental level of consumer awareness of sustainability issues, with a focus on the environmental dimension, and to analyse the main characteristics that distinguish a genuinely sustainable consumer, through their behaviour from a pseudosustainable consumer. Therefore, the chapter is composed as follows: in Sect. 38.2, the primary research in the literature on the topic of sustainable consumer behaviour is reported; in Sect. 38.3, the description of the methodology and the main results; Sect. 38.4, the discussions; and Sect. 38.5, the conclusions.

38.2 Review of the Literature

The transition to sustainability and CE involves several challenges not only in environmental and economic terms but also in social terms through effective management of all stakeholders in the closed system (Opferkuch et al. 2021; Ritzén and Sandström 2017; Stewart and Niero 2018).

In this context, consumers play a crucial role in reducing the environmental impact of business processes through their choices and behaviours (van Bussel et al. 2022). According to Leary et al. (2014), sustainable consumer behaviour is a type of behaviour that helps meet the current generation's needs without negatively affecting the ability of the environment to meet the needs of future generations. The responsible consumer seeks to consider economic (in terms of personal well-being), ecological (including animal welfare), and social aspects along the entire consumption chain, such as the type and number of products, their use, and disposal (Terlau and Hirsch 2015).

However, despite this apparent evolution of the consumer/citizen into an individual who is aware of the adverse effects caused by unsustainable human activities, such as climate change, loss of biodiversity, melting ice, plastic pollution, and ocean pollution, the percentage of people who accompany this awareness with truly sustainable behaviour and are therefore willing to embrace the goal of "saving the planet" is small (D'Arco and Marino 2022). The main obstacles that negatively affect sustainable consumption are high price, perceived lack of environmental impact, lack of benefit to personal image, less use by family and friends, and lack of product awareness (Harris et al. 2016; Sheoran and Kumar 2022). However, to bridge the attitude–behaviour gap and improve sustainable consumption, several concrete measures can be implemented to increase consumer responsibility. According to Gupta and Ogden (2006), consumer involvement in environmental issues and perceived consumer effectiveness are the main drivers that strengthen the attitude–behaviour link.

38.3 Material and Methods

38.3.1 Questionnaire and Data Collection

In this study, a questionnaire was prepared to investigate consumers' behaviour on sustainable consumption.

The research was performed in April and May 2021 through Google Forms and social media (Brito et al. 2021; Majeed et al. 2022; Sarfraz et al. 2021). The difficulty in clearly identifying the population of customers led to the adoption of a nonprobabilistic sampling scheme, specifically accidental sampling, as is widely used in market research (Bracalente et al. 2009).

The questionnaire analysed the following three sections:

- Consumer's analysis.
- Sustainable consumer behaviour.
- Consumer profile.

The Likert measurement scale was used to measure sustainable consumer perception with a score assigned to the respondents between 1 and 7, ranging from "strongly disagree" (scoring value 1) to "strongly agree" (scoring value 7) (Likert 1932). The questionnaire was submitted online with Google Forms, and the sample was composed of 410 individuals. Data were analysed using the statistic program "STATA 12 Data Analysis and Statistical Software" (www.stata.com).

38.3.2 Factor Analysis

Factor analysis (FA) made it possible to identify three factors that encompass 80.1% of the information contained in the original data set. For this reason, the first three factors were considered to identify the new variables. Factor interpretation was achieved by considering the so-called saturation matrix (Appendix A), where the correlations between the original variables and the factors were identified. Each variable is associated with others according to the highest correlation factor, and then this factor is interpreted according to the associated variables. Factor 1 synthesizes the variables related to customer awareness (such as global warming and water pollution). Factor 2 synthesizes the variables related to customer concern attributes (such as environmental deterioration and lack of attention by companies to the reuse of waste). Finally, factor 3 synthesizes the variables related to customers' mindshare (such as involvement in environmental issues and moral responsibility for green products).

38.3.3 Cluster Analysis

For this research, Ward's hierarchical method (Annunziata and Vecchio 2013; Dahl and Næs 2004) was used, and the number of groups was determined by inspecting the dendrogram. The number of clusters to be considered can be defined through the Calinski and Harabasz indicator and the dendrogram (Bracalente et al. 2009). Based on the correlation link intensity, it is possible to define the characteristics of the four clusters (Table 38.1).

Finally, Table 38.2 summarizes the socio-behavioural characteristics of the four clusters.

Table 38.1 Cluster analysis – correlation link intensity

Cluster	FA1 – awareness	FA2 – concern	FA3 – mindshare
CL1 – sustainable consumer	0.02	0.48	0.61
CL2 – fake sustainable consumer	0.57	−1.33	0.18
CL3 – not engaged consumer	0.51	0.48	−1.13
CL4 – not sustainable consumer	−2.15	−1.14	−0.80
Total	1.77E-09	3.28E-09	−2.66E-09

Source: Elaborated by the authors using the created data set

Table 38.2 Cluster characteristics

Cluster	Gender	Age	Job	Educational qualification	Purchase of sustainable products	Communication channels	Environmental sustainability importance	Environment attention
Cluster 1 – "sustainable consumer" – 50%	Female	>46	Office workers or homemakers	University graduates	4 or more times a week	Newspapers, TV, radio, social media, personal experience, flyers, and environmental organizations	High (score 7)	Yes
Cluster 2 – "fake consumer"– 17.32%	Male	26–35/46–55	Freelancers, blue-collar workers, and retirees	Bachelor's degree to a postgraduate degree	Up to three times a week	Newspapers, TV, radio, social media, personal experience, flyers, and environmental organizations	Medium (score 4–6)	No
Cluster 3 – "not engaged consumer" – 22.44%	Male	<25/36–45	Unemployed	High school diploma	Once a week	Newspapers, TV, radio, social media, personal experience, flyers, and environmental organizations	Medium – High (score 5–6)	No
Cluster 4 – "not sustainable consumer" – 10.24%	Male	<25 46–55	Office workers, homemakers, and retired	High school diploma	Once a week	Little importance	Low (1–5)	No

Source: Authors' elaboration from previously created data set

38.4 Discussions

The analysis developed in this research shows significant findings regarding sustainable consumer behaviour. The study aims to understand whether consumers who claim to be attentive to sustainability adopt sustainable behaviours.

The results show that out of four clusters, only one (cluster 1 – sustainable consumer) is composed of genuinely attentive individuals to environmental issues, accompanying their awareness with sustainable behaviours. These individuals gather information about environmental problems using all the communication channels at their disposal. This is significant given the importance of communication/educational channels in supporting the consumer at the time of purchase (Eldesouky et al. 2020). A greater degree of consumer education often goes hand in hand with a better understanding of environmental issues. Consumers show greater sensitivity or willingness to consider them as relevant attributes during their purchases (Eldesouky et al. 2020).

Additionally, consumers are unwilling to pay for the type of products they are least aware of and have never seen any advertising (De Pelsmacker et al. 2005). This demonstrates the importance of using appropriate communication channels to inform consumers about the environmental aspects of products. Lack of awareness/advertising regarding sustainable products among consumers reduces the likelihood of further purchase/use (Annunziata and Mariani 2018; Biel et al. 2005; Carol Cavender 2018; Wheale and Hinton 2007; Young et al. 2009), becoming a significant barrier to sustainable consumer behaviour.

Among the communication channels contemplated in this research, personal experience emerges. Individuals in cluster 1, for their purchases, seem to rely heavily on their past experiences, assigning a score of 7 (Likert scale 1–7) to the importance this factor has on their purchase choices, in line with the literature (Bernard et al. 2015). This aspect is crucial. A sustainable consumer who has positive shopping experiences can contribute to positive word of mouth, breaking down one of the main barriers highlighted by Sheoran and Kumar (2022) related to friends and family not using sustainable products. According to Öberseder et al. (2011), negative experience and subsequent negative word of mouth can discourage the purchase of a particular product, even if it is environmentally friendly or made by a socially responsible company.

Another significance is related to gender and age, i.e. the two demographic variables considered most important in analysing consumer behaviour (Jegethesan et al. 2012; Rahman and Koszewska 2020; Seock and Bailey 2008; Zelezny et al. 2000).

Cluster 1 predominantly comprises women, highlighting that the female gender is more sustainable than the male gender. Previous studies focusing on sustainable consumer behaviour have found a robust "gender effect": Women are more likely than men to express concern about consumption's broader impacts and act on those concerns (Luchs and Mooradian 2012). Therefore, women are more concerned about social and environmental issues and report more socially and environmentally friendly purchasing behaviours (Luchs and Mooradian 2012).

Cluster 4 comprises individuals who do not pay any attention to environmental issues and assume unsustainable behaviours. According to some authors (Abdul Rahman et al. 2017; Chang et al. 2015; Godard et al. 2002), young people tend to pay more attention to a product's aesthetic aspects (attributes based on desire/hedonic) than to functional and sustainable ones. Another critical aspect that young people consider when purchasing a product is the economic aspect, followed by the social and environmental aspects (Pena-Cerezo et al. 2019). This means that young people would adopt sustainable behaviours if the prices of green products were not as high as they often are. Price is one of the significant obstacles that has emerged in the literature (Sheoran and Kumar 2022).

In this context, it thus appears that people tend to place a higher priority on utilitarian and sustainable values as they age. Indeed, the age that characterizes cluster 1 is above 46 years old. The result obtained in our study is also reflected in another study. For example, (Apostolidis and McLeay 2019) showed that consumers who adopt sustainable behaviours, such as consuming less meat to reduce environmental impact, are those who are over 46 years old and female.

The individuals who make up cluster 2, "Fake consumers," are individuals who rarely use existing communication tools to acquire information about purchases. This demonstrates (1) how a lack of information and education negatively affects sustainable behaviours (Eldesouky et al. 2020) and (2) that individuals in this cluster could fall into the category of those individuals who perceive information messages about environmental consequences as manipulative. People's resistance towards pro-environmental behaviour could arise due to the psychological distance of environmental threats (Gifford 2011; Milton 2010) or habit (Verplanken and Roy 2016), rejecting all "what is perceived as a power, a pressure, an influence, or any attempt to act upon one's conduct" (Roux and Izberk-Bilgin 2018). Finally, according to Sheoran and Kumar (2022), consumers tend not to buy a green product because of their mindset, believing that their effort is not enough to change overall consumer behaviour.

Finally, cluster 3, "not engaged consumers," includes individuals who do not appear to be involved in environmental issues and, for that reason, state that they do not consider themselves sustainable consumers. Information asymmetry decreases consumer expertise in sustainable products. This lack of expertise correlates with low consumer empowerment, vital for long-term sustainable consumption choices (Balderjahn et al. 2020).

38.5 Conclusions

The aim of this research was to analyse whether consumers who declare themselves environmentally aware adopt sustainable behaviour. Based on the 4 clusters identified in this study, only one (cluster 1 – "sustainable consumer") comprises individuals who declare themselves attentive to environmental issues and accompany this awareness with natural, sustainable behaviour. The other clusters are instead composed either of individuals who are indifferent to environmental issues (cluster 4 – "not sustainable consumer") or of individuals who, despite showing a minimum of attention to sustainability, do not behave sustainably (cluster 2 "fake consumer") or lack involvement (cluster 3 – "not engaged consumer").

From a scientific point of view, it would be appropriate to go deeper into the theme of sustainable consumer behaviour, focusing both on the sociodemographic dimensions of consumers and on how digital tools can contribute to improving sustainable behaviour. However, the research has limitations, primarily the sample size, the sampling method itself (not accidental probabilistic), and the national nature of the research. Future avenues of research should broaden the survey and include consumers who also live abroad. A more in-depth study of this topic could focus on communication tools and then analyse the impact of new digital tools on individuals' sustainable behaviours.

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Chapter 39
Greenwashing and Consumer Awareness of Environmental Issues: A Pilot Analysis

Michela Piccarozzi, Tommaso Gallo, and Cecilia Silvestri

Abstract Sustainability and the circular economy are topics of great interest in management, and in recent years, they have assumed considerable prominence in marketing and its strategies. Research interest in the topic is prompted by the presence of questions that are related to "green" marketing and require a more thorough approach to the study of this problem. In addition, one of the most important components of "green marketing," namely, the phenomenon of "greenwashing," also remains unexplored. The area of this work is "greenwashing" as one of the phenomena of "green" marketing. The subject of the research is a pilot analysis of consumer awareness of the "greenwashing" phenomenon in Italy. The method used is a survey and expert (in-depth) interviews. This study makes a theoretical contribution to solving one of the pressing problems of environmental marketing – the problem of ignorance about one of the phenomena of unfair marketing – greenwashing.

Keywords Green marketing · Greenwashing · Communication · Consumers · Survey · Interview

39.1 Introduction

Climate change and environmental disasters indicate that humanity is fearlessly destroying the environment (Orr 2004). The main aim of ecological or "green" marketing is to make a green market and increase demand for products that do the least harm to the environment (Boztepe 2012). Green marketing has a special task here; it can become fundamental for changing not only the opinion of consumers but also their lifestyle and attitude towards natural resources (Delafrooz et al. 2014).

M. Piccarozzi (✉) · T. Gallo · C. Silvestri
Department of Economy, Engineering, Society and Business Organization, University of Tuscia, Viterbo, Italy
e-mail: piccarozzi@unitus.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_39

However, in today's competition, companies and manufacturers face different challenges. Companies must continue to make their products attractive, as well as interesting for consumers, since the understanding of sustainability has not yet been fully entrenched in our society. Green marketing, in this sense, offers ideal entry points for behavioural change in both segments. However, recently, a phenomenon called "greenwashing" has become widespread (Delmas and Burbano 2011). It indicates the communication strategy of certain companies aimed at constructing a deceptively positive self-image in terms of environmental impact to divert public attention from the negative environmental effects of their activities or products (Seele and Gatti 2017). The effects on consumers and their knowledge of greenwashing are only partly analysed in the literature (Nyilasy et al. 2014). In this context, the aim of the chapter is to analyse the phenomenon of greenwashing by directly studying consumer behaviour and its influence. To this end, the questionnaire tool will be used for an initial pilot survey of Italian consumers. The survey will be supplemented with targeted interviews with green marketing experts. The chapter is structured with a literature review on green marketing and greenwashing, followed by a description of the applied methodology, results, and discussions. The chapter concludes with final considerations, limitations, and implications.

39.2 Green Marketing and Greenwashing

Various definitions of the term "green marketing" can be found today (de Freitas Netto et al. 2020). Peattie and Charter (2003, p. 727) define green marketing as "*a holistic management process that is responsible for identifying, awakening, and meeting customer needs using the principles of environmental sustainability.*" According to Ottman (2011), green marketing has two main goals: the development of a "green" product, that is, reaching agreement between consumer expectations; the second goal is to "green" the company that must act as "environmentally conscious." To achieve the second goal, companies can use communication tools. Environmental friendliness changed the consciousness of the current consumer, teaching them environmental responsibility (Leonidou and Leonidou 2011). The term "greenwashing" was coined for the first time in 1986 by Jay Westerveld. It is used to describe the dissemination of false information, for example, in advertising and public relations, to give a company or product a particularly green image (Delmas and Burbano 2011). Some authors (Laufer 2003; Ramus and Montiel 2005) described greenwashing as "corporate disinformation" or the act of misleading consumers regarding the environmental practices of organizations or the environmental benefits of a product or service (Delmas and Burbano 2011). Several factors can lead companies to fall into the trap of greenwashing (Ruiz-Blanco et al. 2022). Delmas and Burbano (2011) assume that the main drivers can be subdivided into three sublevels: external, organizational, and individual reasons. The controversial issue is whether greenwashing is always deliberate or accidental or whether it arises in the absence of clear clarification, negligence, naivety, or indifference

(Furlow 2010). Therefore, honest environmental statements from critical groups can also be interpreted as greenwashing (Du 2015). However, the study of this phenomenon is still scarce and inconsistent, and one can distinguish the effect of greenwashing into two main categories: a macro and a micro effect (Ha et al. 2022). The first level encompasses the financial aspect, while the second concerns the effect on consumers of messages tainted by falsehood and deception (De Jong et al. 2018). This work focuses on the second aspect by investigating not the effect but the preceding dynamic.

39.3 Material and Methods

The methodology used is both qualitative and quantitative (Marsh 1982; Bryman 2003). Interviews were conducted with experts (two experts, an eco-activist and eco-blogger and an environmental engineer and eco-activist), and a survey was administered to Italian consumers (Roberts 1999). Selection in such a sample was carried out according to a subjective criterion – availability, typicality, etc. In addition, the spontaneous sampling presupposed a survey of the most accessible respondents; therefore, the size and composition of the sample were not known in advance and were determined by only one parameter: the activity of the respondents. At the third stage, a survey form was created in the Google Forms service, which was subsequently posted on social networks. The survey involved respondents of different professions, different sexes, and ages, which made it possible to study in more detail the general characteristics inherent to Italian consumers.

39.4 Results

39.4.1 Interviews

Both experts expressed their dissatisfaction with the ecological situation in Italy, which requires significant adjustments. Experts point to a slow definition and implementation of environmental policies compared to the international landscape. Regarding the changes and trends that have occurred in the last 2–3 years, experts note that consumers have become more "sensible." Italian experts are willing to pay an excessive price for a product if it is proven to be environmentally friendly. Experts prefer to buy a proven environmentally friendly product at a high price because they are convinced environmentalists and try to be conscientious consumers as much as possible. To distinguish unscrupulous companies from bona fide ones, the experts believe that it is necessary to examine the actions of such companies, particularly if prices are excessively low and there is a lack of transparency, aggressive marketing strategies, and product quality. Both experts were aware of the phenomenon of greenwashing and gave their free interpretations, stating that it is bad green marketing, misleading consumers about an organization's environmental practices or the environmental benefits of a product or service. Both experts believe that the main method to tackle greenwashing is complete transparency on the part of manufacturers. They believe that the more honestly a manufacturer communicates with its customers, the easier it is to separate bad marketing from good marketing.

39.4.2 Survey

The structure of the questionnaire included a preamble, which revealed the purpose of the study; consumer portrait (questions 1–6, in which personal information about the respondent was collected); and the main part (questions 7–15, in which open and closed questions were placed to test the hypotheses and subhypotheses of the study). The questionnaire was posted on the social networks of Instagram and Facebook. The total number of respondents who took part in the survey was 101 who were Italian consumers, and there were no excluded responses. The survey was conducted between February 2022 and April 2022. The sample consisted of 58.4% women. The age cluster with the highest response is 18–25. Approximately 50% of the sample respondents have children and are married. The sample is predominantly located in the cities of Rome (37%) and Milan (30%). Concerning interest in environmental and ecological issues, 53.5% replied that they were interested, and about factors influencing the choice of purchase, 18.8% stated that they chose based on the presence of environmental certifications and/or labels. Many respondents (38%) consider only price as the determining factor in their choice. Moreover, consumers pay great attention to ecolabels and certificates and are willing to buy products labelled "bio," "eco," and "organic" (66.3%). A total of 63.4% of the consumers surveyed did not recognize counterfeit ecolabels and expressed their willingness to buy a similar product. Italian consumers sorted garbage (69.3%), stopped using plastic bags (44.6%), and sorted clothes (30.7%). Regarding "greenwashing," only 22 people were able to explain what greenwashing is, while 79 people said they did not know the meaning of this phenomenon. A total of 61.4% are ready to overpay for an environmentally friendly product, while only 38.6% prefer a product for a low price. Finally, 63.4% of consumers treat Italian producers better than foreign producers.

39.5 Discussions

The results from the interviews and survey, albeit partially, underline the impressions of experts and consumers on the environmental issue and its impact on consumer choices. In particular, the awareness of environmental protection through production represents the best weapon to defend consumers in understanding possible greenwashing phenomena. The experts identify him as environmentally irresponsible. Although consumers are willing to buy an environmentally friendly product, companies may use greenwashing as a technique to deceive them. Furthermore, experts believe that the more honestly a manufacturer communicates with its customers, the easier it is to separate bad marketing from good marketing. From the experts' opinion, there seems to be a need for more consumer education towards sustainable and green purchasing choices. This process must start with institutions, creating awareness in the minds of consumers and directing them towards a sustainable lifestyle. On the side of consumer research, we can gather some first important information on consumer behaviour. First and foremost, they seem to be aware of and oriented towards making sustainability-oriented choices, both in their purchases and in their daily life at home. Based on the results, consumers are attentive to the presence of eco-labels and certificates on the product, but they are not always fully aware of it. Indeed, regarding the knowledge of the counterfeit eco-labels, 63.4% of the respondents are not able to recognize them. Thus, consumers often trust the presence of one or more eco-labels without, however, understanding whether this is real and concrete. We can therefore say how the physical attributes of the product, primarily the packaging, are decisive in the choice and often misleading. However, at the same time, there is greater consumer awareness (50% of consumers surveyed) of the phenomenon of greenwashing. Some consumers are attracted to packaging and certification marks, even if they are not fully aware of them, and the colours, logos, and physical aspects of packaging can very easily mislead/confuse them.

39.6 Conclusions

During this study, the terminology of the phenomenon of greenwashing and related concepts was studied. During the analysis, the characteristics of consumers were identified, and their behaviour in the ecological market was described. Additionally, the study devoted considerable time to reducing the impact of this phenomenon on both consumers and conscientious manufacturers. The chapter shows theoretical and managerial implications. From a theoretical point of view, the research aims to fit into the panorama of studies on consumer behaviour in relation to environmental issues, partly contributing some useful information to understand the evolution of consumer attitudes in light of the recent pandemic. From a managerial point of view, the chapter aims to provide entrepreneurs with the consumer's view on environmental issues and the attention given to products, their characteristics and communication by companies about environmental sustainability. Entrepreneurs can understand from some considerations how consumers are more attentive and less conditioned by the mere external appearance of the product, for example, and are able to understand real attention to the environment from untruthful or greenwashing-oriented communication. Moreover, it is important to note that the chapter has limitations. In particular, the small number of experts and questionnaire responses and questions asked allows only a partial analysis of the situation.

This survey can be expanded to fully investigate the characteristics of consumer choices and the tools that can defend them from false corporate communications or products that are not truly green. The prospect of research may be to consider greenwashing in other countries and a detailed description of consumer behaviour in each of them.

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Chapter 40
What Factors Influence Post-COVID-19 Consumer Purchase Habits? An Empirical Survey in the Italian Agri-food Sector

Maria Giovina Pasca, Gabriella Arcese, Stefania Supino, and Grazia Chiara Elmo

Abstract The study investigates the change in the purchasing practices of agri-food products, analysing whether traditional, health, and environmental aspects influence postpandemic purchasing intention.

The empirical study conducted in Italy aims to understand the state of the art and investigate consumer behaviour in the agri-food system after the pandemic. Thereafter, a quantitative analysis was conducted, and the theoretical model was analysed through structural equation modelling techniques.

The findings show that health and traditional aspects (culinary traditions, ingredient usage from one's territory of origin, and product origin attention) are among the main reasons for purchasing agri-food goods after the pandemic. Instead, environmental aspects negatively affect consumers' purchase intentions.

The research provides insights for food companies and governments by highlighting the aspects to be improved to optimize the agri-food sector following a sustainable perspective.

Keywords Agri-food products · Consumer habits · COVID-19 · Traditional aspects · Health awareness · Environmental concerns

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M. G. Pasca (✉) · G. Arcese
Faculty of Economics, Niccolò Cusano University, Rome, Italy
e-mail: mariagiovina.pasca@unicusano.it; gabriella.arcese@unicusano.it

S. Supino
Department of Human Science and Promotion of the Quality of Life, San Raffaele University, Rome, Italy
e-mail: stefania.supino@uniroma5.it

G. C. Elmo
Department of Economics, Business, Mathematics and Statistics, University of Trieste, Trieste, Italy
e-mail: graziachiara.elmo@units.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_40

40.1 Introduction

The COVID-19 pandemic has changed food consumers' purchasing habits (Desa and Jia 2020; Phillipson et al. 2020). The effects of pandemic restrictions on consumer purchasing behaviour involve multiple aspects (Mishra et al. 2021). Consumers are the subjects who are mainly affected by the pandemic, as they are the final recipients of all productive and commercial efforts and the efforts of various organizations (Hesham et al. 2021; Poelman et al. 2021). The literature highlights that food choices are associated with mental and physical health (Chen 2009; Michaelidou and Hassan 2008). Furthermore, unsustainable production and consumption have favoured greater environmental awareness among individuals, consolidating new consumption models (Sobhani et al. 2018). In recent months, due to restrictions on mobility, consumers' preferences switched towards local and fresh products that follow culinary traditions and preferred to shop at proximity stores (Rahmani et al. 2020). However, the growing concern for the environment translates globally into the demand for green products associated with increased awareness of healthy living (Thøgersen et al. 2015). Additionally, sustainable development goal 2 "Zero Hunger" of the 2030 Agenda promotes the pursuit of sustainable development by focusing on the agri-food system to provide all countries with healthy and sustainable food products. Despite differences in consumers' food habits emerging before and during the pandemic, the aspects that influence food purchasing habits after the health crisis have not been delved (Marinković and Lazarević 2021). In light of this, our study analysed the aspects that influence the change in food habits. Empirical research was conducted in Italy to understand whether tradition, health, and environmental aspects influenced consumers' food purchase intention. The chapter is structured as follows: Sect. 40.2 presents the literature review highlighting the research gaps. Section 40.3 explains the methodological approach, and Sect. 40.4 illustrates the results and the discussion of our empirical study. Finally, Sect. 40.5 provides conclusions and future research paths.

40.2 Theoretical Background

The intention to purchase translates into the willingness to purchase a specific product or service (Astuti and Asih 2021). Purchase intention predicts future consumer behaviour (Espejel et al. 2007). Pramono and Ferdinand (2012) identify four indicators through which it is possible to identify the interests of purchase: transactional interest, which is the predisposition of an individual to buy a product; reference interest, which is the tendency of an individual to refer to the products of other individuals; preferential interest, which represents the behaviour of those who prefer a given product; and exploratory interest, which describes the behaviour of an individual in researching the additional information about the product of interest. The literature has highlighted the importance of identifying the aspects that may influence the consumer's intention (Ferraz et al. 2017). Monitoring consumer intentions allows the development of effective business strategies to improve the agri-food system.

The restrictions to contain the health pandemic have generated an increase in the purchase of local products and oriented their preferences on products made with techniques typical of the area and on local traditions (Wachyuni and Wiweka 2020; Palau-Saumell et al. 2021). Jordana (2000) defines the traditional aspects as follows: "To be traditional, a product must be linked to a territory and it must also be part of a set of traditions, which will ensure its continuity over time." The perception of the consumption of traditional foods is linked to daily consumption, associating the habit of traditional food products (Guerrero et al. 2009). Consumers perceive these traditional foods to be healthier and more quality (Sadílek 2018).

To understand the influence of traditional aspects on food purchasing intention post-COVID-19, we developed the following hypothesis: *H1*-Traditional aspects impact consumers' food purchase intention.

Consumers increasingly adopt protective measures to improve and/or sustain their state of well-being through healthy behaviours, such as consuming natural and healthy food products (Imani et al. 2021; Sobhani et al. 2018). Indeed, consumers, to preserve their health, check the ingredients, origin of raw materials, nutritional values, and presence of preservatives (Katt and Meixner 2020). The literature has highlighted that buyers of organic and environmentally friendly products are more aware that food intake affects their health (Michaelidou and Hassan 2008). Health awareness fosters an attitude towards purchasing healthy foods (Mai and Hoffmann 2012). Therefore, the following research hypothesis is formulated: *H2*-Health aspects positively influence consumer intention when purchasing food.

The consequences of unsustainable consumption and lifestyles have led to greater environmental awareness among individuals (de Watanabe et al. 2020). Webster (1975) defined environmental concerns "as the extent to which an individual takes the environmental consequences of his/her consumption into account." Environmental concerns influence consumer behaviour to purchase healthy and organic foods (Imani et al. 2021; Sobhani et al. 2018). Based on the previous literature, this research hypothesis has been proposed: *H3*-Environmental aspects influence consumers' food purchase intention.

40.3 Methodological Approach

The study aims to analyse how consumer food purchasing intention changed post-COVID-19. An empirical study involving Italy was developed. Based on literature and scales validated in other studies, the authors developed a questionnaire to investigate the effect of traditional, health, and environmental aspects on consumers' food purchasing behaviour.

First, the questionnaire was tested through a pilot survey of 30 respondents in October 2021 to ensure the clarity and consistency of the items. Then, the survey was administered online (on social networks) from November to December 2021 to a convenience sample to test the research hypotheses of the theoretical model proposed. The questionnaire was structured in five sections (traditional aspects; health aspects; environmental factors; purchase intention, and sociodemographic characteristics) using a 5-point Likert scale (1 = disagree; 5 = agree).

There were 622 completed questionnaires. The data were analysed with descriptive and multivariate statistical techniques using the SPSS and Mplus software. The model was tested using structural equation modelling (SEM), a method used to evaluate the relationships between variables (Ullman and Bentler 2003) and verify the model's goodness of fit.

40.4 Results and Discussions

The sample was composed of 622 individuals: 51% (340) males and 49% (322) females. Most of the sample was in the age range 26–41 (40%; 261) and 41–65 (35%; 231). The other age groups are distributed as follows: 18–25 (24%; 161) and over 65 (1%; 9). The sample consisted of students (17%), employees (66%), freelancers (12%), unemployed (3%), and retired (2%). A total of 390 (59%) of the individuals followed a Mediterranean diet, and most of the sample preferred to buy food in the physical shop (95%). The existing relationship between constructs in the theoretical model was tested with structural equation modelling (SEM). The analysis suggested that goodness-of-fit indicators were *(Chi-squared): 2338.473; df: 66; p value: 0.000; standardized root mean square residual: 0.042; comparative fit index: 0.953; Tucker–Lewis index: 0.935; root mean square error of approximation: 0.058 (0.048–0.069)]*, as the values fall within the thresholds proposed by the literature (Byrne 2012; Hu and Bentler 1999; Browne and Cudeck 1992). The analysis showed that the regression coefficients were all significant ($p < 0.05$). Indeed, the observed model supports the hypothesis that the factors "traditional aspects" (H1; $\beta = 0.581$) and "health aspects" (H2; $\beta = 0.551$) positively influence postpandemic food "purchase intention." The "environmental aspects" (H3; $\beta = -0.382$) negatively influence purchase intention. The research highlighted an increase in purchases made of Italian products or typical products of the country. Consumers have tried to consume local products and traditional products of the culinary tradition, as they are considered healthier. After the health crisis, consumers are increasingly attentive to their well-being and health. In light of this, consumers follow the culinary recipes of their country by choosing typical local products and checking the ingredients and their origin, the presence of preservatives and nutritional values. However, the study results showed that after the health crisis, environmental aspects (such as organic ingredients, eco-sustainable packaging, and products made with low environmental impact technologies) are not the main concern of consumers when purchasing food products (Le-Anh and Nguyen-To 2020).

40.5 Conclusions

The research analyses the impact of the COVID-19 outbreak on consumers' purchasing habits, providing insights for food companies and governments on the aspects to be improved to optimize the agri-food sector following a sustainable perspective.

Consumers have become more attentive to health and food safety by purchasing fresh, healthy products without preservatives and checking the nutritional values by favouring the purchase of typical products of their territory that follow culinary traditions. However, environmental concerns affect purchase intentions but are not considered relevant to consumers purchasing agri-food products. In light of these results, to improve the agri-food sector, companies and the government must focus on the healthy and traditional aspects in the purchase phase of agri-food products but, above all, invest in educating the consumer on the importance of environmental aspects to follow a sustainable perspective. Indeed, governments and food companies need to promote environmental awareness by providing more information on green products and their impact on the environment and by encouraging consumers to make healthy and sustainable consumption choices. Companies must invest in sustainability by promoting real implementation from an environmental, social, and economic point of view. Future studies should investigate the factors that influence consumer purchasing behaviour in other cultural contexts after the pandemic.

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Chapter 41
Towards a Sustainable Diet: The Profile of Vegan and Vegetarian Italian Consumers

Lolita Liberatore, Nicola Casolani, Federica Murmura, and Laura Bravi

Abstract The actual pandemic has made the balance between health, ecosystems, the global supply chain, and resources more evident. Numerous studies have shown that diets based on plant-origin food are less impacted on the environment than those of animal-origin food; therefore, consumer choices can affect the sustainable development of the agri-food sector. In this chapter, the profile of Italian vegan and vegetarian consumers was investigated to understand the role that environmental sustainability and other issues play in the choice of these diets. The data of the Eurispes Italy 2020–2021 report relating to vegan and vegetarian consumers were analysed. From 2018 to 2021, the trend of vegan consumers showed positive values, since it improved from 0.9% to 2.4%; vegetarians showed a discontinuous trend, from 2018 onwards between 5.4% and 6.7%. The results reveal the main reasons that push consumers to adopt these diets, which are inherent to health issues (23.2%) and respect for animals (22.2%). Environmental sustainability is still a minor driver for orienting consumers' choice towards a vegan/vegetarian diet (only 5.1% of the total sample); however, there is a growth in awareness among young people (18–24 years) in attributing to environmental protection issues a reason for being vegan/vegetarian.

Keywords Vegan Consumer · Vegetarian consumer · Plant-based diet · Sustainability of consumption

L. Liberatore (✉) · N. Casolani
Department of Economic studies, University G. D'Annunzio of Chieti-Pescara, Pescara, Italy
e-mail: l.liberatore@unich.it

F. Murmura · L. Bravi
Department of Economics, Society, Politics, University of Urbino Carlo Bo, Urbino, Italy

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_41

41.1 Introduction

The Farm to Fork strategy, at the heart of the European Green Deal, presented on 20 May 2020, aims to create a healthy and sustainable food system (Giovannini and Riccaboni 2021). Parajuli et al. (2019) highlighted the importance of fruit and vegetable production supply chains for environmental sustainability. The vegetable proteins market, according to the Rapporto Coop (2021), improves the performance (+15.6% of sales in value in the first half of 2020 compared to 2019) more than the animal proteins market. The vegetable consumer market considers a niche of consumers that do not eat meat (vegans and vegetarians); vegan consumers, who differ from vegetarians because they do not eat food that is even derived from animal products, have increased in many industrialized countries (Janssen et al. 2016). The latest Rapporto Coop (2020) showed that attention to environmental issues is an important driver for Italian consumers, who increasingly eat sustainable products and prefer products engaged in environmentally friendly initiatives.

Hever (2016) examined the impact of plant-based diets on human physical performance and environmental sustainability. The article highlighted how these diets generally reduce the risk of developing numerous chronic diseases, improve life expectancy, and require the use of fewer natural resources than diets containing meat. According to the Academy of Nutrition and Dietetics, vegetarian and vegan diets, if properly planned, are nutritionally adequate and can bring health benefits through the prevention of certain diseases (Melina et al. 2016) and the improvement of longevity (Trichopoulou and Vasilopoulou 2000).

The consumer perception of vegan/vegetarian diets assumes a certain importance for their acceptance, as various studies have shown (e.g. Radnitz et al. 2015; Marangon et al. 2016; Raggiotto et al. 2018; Ghaffari et al. 2021). Janssen et al. (2016), in research conducted in seven vegan supermarkets in Germany on 329 vegan consumers, analysed the reasons for adopting a vegan diet; three main motivations emerged: the protection of animals (mentioned by 89.7% of the interviewees), personal well-being and/or health (69.3%) and environmental protection (46.8%); most of the respondents (81.8%) mentioned more than one reason. With increased ethical awareness, people have begun to criticize issues associated with the use of animal materials (Choi and Lee 2021). Kilian and Hamm (2021) found differences in vegan food perception between vegans/vegetarians and meat consumers. The first group perceives vegan foods primarily as being beneficial for animal welfare, healthy, and environmentally friendly, while the second perceives vegan food primarily as containing no animal ingredients and as being healthy. Social influence and health consciousness positively influence vegan food consumption (Tobias-Mamina and Maziriri 2021). Raggiotto et al. (2018) showed that religiosity exerts a certain effect on the predisposition of consumers and on vegan purchase intentions, in agreement with Martinelli and De Canio (2022).

Based on the above, the purpose of this chapter is to analyse the trends of vegetarians/vegans in Italy through Eurispes data reports and the motivations for being a vegetarian/vegan consumer, highlighting the role of the environmental protection issue.

41.2 Materials and Methods

The growing awareness of the importance of environmental issues reflects food consumer choices. The consequences of meat consumption and the increased push towards plant-based diets play a significant role in the scientific debate in relation to environmental sustainability.

In this context, the trend of vegans and vegetarians in Italy, which represent a niche of plant-based consumers, was analysed through Eurispes data reports (2020, 2021).

The issues investigated were the historical series of vegetarians and vegans, percentage of vegetarian and vegan consumers in Italy, and reasons for adopting a vegetarian or vegan lifestyle in relation to sociodemographic variables.

The results were compared with the indications that emerged from the international literature and are discussed in the next section.

41.3 Results

Figure 41.1 shows the historical series of vegetarians and vegans from 2014 to 2021. The percentage of Italians being vegetarian/vegan has fluctuated since 2014.

In the 2018–2021 period, the trend of vegan consumers shows positive values, since it has increased from 0.9% to 2.4%. Vegetarians showed a discontinuous trend, from 2018 onwards, between 5.4% and 6.7%. Veganism is considered an extreme type of vegetarianism (Larsson et al. 2003), and consequently, it is not surprising that the historical series of vegetarians showed higher values.

Figure 41.2 shows that a traditional diet is followed by 84.8% of respondents; 6.3% of the total sample reveals that they are not currently vegetarians, but they were in the past. The percentage considering gender specificity shows that females and males represent 5.5% and 7.9% of vegetarians and 2.7% and 1.6% of vegans, respectively.

Figure 41.3 shows that age plays an important role in the choice of vegetarian and vegan lifestyles. Most vegetarians ranged between 18–24 years (8.6%) and 25–34 years (8.5%), while 65-year-old people represented only 4.1%; the largest age range of vegans was represented by 45–64 years (3.1%) and 35–44 years (2.4%) consumers.

In Fig. 41.4, the motivations for adopting a vegetarian/vegan lifestyle are reported. The main reasons are related to health (“because it’s good for health” – 23.2%) and respect for animals (22.2%); this is in line with what has been found by Choi and Lee (2021). People are more sensitive to meat consumption and are shifting individual food habits in favour of a more plant-based diet, as Bedin et al. (2018) reveal. Then, it follows aspects related to diet (“to eat less and better” – 19.2%) and curiosity/experimentation (9.1%). Environmental protection (5.1%) represents a minor driver, as also found by Cooper et al. (2022).

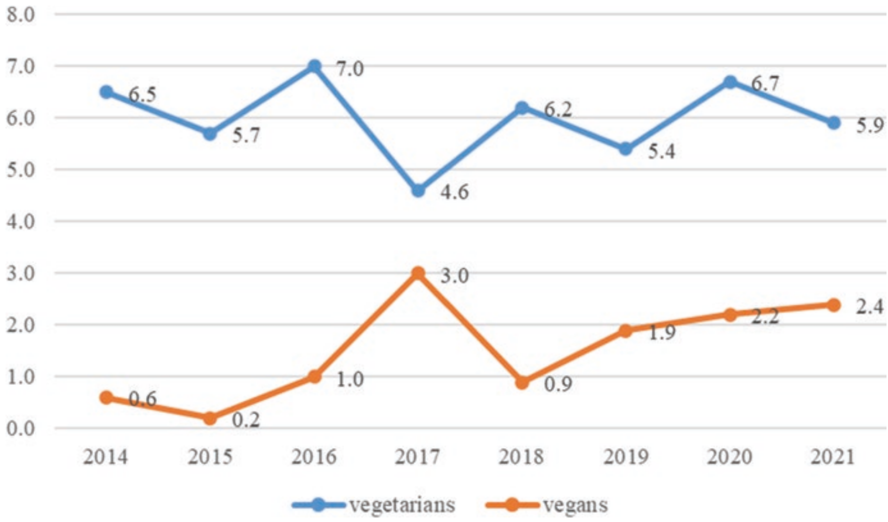

Fig. 41.1 Historical series of vegetarians and vegans in percentage values
Source: Personal elaboration using data from Eurispes (2021)

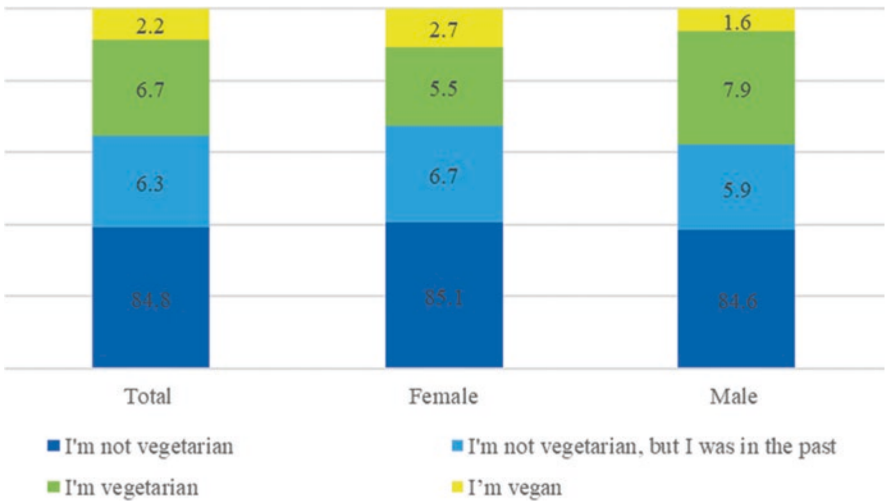

Fig. 41.2 Vegetarian and vegan, percentage values divided by gender
Source: Personal elaboration using data from Eurispes (2020)

Figure 41.5 shows the reasons for adopting a vegetarian or vegan lifestyle by age groups; the group of young people (25–34 years) indicates that the main reasons for being vegan/vegetarians are linked to health (35.3%) and to respect for animals (29.4%); environmental protection (18.2%) is a motivation mainly indicated by young people (18–24 years); the middle age group (35–44 years) and the group of

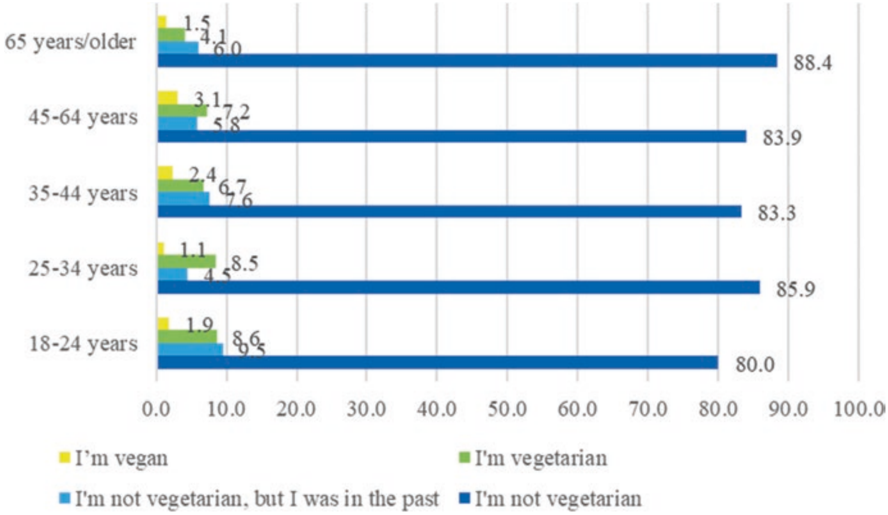

Fig. 41.3 Vegetarian and vegan, percentage values divided by age
Source: The authors used data from Eurispes (2020) for figure elaboration

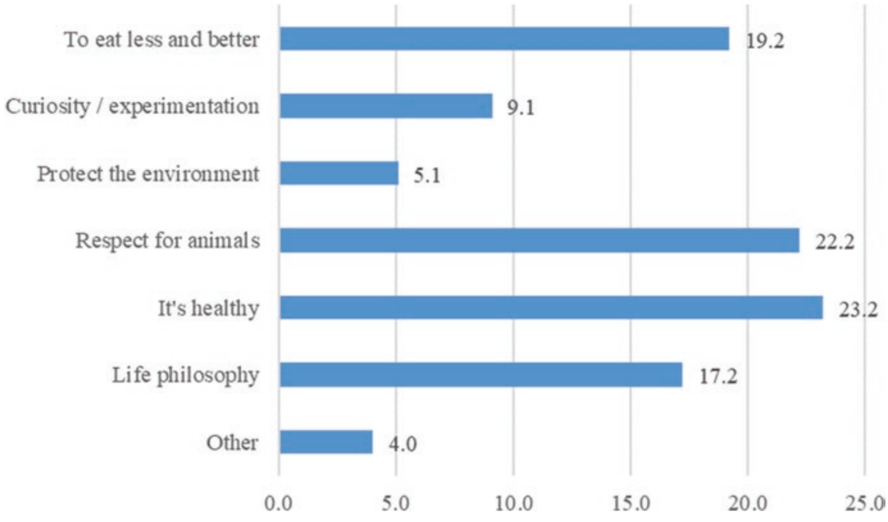

Fig. 41.4 Reasons for adopting a vegetarian/vegan lifestyle (percentage values)
Source: Personal elaboration from Eurispes' (2020) data

65 years old and more do not consider environmental issues; the group 25–34 years considers "healthy" (35.3%) and "respect for animals" (29.4%) as the main reasons for being vegetarian/vegan. Sociodemographic characteristics of vegans/vegetarians affect consumers' perceptions, in line with other studies (e.g. Ponzio et al. 2015; Janssen et al. 2016; Kilian and Hamm 2021).

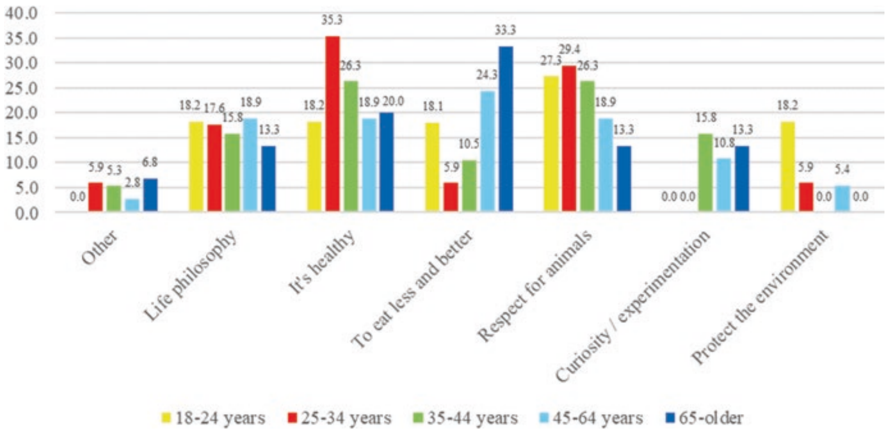

Fig. 41.5 Reasons for adopting a vegetarian or vegan lifestyle by age group in percentage values
Source: Data from Eurispes (2020) were extrapolated and elaborated by the authors in the figure

41.4 Conclusions

The role of the plant-based food industry has been consolidated and has been expanding constantly in recent years, becoming a fundamental component of the global food system. The desire for healthier and more sustainable lifestyles is behind these changes. In the last 10 years, veganism has grown considerably in Italy, more than vegetarianism.

Sociodemographic characteristics affect the percentage of and motivations for being vegan/vegetarian. The main reasons that push the consumer to adopt a vegan or vegetarian diet are health, respect for animals, and a balanced diet; these vary greatly depending on the age group. Only a small part of the sample attributes to being vegan/vegetarian the property of helping the environment, despite the clear scientific evidence that supports this relationship. In fact, environmental issues are an important driver of being vegan/vegetarian mainly for people aged 18–24 years and, even in this group, they do not represent the main motivation. Life philosophy is also an important driver revealing that the phenomenon of veganism/vegetarianism could be considered in a cultural and social key. Actual information campaigns on plant-based diets have mainly emphasized health properties. In addition, a correct communication focus on the beneficial role of plant-based diets for environmental sustainability could contribute to improving the perception of these products as “environmentally friendly.” Further studies could reveal new trends relating to the plant-based market, which is constantly evolving.

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Chapter 42
Not in My Backyard or Please in My Backyard? A PRISMA-Based Literature Review

Bianca Maria Tragnone, Eliana Mancini, Luigia Petti, and Andrea Raggi

Abstract The increasing need for energy and the decarbonization of production activities, as well as the necessity for the sustainable management of the growing amount of waste, have led to the identification of alternative technological solutions that are often strongly contested. For this reason, one of the most important non-technical factors to consider in project development is opposition from local communities. However, there are cases where such proposals are welcomed. This study aims to identify, through a systematic literature review, the reasons leading communities to accept or reject a proposal for intervention in their territory. The results show that communities do not necessarily perceive the implementation of potentially hazardous projects as undesirable. On the other hand, explaining the support for a project solely based on the related economic benefits would be reductive; indeed, it would not take into account the complexity of a phenomenon in which social and cultural factors, such as the sense of belonging and sharing and the perception of generated progress and prosperity, are decisive and deeply context related.

Keywords Not in my backyard · NIMBY · Please in my backyard · PIMBY · Social acceptance · Project development

B. M. Tragnone (✉) · E. Mancini · L. Petti · A. Raggi
Department of Economic Studies, University "G. d'Annunzio" – Chieti-Pescara, Pescara, Italy
e-mail: biancamaria.tragnone@unich.it; eliana.mancini@unich.it; l.petti@unich.it; a.raggi@unich.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_42

42.1 Introduction

The local reactions to a project planned in a specific area may affect its outcomes. Indeed, one of the main nontechnical barriers to the development of projects is the opposition by local communities, also known as the "Not in My Backyard" (NIMBY) effect. This residents' attitude is not linked to the proposed technology per se but only to the fact that it occurs in their direct socio-environmental sphere (Jenssen 2010). In other words, the public response to a project reflects residents' self-interests regarding the relevant foreseen impacts (Dokshin 2016). In this context, geographic proximity represents a key factor in analysing such phenomena (Huang and Yang 2020). When a part of the dissenting community is strongly opposed, a series of negotiations can take place to compensate people who might (or might not) accept the adverse risks of the proposed project (Lesbirel 2003).

Conversely, local communities sometimes do not show a clear position or, in other cases, welcome the project (Dokshin 2016). This is the case for the "Please in My Backyard" (PIMBY) – also known as "Yes in My Backyard" (YIMBY) – phenomenon. The perception of risks or benefits may depend on several factors, such as political ideologies (Dokshin 2016) as well as economic and cultural dynamics (Kojola 2020). The perceived fairness by residents regarding the distribution of the benefits among stakeholders is also an important element (Mancini and Raggi 2022).

Local reactions to new projects are an object of interest to social scientists. NIMBY movements and their reasons are generally more explored than PIMBY ones, regarding which there is a lack of sociological attention (Jerolmack and Walker 2018). However, this issue is not only of interest for the social sciences. Indeed, in a recent review regarding the social acceptance of biogas projects on a global scale, hard sciences represent the disciplines most investigating this aspect (Mancini and Raggi 2022). Understanding divergent community feedback is of pivotal importance for foreseeing local development models that are most suitable for communities. Therefore, this work aims to provide an overview of the social dynamics behind the different attitudes of the local community in accepting or refuting a project.

42.2 Material and Methods

A systematic literature review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Page et al. 2021) to address the focus of the research.

The Scopus and Web of Science (WoS) databases were used to search, without time limits (up to 14 March 2022), in "article title, abstract, keywords" (Scopus) and in "topic" (in WoS), the keywords "Please in My Backyard" and "Yes in My Backyard." Each one was combined with the corresponding acronym, "PIMBY" and "YIMBY", respectively, via the Boolean operator "OR." The results were then

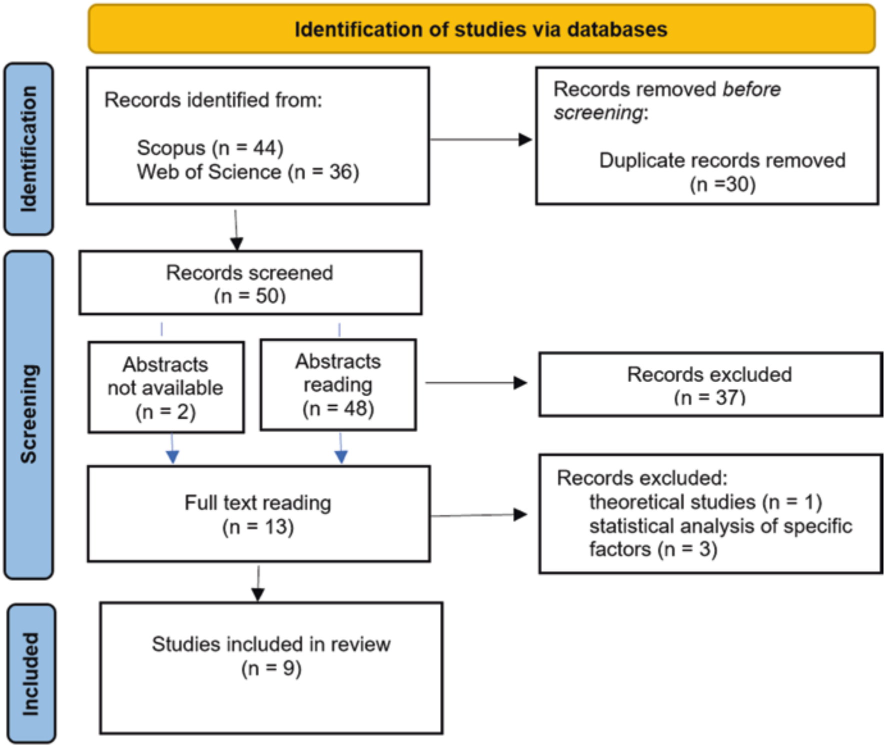

Fig. 42.1 Flow diagram of the selected documents according to PRISMA guidelines
Source: Personally adapted from Page et al. (2021)

narrowed down to English language studies classified as articles, reviews, and conference proceedings (80) and were further reduced (50) by eliminating duplicates. A preliminary reading of the abstracts (missing in two studies, screened directly by the full-text reading) allowed for selecting the studies on YIMBY and PIMBY, excluding those focused on housing, considered too specific for the purpose of this study. A successive full-text reading of the selected studies made it possible to identify only those converging on the reasons underlying the local community's acceptance or opposition to the installation of potentially environmentally and health-hazardous facilities (9), while theoretical studies (1) and studies on the statistical analysis of specific factors (3) were excluded (Fig. 42.1).

42.3 Results and Discussion

The analysed studies are heterogeneous with regard to the type and location of the contested projects examined (Fig. 42.2). In particular, Auer (2001) reconstructed the contrasts arising over a nuclear waste repository project in the Goshute Indians

Fig. 42.2 Geographical map of the reviewed studies, with an overview of contested projects

reservation in Utah. The local community was divided between the institutional leaders, who promoted the agreement to build the repository emphasizing the consequent economic benefits, and those who contested the legitimacy of its stipulation, highlighting the damage to cultural heritage.

The strong resistance to an incineration plant in Hangzhou, China, and the efforts made to overcome it were analysed by Huang and Yang (2020). The need to protect health and property values and the distrust of institutions due to the lack of transparency in managing risky plant projects, often accompanied by manipulation tactics and forceful actions, were at the heart of the opposition movements. Steps were taken to improve public participation, increase transparency in the project, and ensure investment in the affected areas.

Lesbirel (2003) examined the correlations between markets and institutions as crucial factors for a better understanding of the dynamics concerning nuclear power plants in Japan. The construction of nuclear plants was historically accompanied in Japan by mechanisms of direct compensation to property rights holders, while the entire host and neighbouring communities benefited from subsidies. Consequently, economic growth due to the presence of plants favoured local communities spread, leading to a condition of dependence, despite growing concerns, e.g. over safety, accidents, earthquake risk, and radiation. The transience of economic welfare due to nuclear power plants, which tends to diminish after their construction, made local communities inclined to accept further interventions on existing facilities to maintain their standard of living. In addition to economic dependence as a factor behind the acceptance of the plants, there was a different perception of the project, no longer experienced as an imposition, and of the related risks.

Similarly, Williams (2013) believed that a phenomenon of "reverse NIMBY syndrome" (p. 965) occurred in Henoko, Okinawa, where the community welcomed a controversial proposal to have an existing US military base expanded by transferring another military base to it. The post-war socioeconomic conditions favoured the structural incorporation of the village into the US economy, leading to a disease of dependency that significantly affected the political, economic, and institutional set-up, making Henoko a propitious environment for the location of military bases. The distribution among all the villagers of the payments made for the occupation of the land, centralized and efficient institutions, and participation in state compensation mechanisms fostered the economic and cultural growth of the village. However, this led to a strong dependence on such revenues, diminishing the capacity for autonomous development. This situation was generally accepted due to the economic benefits it brought and the trust in the financial stability of the military base. However, the local opposition believed that relocating an army base to an existing facility would not have increased the economic benefits since it would not have resulted in an expansion of the occupied land area and consequently compensation mechanisms for the local community. At the same time, there would have been significant growth in military activity with consequent accidents and disturbances, crime, and risks to the environment and marine fauna associated with infrastructure upgrades.

Different reasons appear to underlie the acceptance of fracking activities in Pennsylvania. Jerolmack and Walker (2018) pointed out that the economic benefits for individuals and the community in terms of payments, royalties, incentives, job creation, and infrastructure development cannot fully explain why traffic, noise, visual pollution, environmental, and health risks had not at all prompted the community to consider the intervention undesirable. Indeed, even when personal benefits were limited and despite the related harmful effects observed, such as groundwater pollution, attitudes towards fracking remained positive. The analysis showed that this acceptance was caused by the conception of private property and the freedom to exercise-related rights. Therefore, the damaging consequences of fracking were at least framed as dependent on operator negligence to be remedied by legal action. On the other hand, the sense of belonging to the community justified an attitude favourable to the intervention for the collective benefits derived from it (e.g. increased jobs, new business activities, and tax revenue growth) also by those who had no rights to the area subject to fracking and therefore did not benefit from direct compensation. The reaction to installing wind turbines was instead the focus of studies by Sowers (2006) and Fokaides et al. (2014). Both started from the observation that their implementation is generally accompanied by resistance on the part of local communities due to feared repercussions on tourism, depreciation of the value of the real estate in the affected area, visual impact on the landscape, adverse effects on flora and fauna (especially on birds), noise, disturbance caused by intermittent red lights, and extensive land use. However, the reality that emerged from the analyses was quite different. In particular, the interviews conducted by Fokaides et al. (2014) with residents of the Oites wind farm in Cyprus and those in neighbouring towns revealed that economic incentives were considered sufficient and that noise and impact on the landscape and flora and fauna were not perceived as problems. In contrast, wind turbines were seen as an opportunity to attract investment and tourism, contribute significantly to the area's energy independence, and be a tangible symbol of its progress. Although inadequate information was noted and concerns were expressed about a possible decrease in property values and damage to health, the overall opinion recorded was considered positive. Sowers (2006) presented similar conclusions after interviewing residents on the wind farm in the Great Plains, Iowa. The owners of the land on which the wind turbines were constructed felt that the economic benefits outweighed the concerns about soil compression during their construction, interference with Amplitude Modulation (AM) radio signals, and possible impacts on crops. In fact, in addition to the payments from the construction company, the owners benefited from the possibility of using the land removed for levelling fields, the improvements to the road network, and the creation of vegetable gardens. The sense of belonging to the community explains the positive attitude towards the turbines, even on the part of those who did not directly benefit economically. In addition, the community benefited from the increased flow of tourists and visitors and did not perceive the noise as a problem, while farmers positively considered the death of birds, seen as a factor in reducing the costs needed to keep them away from crops. Finally, the visual impact of the turbines was intended as a distinctive element of the local landscape and a symbol of prosperity and identification. The sense of community belonging emerged as a key element underlying the cultural dynamics behind the tensions related to the copper mining proposal in the Iron Range region of Minnesota analysed by Kojola (2020). The attitude of support for mining was explained by the expected job growth and the area's identification with the mines. Indeed, they were considered an integral part of local tradition and collective identity, defining the way of life and landscape. The same landscape was at the heart of opposition movements, which appealed to the prejudice against the natural landscape, emphasizing the emotional connection with the area as the scene of summer holidays. On the other hand, the health risks feared by the opposition movements were downplayed by mining supporters who, accustomed to living with mines in the area without any particular consequences, did not believe that the situation could change and, in any case, had confidence in the reassurances of multinationals and the regulation of the sector. In addition, there was also a difference in the way mining development is understood, seen by the supporters of the project as a way to protect an established rural, mining, and working-class way of life and by its opponents as a danger to the land and public health for the profit of foreign mining companies.

Jenssen (2010) focused, instead, on two bioenergy projects in Ludwigsburg and Mauenheim, Germany, one negatively and the other positively received, using them as models for finding shared solutions. Although essential to meet growing energy demand and reduce emissions, the implementation of bioenergy projects is generally accompanied by resistance due to concerns over noise, traffic, odours, and particulate matter that would result, not balanced by a fair distribution of related benefits and exacerbated by a lack of transparency in the planning process. The analysed cases revealed how effectively informing and involving local communities is essential to favour the acceptance of a project perceived as risky and therefore undesirable. In the case of the Ludwigsburg plant, the strong protests were underestimated by the project proponents, who considered them unfounded; they actually failed to adequately involve the local community and just provided them with information without an effective dialogue. In Mauenheim, on the other hand, an opposing attitude on the part of the proponent towards the local community meant that the project could be implemented without any opposition. According to Jenssen (2010), the analysed cases revealed that local opposition should not be underestimated, despite not being an insurmountable obstacle to implementing biotechnology projects. Therefore, it becomes essential to establish effective communication and involvement mechanisms with the local community.

42.4 Conclusions

The analysis revealed that installations traditionally associated with NIMBY phenomena are not always unwanted by the local population.

However, explaining the reasons for acceptance in terms of economic benefits alone, which certainly have considerable weight in orienting consensus, is reductive. Indeed, dynamics dependent on historical, social, economic, and cultural factors deeply linked to a specific context may come into play.

On the other hand, the opposition should be understood and interpreted by considering such dynamics. From this perspective, a key factor for the successful implementation of controversial projects is to inform the community about the actual risks, costs, and benefits in an effective and constructive dialogue from the earliest stages.

Acknowledgements This study is part of a PhD Course, the scholarship of which was co-financed with funds by Programma Operativo Nazionale Ricerca e Innovazione 2014-2020 (CCI2014IT16M2OP005), Fondo Sociale Europeo, Azione I.1 "Dottorati Innovativi con caratterizzazione Industriale."

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Part V
Consumers' Awareness and Behaviors: Quality

Chapter 43
From Knowledge to Consumption: How Consumers Perceive Food Quality

Ilenia Bravo, Angela Carelli, Lucio Cappelli, and Patrizia Papetti

Abstract Italy is a country of great local customs and traditions, and each region has peculiar typical characteristics, which determine different qualitative, sensory, and organoleptic attributes in food products. This allows the promotion of the growth of POD- and PGI-certified brands, transforming it into an important production area of "Made in Italy" food excellence. The quality of food is linked to the sustainability of the "agri-food system," a term increasingly used in various strategic documents, policies, and development plans at the international, national, and local level: "Agenda 2030" (UN), the Common Agricultural Policy (CAP), the Green Deal, and the "Farm to Fork" strategy that represents the attention and the acquisition of greater awareness of the consumer, who wants to be informed about the origin and the nutritional composition of a food. This work investigates the behaviour of Italian consumers towards certificated products through survey administration. From the observation of the results obtained, it emerges that 90% of respondents recognize certification logos and their main differences, while food safety is chosen by 62% of consumers to represent the concept of quality.

Keywords PDO/PGI certification · Consumer perception · Sustainability · Survey

43.1 Introduction

The term "food *quality*" is widely defined by different regulations and control systems, but from the consumer's point of view, it is not so simple to define. It is linked to various components: organoleptic (flavour, texture, and visual aspect), nutritional (composition and energetic value), commercial (price and profit), technological

I. Bravo (✉) · A. Carelli · L. Cappelli · P. Papetti
Dipartimento di Economia e Giurisprudenza, Università degli Studi di Cassino e del Lazio Meridionale, Cassino, Italy
e-mail: ilenia.bravo@unicas.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_43

(attitude to transformation), and hygienic-sanitary (healthiness). The common thought associates the quality product with a traditional product that does not have specificity, while for a *typical product*, we mean the outcome of a historical and localized process based on a combination of territorial and anthropic resources, which have a strong link with the cultural tradition and the territory of origin, which come from geographical areas, with specific raw materials and treatment processes. The elements that distinguish it are its enhancement and competitiveness in the market. The protection of geographical indications is one of the main tools used as a distinctive sign between product and territory and between diversity in the market. By regulation, we have defined two main key labels of product quality: protected designation of origin (PDO) and protected geographical indication (PGI). PDOs are products essentially due to a particular geographical environment (intrinsic natural and human factors) and whose production phases all take place in the defined geographical area, while PGI products are essentially attributable to their geographical origin and have at least one of the production stages in the defined geographical area (Behnke and Janssen, 2020; Sampalean et al. 2021). For these reasons, the PDO and PGI marks represent the compliance and compatibility requirements for a product of origin to be recognized as a food good and facilitate its access to market areas. The general objectives of European Union (EU) action concern the transition of the European agri-food sector towards a model of sustainable production and consumption; it should be economically viable, provide equitable benefits to society, and have minimal environmental impact. This objective is consistent with the results of several studies that link sustainability and healthy eating through the concept of food system, recalled by the European strategy "Farm to Fork." Sustainable food systems emphasize the role of eating styles as fundamental links between food, human health, and nutritional benefits.

According to the Institute of Services for the Agrifood Market (ISMEA) report, the economy based on the supply chain of branded products provided a contribution of 19% to the total sales in the agri-food sector. PDO and PGI brands represent 27% of the "Made in Italy" in the world, with an export growth of 5.1%. It is evident that in recent years, the awareness, perception, knowledge, and consumption of agri-food products marked by quality brands have increased among consumers. At the same time, consumer acceptance of the certified product has grown, which has been recognized as a key success factor in determining product development, orientation, and market opportunities. Singh (2019) reported that "attitude" is a learned predisposition to respond with respect to a certain object (Maxim et al. 2019). Schifferstein (2001) reported that various factors contribute to the formation of attitudes, which can be classified into consumer attributes and product attributes, such as direct observation; indirect knowledge; positive or negative opinion formed by different variables such as personality, values, risk perception, age, education, sociocultural position, culture, nationality, media exposure to information; and social support (Fishbein and Ajzen 2011; Singh 2019). In this study, we tried to define the relationship between eating habits and PDO- and PGI-branded products to investigate consumers' awareness, knowledge of geographic brand products, and interest in Italian certification food and their consumption.

43.2 Material and Methods

43.2.1 The Survey

The survey aims to examine the Italian quality certifications through the compilation of an anonymous questionnaire to understand if they are recognized by consumers, to understand how they perceive quality, what degree of judgement is attributed to them, and know their awareness at the time of purchase. The questionnaire consisted of 20 multiple choice questions distributed in virtual form, with a system of instantaneous messages multiplatform, allowing a descriptive analysis of the attention towards food-certified products and an evaluation of their performance on the market based on the choices of customers. The study was conducted on 203 respondents, all of whom were adults from urban areas with different levels of education. In fact, according to Maxim et al. (2019), the interest of consumers in certificate products is influenced by factors such as gender, age, education, and geographic origin.

The data were collected over a period of 1 year, specifically from May 2021 to June 2022, and all the answers were centralized by the research team through a sharing app, which allowed us to obtain and analyse the answers online and in real time. The data collection questionnaire was made up of four sections and was based on four main aspects: food safety and human health, knowing the meaning of certification, quality, and buying trend. The first section asked about sociodemographic characteristics, including sex, age, educational level, and environment of origin; the second section consisted of questions about the understanding of the PDO and PGI brands; the third aspect that we have considered is the security to understand what role it plays in consumer choices; and the last section regarded rapport between price and quality and the influence on purchasing choices.

43.2.2 Statistical Analysis

To provide statistical meaning to the data collected, we applied analysis of variance (ANOVA) to assess whether qualitative factors play a significant role in food purchase decisions. A multicomparison between factors' means was performed by a least significant difference (LSD) test.

43.3 Results and Discussions

43.3.1 Demographic Analysis of the Respondents

The aim of this questionnaire was to determine the opinion of consumers on the quality of certificated products, confidence about safe food, and knowledge about them. The initial phase of the survey allowed the start-up methodology for an effective interpretation of the results according to the importance attached to certain factors (age, occupation, education level, and so on). In total, 203 people participated in this study: 43.3% were male and 56.7% were female. Participants ranged in age from 18 to over 60 years: the age group 40–49 (12.8%) and the group under 20 years old (only 7%) are the lowest representatives. These numbers and percentages are similar to those reported by Maxim et al. (2019) and Sampalean et al. (2021). Most of the consumers (68%) have higher education (degree, bachelor's, and postgraduate studies), and some students attend a university course (9.9%). All participants come from the urban environment, from all Italian regions, and the most representative are Lazio, Umbria, and Campania (as shown in Table 43.1).

43.3.2 Knowledge of European Quality Certifications

In the second section of the questionnaire, consumers were shown the EU quality logos, PDO, PGI, and organic farming logos and asked to select the ones they were familiar with. The results indicated that the most familiar logo was the PDO logo, selected by 92% of respondents, followed by the PGI logo (81%). These findings were higher than those reported in a study by Sampalean et al. (2021), where the results indicated that the logo people were more aware of the PGI, selected by 82% of respondents, followed by the PDO (76%) and the organic logo (68%). Regarding the knowledge of the PDO and PGI logos, participants were asked if they knew the meaning of the different certified products. The total number of participants in this study confirmed that they knew their meaning and difference: When asked "Do

Table 43.1 Sociodemographic characteristics

Characteristic		Respondents	
Type	Levels	Number	Percentage out of the total (203)
Age	Under 20	7	3.4
	20–29	64	31.5
	30–39	38	18.8
	40–49	26	12.8
	50–59	31	15.3
	Over 60	37	18.2
Education	High	138	68
	Middle	57	28.1
	Lower	8	3.9
Gender	Female	115	56.7
	Male	88	43.3
Area	North	22	10.8
	Centre	25	12.3
	South	25	12.4
	Lazio region	131	64.5

PGI/PODs mean the same to you?", 87.6% answered "No." For both statements that defined the PDOs out of all respondents, 42% were able to correctly identify the one that refers to "the production steps of which all take place in the defined geographical area" and 43% were able to identify "whose quality or characteristics are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors."

43.3.3 Perception, Attitudes Towards Quality Food Products, and Purchasing Habits

The results reporting respondents' opinions regarding the food safety of EU quality–certified products are detailed in Figs. 43.1 and 43.2. Food safety was used in this section as a tool to study consumers' knowledge of EU quality certifications, as these products are believed to have a higher level of food safety. When asked, nearly 90% of respondents believed that the certified product was safer, while 10.4% did not consider it to be safer than an unmarked product. To assess the relationship between safety and certification, two questions were asked, the first with a yes/no answer asking whether a certified product is considered safer than one without certification and, in the second question, to indicate a value from 1 to 10. A total of 77.2% of the population gave a rating of 8 to 10, less than 20% between 5 and 7, and only 3% a value below 5.

Thus, the relationship between quality and safety was assessed by directly questioning respondents about the perceived interrelationship. For most consumers, quality and safety are clearly related, and they pay close attention to safety and

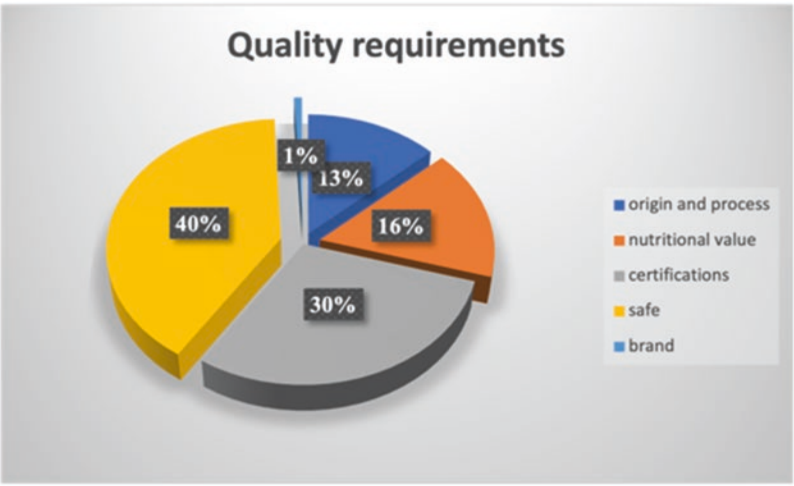

Fig. 43.1 Answers to the question "What is the important factor to define quality"

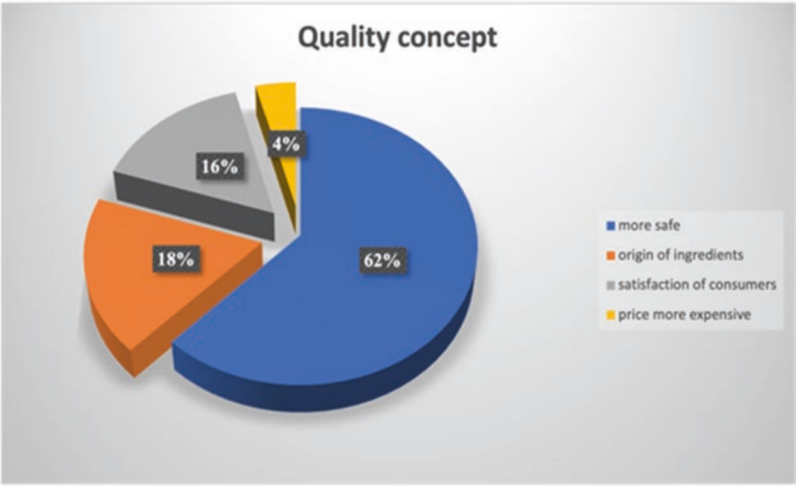

Fig. 43.2 Answers to the question "Which one is associated with the meaning of quality"

health control requirements, which are at the top of the rating scale (75%), followed by PDO/PGI certification (55%) and nutritional value (30%). In fact, possible contamination can be a source of concern, while belonging and possessing a certified label can become synonymous with food safety and guarantee protection and quality.

Questions were therefore proposed to better understand the purchase choice, or if the certification acquires an important requirement in the choice of the product. We have evaluated, with the next step, how much the price of the certified product can influence the consumer; if on the one hand 8.4% answered no, for approximately 35% certification is important but could do without it, a portion of over 56% remains, so certification takes on an important significance at the time of purchase. According to the data collected, the most reasonable purchase price they would be willing to pay is less than 5 € for 43.9% of the population, 29.9% under 10 €, 19.5% is divided between 10and 20 €, and only 6.7% over 20 €. These findings are confirmed in other work where consumers give second priority to the price of products and always seek certified foods (Batra et al. 2000; Zander and Feucht 2018; Giampietri et al. 2018; Thøgersen et al. 2019; Spognardi et al. 2021). They believe that the price of PGD/PGI foods becomes the cost of investing in "good health" (Sandalidou et al. 2002; Geeroms et al. 2008). The study findings further showed that despite having higher prices compared to conventional alternatives, many consumers continue to buy certified products.

An analysis of variance (ANOVA) was used to assess the statistically significant differences between the consumers' perception about the price and qualitative variables. A multicomparison between factors' means was performed by the least significant difference (LSD) test. For consumers' perception of the price of organic products, the parameters presented statistically significant differences ($p < 0.05$).

43.4 Conclusions and Future Perspectives

Italy is one of the European countries that has always supported policies of recognition and institutionalization of geographical denominations to protect territory and food production based on great agro-biodiversity and sociocultural knowledge and traditions. On these assumptions, we carried out this investigation to understand the key factors that guide purchasing decisions and promote consumer confidence and the variables that influence the consumption of certified foods based on sociodemographic characteristics (age and level of education) and economic evaluations. Indeed, the questionnaire revealed that the questions were well designed for the participants and provided clear and useful information.

Of course, a limitation of our study is that the sample is not statistically representative of the Italian population and appears biased towards relatively younger and highly educated buyers and consumers, although in agreement with other research. The data collected showed that consumers are increasingly attentive to labels, nutritional values, geographical origins, and information on traceability. The interest and awareness of certified foods have grown, as evidenced by the high percentage of knowledge on quality and certification systems, which are perceived as healthier and safer than conventional alternatives. It emerges that the guarantee of product safety and quality strengthens consumer confidence. These results can be practical input to follow to increase the production, marketing, and promotion of certified food products at national and international levels, even if a policy is needed that guarantees the POD and PGI brands and invests in agriculture and livestock to guarantee food safety and sustainability, aid farmers and producers, and support their local economies. Therefore, it is necessary to conduct further research with a larger and more representative sample to extend and generalize the results to represent the national population through the development and improvement of methods that better capture the real behaviour of consumers in different experimental contexts.

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Chapter 44
Exploring Consumer and Business Perceptions of the Use of Digital Technologies for Traceability

Chiara Cagnetti, Tommaso Gallo, Cecilia Silvestri, and Alessandro Ruggieri

Abstract Digital transformation affects company competitiveness mainly in terms of innovation, efficiency, and cost reduction and affects global value chains in specialization, geographic scope, governance, and upgrading (Leão, da Silva, Strateg Change 30:421–441, 2021). In food, digital tools can improve competitive advantage by supporting companies in ensuring food quality and safety by addressing the main issues related to this topic: food fraud, food safety and recall, regulatory compliance, social issues, and consumer information (Burke, Food traceability. In: McEntire J, Kennedy A (eds) Food microbiology and food safety, Springer, Cham, 2019). However, many companies still struggle to respond adequately to digital transformation challenges by adopting new technology concepts as a trend and not a real company imperative, misallocating internal resources and capabilities around technology, and expecting good results (Kane et al, MIT Sloan Manage Rev Deloitte 57181:27, 2015). Moreover, studies on the impact of digitization on companies' competitiveness are, for the time being, still at an early stage of development (Leão, da Silva, Strateg Change 30:421–441,2021), as are related impact assessment criteria (Lisienkova et al, A model for digital innovation assessment and selection. In: Beskopylny A, Shamtsyan M (eds) XIV international scientific conference "INTERAGROMASH 2021". Lecture notes in networks and systems, vol 246. Springer, Cham). The objective of this research is to analyse the entire national olive supply chain to understand the level of application of digital technologies by leading companies in the sector and, through consumer research, to understand what consumers' perceptions are regarding the use of digital technologies in traceability.

Keywords Agri-food · Digital transformation · EVO oil · Competitiveness · Digital tools · Traceability

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C. Cagnetti (✉) · T. Gallo · C. Silvestri · A. Ruggieri
Department of Economics, Engineering, Society and Company Organization, University of Tuscia, Viterbo, Italy
e-mail: claudia.cagnetti@unitus.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_44

44.1 Introduction

The Mediterranean area is the leading producer of olive oil. Italy and Spain account for almost all world exports (60% Spain and 20% Italy) (Source: Oil Sector Fact Sheet – June 2021). Italian production covers, on average, 15% of world production, and even on the import side, the largest customer in Italy, followed by the United States. World demand for olive oil grew slowly – averaging 1% annually – but steadily until 2012. From then on, world consumption also stabilized below the three million tons threshold until 2018, when it returned steadily above that threshold. For Italy, production for the 2020/21 marketing year stood at 255,000 tons, a 30% reduction from the previous year (ISMEA 2021). Due to the COVID-19 pandemic, average prices in 2020 fell sharply compared to 2019. However, there is a positive sign for exports to the United States, Germany, and France. At the national level, olive oil represents a key product on the market supply side and demand side. Consumers represent one of the main protagonists in the olive oil supply chain because the continuous growth of EVO (Extra Virgin Olive) oil consumption and consumer preferences pushes companies to make increasingly quality products (ISMEA 2021) through digital technologies (Carlucci et al. 2015). Indeed, in this context, new technologies can play an important role in ensuring food quality and safety by addressing the main issues related to this topic: food fraud, food safety and recall, regulatory compliance, social issues, and consumer information (Burke 2019). However, few companies still use digital technologies for this purpose (Kane et al. 2015).

The objective of this research is to analyse the actual use of digital technologies by companies in the food sector, with a focus on the olive oil sector, and at the same time to understand consumers' perceptions regarding the use of digital technologies in traceability.

44.2 Review of the Literature

Digital transformation affects company competitiveness mainly in terms of innovation, efficiency, and cost reduction and affects global value chains in specialization, geographic scope, governance, and upgrading (Leão and da Silva 2021). In food, digital tools can contribute to improving competitive advantage by supporting companies in ensuring food quality and safety by addressing the main issues related to this topic: food fraud, food safety and recall, regulatory compliance, social issues, and consumer information (Burke 2019). The safety and traceability of food products is, in fact, still the main concern of consumers (Caro et al. 2018), whose focus is not only on the quality of goods and services but also on where they come from, which affects the governance of supply chains (Power 2019). Although, to date, it is still difficult to predict how and in what ways digital technologies will succeed in transforming the food sector, it is still clear that digital tools are the key to improving food traceability systems (Abeyratne and Monfared 2016). However, many companies still struggle to adequately respond to digital transformation challenges by adopting new technology concepts as a trend and not a real company imperative, misallocating internal resources and capabilities around technology while expecting good results (Kane et al. 2015). Moreover, studies on the impact of digitization on company competitiveness are, for the time being, still at an early stage of development (Leão and da Silva 2021), as are related to impact assessment criteria (Lisienkova et al. 2022).

44.3 Material and Methods

44.3.1 Data Set Analysis

The companies selected from the sample are derived from the AIDA (Analisi Informatizzata Delle Aziende Italiane) platform (https://aida.bvdinfo.com/), considering ATECO code 10.41, "production of oils and fats." The selected companies have a turnover of more than 10 million euros as of 31 December 2021. The sample consists of 33 oil-producing companies; three do not produce extra virgin olive oil. Therefore, the final sample consists of 30 companies. Companies with the highest turnover include "Lucchese olii e vini S.p.A." (298 mln €), "Carapelli Firenze S.p.A." (247 mln €), and "Casa Olearia Italiana S.p.A." (222 mln €).

44.3.2 Questionnaire

The questionnaire used for the survey investigates consumer perceptions of traceability and the use of digital tools. Data collected through Google Forms and social media in April and May 2021 represent the sample (Brito et al. 2021; Majeed et al. 2022; Sarfraz et al. 2021). The difficulty in clearly identifying the population of customers led to adopting a nonprobabilistic sampling scheme, specifically accidental sampling, as is widely used in market research (Bracalente et al. 2009). The questionnaire analysed the following two sections:

- Consumer's analysis: containing information about consumers' perception concerning traceability and use of digital tools.
- Consumer profile: containing information on sociodemographic features.

The Likert scale allows for the measurement of sustainable consumer perceptions by assigning a score from respondents ranging from "strongly disagree" (score value 1) to "strongly agree" (score value 6) (Likert 1932). The data sample collected from the questionnaire administration was 464 people, analysed using the statistical "STATA 12 data analysis and statistical software" (www.stata.com).

44.4 Results

44.4.1 Companies

There are 30 oil farms in the sample, and among them, 15 (38.5%) make organic products, 14 (35.90%) PDO/PGI products, and 10 (25.6%) ensure product traceability (Table 44.1).

Regarding traceability, eight out of ten enterprises use the Lot tool, five use the QR code, and five use label information (Table 44.2).

For traceability, enterprises used three tools in combination. The Lot, which turns out to be the main tool, is combined with QR code and label information.

The third stage of the analysis considers the type of information on the label. Table 44.3 shows that most companies (23 out of 30) include the Made in Italy label; 18 have information on extraction, while 11 report the mode of preservation.

Again, the presence of information favours combinations with others. For example, on the label, there is information combined with "Made in Italy," "Extraction," mode of "Preservation," and presence of "certifications."

Considering the 456 responses from the questionnaire, for 299 consumers (66%), traceability of a product is very important when buying EVO oil by assigning a score (its Likert scale from 1 to 6) of 6. Thirty-eight percent of consumers said they would be willing to pay a higher price to purchase a traced EVO oil using new integrated digital technologies. Among the digital technologies perceived by consumers as the most reliable in this context is the QR code (30%), while 11% assign high importance to near-field communication (NFC) technology (Fig. 44.1).

Regarding label information, the country of origin/processing of the oil and the presence of certifications are the aspects that impact the consumer's purchase intention (Table 44.4). The average value attributed to "Country of origin of olives" and "Country of product processing" (which can be associated with the concept of "Made in Italy") has values of 5.29 and 5.16, respectively.

Table 44.1 Dimensions of EVO

Dimensions	*f*	%
Bio	15	38.5
DOP/IGP	14	35.9
Traceability	10	25.6
Total	39	100

Table 44.2 Traceability tools

Tools	*f*	%
Lot	8	44.4
QR code	5	27.8
Label information	5	27.8
Total	18	100

Table 44.3 Indication of the types of label used in the companies' sample

Type of information	*f*	%
Made in Italy	23	30.30
Extraction	18	23.70
Preservation	11	14.50
Certifications	9	11.80
Unfiltered oil	8	10.50
Usage	7	9.20
Total	76	100

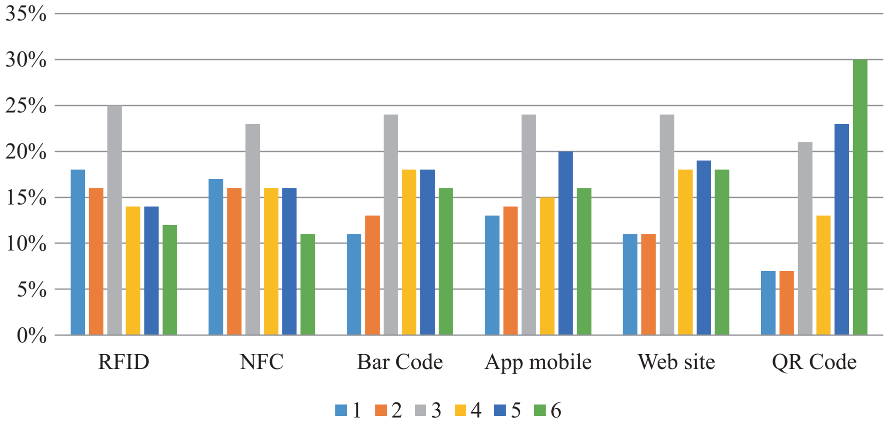

Fig. 44.1 Traceability technologies

Table 44.4 Label information

Label information	Average value
Country of origin of olives	5.29
Country of product processing	5.16
Certifying the body of the controls	5.02
Presence of voluntary controls	4.77
Extraction method	4.77
Polyphenol content	4.66
Olives variety	4.63

44.5 Discussions

Interesting insights emerge by combining the analysis results of companies with those of consumers. First and foremost, consumers express a strong interest in oil traceability, paying particular attention to the information on the label. The presence, in fact, of information affects purchase intention (Leão and da Silva 2021). These tools can improve companies' competitive advantages to ensure food quality and safety (Burke 2019). Consumers consider various digital tools, especially QR codes, important and reliable.

On the company side, however, the issue of traceability is still not particularly heard. Only 10 out of 30 provide consumers with traceability information. Therefore, there is a clear need to increase awareness of this issue among companies, considering the significant importance consumers attach to it, raising the possibility of increasing revenues.

On the digital side, there also emerges a certain lag of companies compared to consumers, who attach particular importance to digital technologies to ensure the security of traceability systems. Among the most reliable digital tools, QR codes stand out for consumers.

The QR code is an important digital technology for consumer perception because it is easy to access and ensures transparency, security, and reliability to consumers (Violino et al. 2019).

Only 5 out of 10 companies (that do traceability) use the QR code system. Therefore, if companies want to try to increase their competitive advantage against their most direct competitors and acquire new customers, they should invest/intervene in this aspect to meet what is explicit customer demand according to the results obtained from the questionnaire.

The analysis of label information shows relationships between consumers and sample companies. "Made in Italy," information was important to 65% of respondents and presented in 23 labels, followed by the presence of "Certifications" (requested by 42% of respondents and presented in 9 out of 30 labels). Information on "Made in Italy" was found to be important by 65% of respondents and present in 23 labels, followed by the presence of "Certifications" (requested by 42% of respondents and present in 9 out of 30 labels). Among the information on the label, the extraction method is present in 18 out of 30 labels. However, the average value of this information, as shown in Table 44.4, in terms of consumer importance is 4.77. However, the average value of this information in terms of importance by consumers is 4.77. Consumers do not seem to perceive this information to be particularly important compared to Menozzi (2014).

There are three main aspects of the consumer–company gap:

- Label information
- QR code
- Certification

Consumers attach high importance to these three aspects in contrast to companies, for which the level of significance varies between low and medium.

This shows that companies need to increase the role of digital technologies in their activities, seeking to use new methods to provide more information to consumers.

QR, through an easy-to-learn interactive approach, offers more information to help consumers understand product features, also increasing consumer confidence in a specific product (Rotsios et al. 2022). Beyond the QR code, companies have to provide information using traditional methods such as labels. Labels show quality

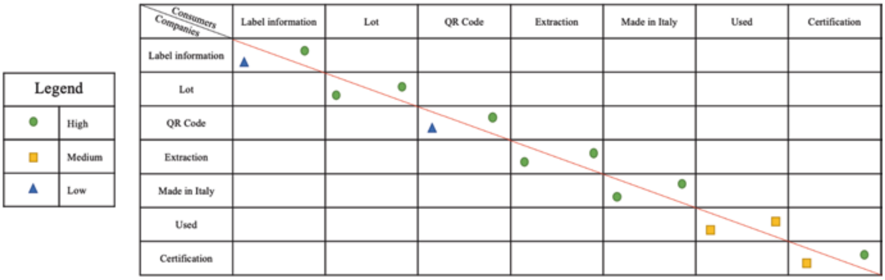

Fig. 44.2 Relevance of aspects for consumer and company

(Chrysochou et al. 2022), raising consumer awareness of product characteristics and environmental impact (Erraach et al. 2021). In this regard, Fig. 44.2 summarizes the significant results of this research.

44.6 Conclusions

The objective of this research was to analyse the entire national olive oil supply chain to understand the level of application of digital technologies by major companies in the sector and to understand consumer perceptions regarding using digital technologies in traceability through consumer research. The analysis highlights the need for greater alignment between consumer demands in terms of label information and traceability and capacity on the part of companies to meet those demands. The research has some limitations. First and foremost is the sample of companies analysed. Future research must be oriented on a larger sample that allows a greater depth of the topic and completeness of data. Finally, the study involves the use of digital technologies to foster greater consumer awareness at the time of purchase. The chapter highlights the importance of the use of digital technologies by olive oil companies. Their application allows companies to improve consumer awareness. Thus, consumers will buy more products from a company that uses digital technologies rather than another company that does not use them.

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Chapter 45
Functional Properties and Preferences of Consumption of Honeys from Different Origins

Leonardo Borsacchi, Francesca Camilli, and Patrizia Pinelli

Abstract In the bioeconomy, beekeeping and honey production are of great importance and contribute to sustainability. Honey is a nutritious, healthy, and flavoured product embodying the biodiversity and culture of the lands of origin and the peculiarities of the production areas through the work of many smallholder farmers providing honey with added value derived from the local environment. The functional properties of honey are largely attributed to minor constituents (polyphenols, including flavonoids and phenolic acids), which can function as natural antioxidants in our diet. In addition to the analytical results on the antioxidant activity of Tuscan and Sardinian honeys, this work reports the data of a survey to evaluate the preferences for honey consumption in a group of young adults. In particular, the objectives were (i) to compare local honeys produced by smallholder farmers to industrial honeys and to highlight the added value of local productions; (ii) to analyse the findings of the survey on honey consumption in young adult consumers; and (iii) to evaluate the antioxidant properties of local honey to promote it as a valuable component of a healthy and balanced diet and to disseminate among consumers' food culture and food functional property awareness.

Keywords Quality · Antioxidants · Local honeys · Consumer choice

L. Borsacchi (✉)
Action Research for CO-development (ARCO) – PIN, University of Florence, Prato, Italy
e-mail: leonardo.borsacchi@pin.unifi.it

F. Camilli
BioEconomy Institute (CNR-IBE), Florence, Italy
e-mail: francesca.camilli@ibe.cnr.it

P. Pinelli
Department of Statistics, Informatics, Applications "G. Parenti" (DiSIA), University of Florence, Florence, Italy
e-mail: patrizia.pinelli@unifi.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_45

45.1 Introduction

The importance of beekeeping and honey production is relevant for the bioeconomy and sustainability issue, and there are significant benefits for society, both economically and environmentally. Ninety percent of the benefits of honeybees to humankind lie in their pollination capacity, and only 10% lies in bee products, such as honey, propolis, and wax. Honey, the product of bee digestion, is a nutritious, healthy, and flavoured product bringing with it the variety and richness of the lands of origin. As with many other products, honey embodies the peculiarities of the production areas through the work of many smallholder farmers providing honey with added value derived from the local environment and biodiversity. In Italy, there are 50,236 beekeepers: 31,425 of them (63%) produce honey for self-consumption, while 18,811 (37%) produce it for the market. Italy is the fifth European country for honey production. The aims of this work are (i) to compare local honeys produced by smallholder farmers to industrial honeys and to highlight the added value provided by local productions; (ii) to analyse and discuss the findings of the survey on honey consumption in young consumers; and (iii) to evaluate the antioxidant properties of local honey to promote it as a valuable component of a healthy and balanced diet and to disseminate awareness of food culture and food functional properties among consumers.

45.2 Review of the Literature on the Subject

Honey is a concentrated aqueous solution of sugars that also contains a complex mixture of other saccharides, enzymes, amino acids, organic acids, polyphenols, carotenoid-like substances, vitamins, and minerals (Gheldof et al. 2002). Among the minor constituents of honey, polyphenols and, particularly, flavonoids and phenolic acids can function as natural antioxidants in our diet. Polyphenols are an important group of secondary metabolites of plant origin that, in addition to providing plants and flowers with colours, have different biological functions, including antimicrobial, antifungal, anti-inflammatory, antiradical, and heavy metal chelation activities (Uthurry et al. 2011). Kroon and Williamson (2005) discussed the benefits of a polyphenol-rich diet for health, evidencing that the presence of substances, such as flavonoids in a balanced diet, can be particularly valuable. Functional foods, enriched foods, and nutraceuticals well suit the concept of optimal nutrition, providing our diet with health properties. From this perspective, honey, propolis, and royal jelly have long been considered among the foods that have functional properties, as they are potentially high natural antioxidants and anti-inflammatory (Uthurry et al. 2011).

A previous study performed on Italian honeys (Blasa et al. 2006) determined the content of total polyphenols in wildflower and acacia honeys (12.5–17.5 mg/100 g and 3–11 mg/100 g, respectively) and flavonoids. In this study, the antioxidant activity was assessed through an in vitro test that measures the reducing capacity of antioxidants against iron ions (FRAP), highlighting that wildflower honey shows greater antioxidant power than acacia honey. The same work reported that in industrial honey, which is very frequently subjected to thermal processes, the polyphenol content is 3–4 times lower than that in raw honey. Another study on honey from Slovenia (a country with a high vocation for beekeeping) evaluated samples with different botanical origins, highlighting that the plant origin greatly influences the antioxidant properties of the final product, even more than honey processing does (Bertoncelj et al. 2007). According to the results reported in this paper, darker honeys, having a higher content of polyphenols, show the greatest antioxidant power, while acacia honey (the lightest honey in terms of colour) shows the lowest antioxidant activity.

The concentration of antioxidant molecules in honey depends not only on the botanical and geographical origin but also on the production method. In industrial production, honey is thermally treated, particularly to reduce moisture and increase shelf life, delay granulation, and destroy spoilage microorganisms. Nevertheless, thermal processes significantly affect the honey quality (Singh and Singh 2018). Small farms generally produce honey without applying industrial processes, such as filtration and pasteurization heat treatment, thus preserving the natural composition of raw honeys.

45.3 Material and Methods

45.3.1 Questionnaire and Consumer Preferences

A background questionnaire on habits and preferences about honey consumption was submitted to a group of 123 young adults (aged 21–33, 82% women and 18% men).

The first part of the survey concerned the frequency of honey purchase, the places of buying, and the type of honey preferences (uni- or multifloral; fluid or crystallized). The second part of the survey includes a 5-point scoring scale (1 = not important; 2 = slightly important; 3 = on average important; 4 = fairly important; and 5 = very important), which can extract statistical information on consumer choices.

45.3.2 Samples

Two types of unifloral Tuscan honey (sunflower and ivy) were provided by agritourism in San Casciano Val di Pesa in the countryside between Florence and Siena. Two types of Sardinian honey were provided by *Agenzia forestale regionale per lo sviluppo del territorio e dell'ambiente della Sardegna* (FoReSTAS): unifloral strawberry tree and wildflower honey, both produced in the area of Arci-Grighine in the province of Oristano. The local honey was analysed and compared with a commercial wildflower honey purchased in a store of the large-scale retail trade.

45.3.2.1 Extraction of Honey Samples

Ten grams of each honey was dissolved in 10 mL of a hydroalcoholic solution consisting of 70% ethanol (EtOH) and acidic water at pH 3.2 by formic acid (30%). After 1 hour of extraction at room temperature in the dark, the extracts were centrifuged at 5000 rpm for 5 min in a centrifuge at a controlled temperature (18 °C) to separate the hydroalcoholic supernatant from the residue.

Antiradical Capacity Evaluated by the DPPH Test

The antiradical capacity of the extracts was estimated according to a previously reported procedure (Heimler et al. 2005), with slight modifications. More specifically, the extracts were opportunely diluted, and an amount equal to 1:1 was added to an ethanol solution of 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) (0.04 mg/mL). Measurements were carried out at 517 nm with a Lambda 25 spectrophotometer (Perkin-Elmer) at time 0, after 30 s, 1 min, 90 s, 2 min, and then every 2 min for the following 20 min. The antiradical activity (AR%) was calculated through the following relationship:

$$\left[\mathrm{AR\%} = 100\left(A_0 - A_{20}\right) / A_0\right]$$

where A_0 and A_{20} are the absorbance of DPPH at time 0 and 20 min, respectively, after adding the diluted extracts; the IC50 is the concentration of the honey sample (mg/mL) required to scavenge 50% of DPPH.

The IC50 of the extracts was determined by using the 5-point linearized curves [AR%-ln (concentration in polyphenols)], which were built by determining AR% for five different dilutions of each extract and then by calculating the molar concentration in polyphenols of the solution that inhibits the DPPH activity to 50%.

The antiradical efficiency (AE) was calculated following Mansouri et al. (2005) with the following formula: [1/IC50*100].

45.4 Results and Discussion

45.4.1 Survey Results

The increasing popularity of honey nutritional benefits was the trigger for an in-depth investigation on factors influencing consumers' purchase intentions. A recent study (Cosmina et al. 2016) performed among Italian consumers showed that respondents had a higher willingness to pay for honey from their country of origin versus the production method used (organic instead conventional).

In our survey, regarding the choice of the preferred type of honey, 42.3% of respondents answered "unifloral" and 57.7% "multifloral"; therefore, the majority seemed to pay only slight attention to the single botanical origin of honey. The preference of respondents towards fluid honey (75%) rather than crystallized (25%) was much more evident.

It should be noted that almost all honey is liquid at the time of extraction, but it tends to crystallize in a time ranging from a few days to a few months. Such a process is natural and can affect the appearance and texture of honey in various ways but not its nutritional value. Honey crystallization depends on the botanical origin of the product and the storage temperature, and it is simply due to the excess sugars that cannot be permanently present in the solution. Crystallization is faster in honey rich in glucose (dandelion, sunflower, and rapeseed), while it tends to be delayed and incomplete in honey poor in glucose but rich in fructose (acacia, chestnut, and honeydew). In numerous types of honey, the liquid state could depend on a second melting heat treatment, and such heating causes the loss of some nutritional characteristics. Thermal treatments are used for different purposes, e.g. to thin the already crystallized honeys to pack them or filter them or to lengthen the shelf life of the product in the liquid state. Thermal treatments always have a negative effect on honey, such as the loss of aroma, which is proportional to the temperature and the duration of the heating process.

The results of the second part of the survey (Table 45.1) showed that the respondents' preferences were first related to those types of honey labelled with an indication of sustainability (organic, fair-trade labels, etc.), second to the honey's geographical origin, and third to its botanical origin.

The data related to botanical origin are in agreement with the higher preference of respondents for multifloral honey, which highlights a weaker interest in honey derived from a single plant species. Finally, the brand seems to have the least importance with regard to the purchase choice.

Table 45.1 Average values of the survey with a 5-point scoring scale (*1 = not important; 2 = slightly important; 3 = on average important; 4 = fairly important; 5 = very important*) in the questions "About honey, how much important is for you the …"

Botanical origin	3.58
Geographical origin	3.79
Brand	2.89
Sustainability	3.90

Table 45.2 Results of the DPPH antiradical test on local honeys and the control sample

Honey sample	Texture	Antiradical activity (IC50 as mg)	Antiradical efficiency AE
Tuscany sunflower	Crystallized	910	0.11
Tuscany ivy	Crystallized	712	0.14
Sardinian wildflower	Fluid	740	0.14
Sardinian strawberry tree	Crystallized	148	0.68
Control (commercial product from GDO)	Fluid	1785	0.06

45.4.2 Antioxidant Activity

The DPPH method with the stable organic radical 1,1-diphenyl-2-picrylhydrazyl is used to determine the free radical scavenging activity, usually expressed as IC50, the amount of antioxidant necessary to decrease the initial concentration of DPPH by 50%. This means that the lower the IC50 value of the sample is, the higher its antioxidant activity.

The investigated honeys were evaluated in comparison with a wildflower commercial honey purchased at the supermarket.

The results in Table 45.2 show that the antiradical activity (IC50) of Sardinian and Tuscan honey varies in the range 148–910 mg and is, therefore, higher than the antiradical activity shown by the commercial honey (1785 mg). Considering the antiradical functions, Sardinian and Tuscan honeys are from 1.8 to 11.3 times more efficient than the control. The antioxidant activity of Sardinian strawberry tree honey is particularly relevant. This sample is, in fact, the richest in antioxidants, as the phenolic content expressed by the Folin–Ciocalteau test (as gallic acid equivalent) ranged from 29.1 mg/kg in *Millefiori* supermarket honey to 913.9 mg/kg in Sardinian strawberry tree honey (data not shown).

The particularly high antioxidant profile of Sardinian strawberry tree honey has already been assessed in a previous study on Sardinian monofloral honeys (Petretto et al. 2015).

45.5 Conclusions

The results of the questionnaire regarding the choice preferences for honey of young adult consumers show a greater trend to buy fluid honey, even though this is opposite to the fact that natural honey tends to crystallize. Moreover, the survey's results show greater attention to an indication of sustainability in comparison with other characteristics of this food item, such as the brand. More aggressive and repeated thermal methods are frequently applied to increase the stability of honey, but such processes compromise the functional and sensory characteristics of honey. Thus, it is advisable to prefer honey locally produced from a short supply chain.

Territorial honey, especially that showing evidence-based beneficial properties, could have greater commercial value. One of the tools to properly promote it could be the achievement of the protected designation of origin (PDO), an European Union (EU) certification recognized for products originating in a specific geographical area. Honey promotion must also be encouraged through consumers' stronger awareness of the functional properties and natural characteristics of honey.

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Chapter 46
Food Safety and Insect Food: A Preliminary Consumers' Indication

Giovanni Peira, Luigi Bollani, Erica Varese, and Alessandro Bonadonna

Abstract Food safety is a topic of central importance in the European context. Since the 1960s, the European Union (EU) has established numerous rules to guarantee the hygienic and sanitary protection of food products and, therefore, the health of consumers. In this sense, EU legislation has introduced an integrated approach to food safety, including information on food products and animal welfare, regulating the stages of the food chain, and offering consumers several pieces of information. Over the past few years, however, the European legislature has regulated the breeding of insects for the production of food for human consumption. In this context, the present paper aims to investigate the perception and behavior of consumers on food safety issues in light of the introduction of insects as food for human consumption. A preliminary survey of a sample of consumers was conducted, and the results show that food safety is an important feature in the process of purchasing food products. Moreover, some differences emerge in terms of insect food confidence related to food safety perception.

Keywords Food quality · Food safety · Insect food · Consumers' perception · Survey

G. Peira (✉) · E. Varese · A. Bonadonna
Department of Management of "Valter Cantino", University of Turin, Turin, Italy
e-mail: giovanni.peira@unito.it; erica.varese@unito.it; alessandro.bonadonna@unito.it

L. Bollani
ESOMAS Department, University of Turin, Turin, Italy
e-mail: luigi.bollani@unito.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_46

46.1 Introduction

The quality of food can be defined in relation to three main aspects, namely, the characteristics of the food, psychosocial use, and service. The first aspect can be divided into four subcategories of quality: agronomic quality, hygienic-sanitary quality, nutritional quality, and sensory quality (Peri 2006). These different kinds of quality are essential to ensuring the success of a food product on the market, and specifically, food safety is fundamental as a necessary condition and therefore as a prerequisite of quality (Peira et al. 2014). Food safety has always been at the center of international debates; indeed, it identifies food hygiene and safety and the commitment to prevent contamination by pathogens. Since the 1960s, the European Union (EU) has established numerous rules to guarantee the hygienic and sanitary protection of food products and, therefore, the health of consumers. In this sense, European legislation has introduced an integrated approach to food safety, including information on food products and animal welfare, regulating the stages of the food chain, and offering consumers a wealth of information on the food chain.

In recent years, European legislators have also regulated insect farming for the production of food for human consumption, mainly due to specific constraints such as the environmental unsustainability of the food sector and the growing world population (Belluco et al. 2015; Lalander and Vinnerås 2022). This type of food has been legal and popular in Asia for a long time, but until now, it was not considered a food alternative in Europe.

In this context, this paper focuses on food safety related to the consumption of insects for human consumption, a topic already debated by the international community (see, e.g., Belluco et al. 2013). In particular, the study investigates the insect food confidence of younger consumers in relation to their perceptions of several food safety aspects.

46.2 Review of the Literature

The EU guarantees high safety standards for food products that are placed on the market by EU members through the definition of specific production requirements. In the last 40 years, there have been cases of fraud and, more generally, food scandals that have undermined the safety of European and international consumers (e.g., methanol wine, "mad cow" disease, foods with dioxine). Therefore, the EU has developed some rules and control systems to guarantee safety in the food sector in line with the needs of the consumer, that is, the integrated food safety policy. Recorded food diseases and infections have increased over the past decade despite the use of modern manufacturing technologies and good manufacturing practices (Peira et al. 2014).

At the same time, the EU enlarged the competencies of EU regulations, and a few years ago, it started to consider insects as food.

Entomology is a common food habit in many parts of the Asia-Pacific region (Yen 2015), and in these countries, insects are a highly appreciated food (Orsi et al. 2019). Although there is anecdotal evidence of insects consumed as food in the past (European Commission 2022), no EU Member State has confirmed, in accordance with Regulation (EU) 2015/2283, human consumption to a significant degree prior to May 15, 1997, for any insect species. For that reason, the above-mentioned regulation states that whole insects and their preparation must be considered novel food (European Parliament and Council 2015). Therefore, to be commercialized for human consumption, they must be authorized in accordance with this regulation, which, among other things, implies that insects should be safe for consumers, properly labelled (so as not to mislead buyers), and, to be marketed within the EU, they have to be included in an authorized novel food union list (International Platform of Insects for Food and Feed 2021). The first decision granting authorization of an insect as a novel food was adopted on June 1, 2021 (European Commission 2021). Even if the topic is quite recent, many scholars have analyzed and studied it as insects represent, on the one hand, a sustainable protein supplier, and on the other hand, they may meet some obstacles in Western consumers' minds with reference to safety reasons.

The literature has been recently revised by Kröger et al. (2021), who assume that consumer acceptance of insects as food is related to a variety of factors such as (1) sociodemographic factors (gender, age, education, place of residence and traditional food culture, nationality, ethnicity and travel experience, religion, income, and occupation); (2) personality factors (sensation seeking, storytelling, mindfulness, attitude; sustainability consciousness/awareness and new ecological paradigm; perceived behavioral control and intention; purchase activism and trust; familiarity; "food neophilia"; neophobia; sensation seeking); (3) personality factors (emotions, disgust); (4) social influences (subjective norms, source of social influence, trend and perceived normality, social and financial acceptability); (5) diet (dietary preferences, meat consumption and liking, previous insect consumption, seafood and sushi consumption, green dietary behavior, food fussiness); (6) product characteristics (preparer dish, characteristics of insect-based products, sensory expectation and ratings, degree of visibility of insects and amount of insect substitute, insect species and life stage, food appropriateness, carrier product characteristics, perceived benefits, perceived risks); (7) food choice motives; and (8) information (information settings: package design).

Insects are currently accepted as regular food by EU consumers, and practitioners need valuable information to motivate and give consumers proper information to dissipate perplexities and barriers.

46.3 Materials and Methods

46.3.1 Sample and Questionnaire Definition

The sample was defined on the basis of international literature and related gaps. In particular, the younger generations were selected in light, on the one hand, of their sensitivity to sustainability issues and, on the other hand, of their approach to novelties such as insect food.

At the same time, the questionnaire was designed on the basis of international literature and EU legislation. In particular, the main aspects related to food safety and insect food were collected to better understand the state of the art on this topic. After collecting the data, a three-step questionnaire definition was followed. In the first step, a version of the questionnaire was carried out after a focus group activity (six young male and female consumers). The second step provided a second version of the questionnaire structured into several closed-ended questions after a second focus group activity (three university scholars and three food professionals). The third step was a pretest, that is, the second version of the questionnaire was tested by 30 young consumers, and consequently, the final version was defined. The questionnaire was administered by the MOODLE platform to younger consumers.

After the collection of questionnaires, the sample was made up of 5177 individuals, of which 25.81% were males and 74.19% were females. A total of 53.13% of the sample is included in the range ≤ 22 years old, 37.24% belongs to the age group 23–27, and the remainder is in the range ≥ 30 years of age. Therefore, females show a greater propensity to respond and are generally more interested in issues related to nutrition.

46.3.2 Findings

The study focuses mainly on the trust that consumers place in food derived from insects. The sample results show a relatively small difference between those who trust the food safety of these products (52.87%) and those who do not trust them (47.13%) since the EU allowed the marketing of these products (Table 46.1).

The male gender is more willing to trust: the relationship is significant (*P* value <0.05) but quite weak (Cramer's $V = 0.18$ on a scale between 0 and 1) (Table 46.2).

Table 46.1 Relationship between confidence and gender of the sample examined

Gender	I trust	I do not trust	Total			
Male	907	429	1336	Chi-squared test	=	163.05
Female	1830	2011	3841	*P* value	=	2.44E−37
Total	2737	2440	5177	Cramer's *V*	=	0.18

Table 46.2 Relationship between confidence and age of the sample examined

Age	I trust	I do not trust	Total			
≤22	1394	1366	2760	Chi-squared test	=	53.69
23–29	1134	794	1928	*P* value	=	2.35E−13
≥30	209	280	489	Cramer's *V*	=	0.10
	2737	2440	5177			

The 23–29 age cluster is more willing to trust: the relationship between trust and age groups is significant (P value <0.05) but rather weak (Cramer's $V = 0.10$ on a scale between 0 and 1).

Table 46.3 considers a series of items expressed on a Likert scale, reporting, for each of them, both the mean of those who say they trust food from insects and that of those who do not; the difference between these two averages (and its significance) is then presented. Subsequently, this difference is again divided by the overall mean (i.e., of the whole sample: those who trust and those who do not trust) for the item in question to generate an index indicating the importance of this difference. The items in the table are ordered according to this index.

All the differences between the averages considered are significant (the values in the P value column are always less than 0.05).

Starting from the top, one finds the questions in which the average of those who trust is higher than that of those who do not trust, progressively decreasing to a tie (i.e., the same average for those who trust and those who do not trust) and then again to an increasingly higher inversion (i.e., a higher average for those who do not trust).

Starting again from the top of the table, those who trust insect food the most appear to be those who also trust regulations, controls, and certifications the most; then, moving downwards, we find those who are concerned about environmental and social sustainability issues; finally, moving downwards again, near the bottom of the table, where those who trust insect food the least appear, are those who are most concerned about food contamination and genetic modification.

46.4 Conclusions

The findings seem to underline that respondents with more confidence in regulations and related applications are more inclined to accept insect-like food. At the same time, the part of the sample that has less confidence in the application of the food rules and related controls seems oriented toward avoiding the consumption of insect food. In this sense, these initial results may already provide some suggestions to public stakeholders, for example, strengthening communication by highlighting the positive role of insect foods in common well-being. In fact, the decision of the European Commission on the commercialization of insects is part of the "Farm to Fork" strategy, which plans to transform the European food system in the direction of greater sustainability in several aspects (i.e., food security and low-impact

Table 46.3 Confidence in some items toward insect food

Questions expressed on the Likert scale (from 1 very little to 5 very much)	I trust	I don't trust	Percentage difference (PD)	*P* value	All	PD/ average All
I trust the safety of the food I buy	3.60	3.31	0.28	4.8E−19	3.46	0.0816
I trust the information on the labels of the foods I buy	3.60	3.33	0.27	2.27E−08	3.47	0.0774
Food safety control bodies are effective	3.56	3.41	0.15	1.79E−08	3.49	0.0430
Buying sensitivity for ethical brands (i.e., Fairtrade)	2.88	2.78	0.10	1.46E−05	2.83	0.0350
Sensitivity to purchase for products sold without packaging	3.20	3.13	0.06	5.58E−06	3.17	0.0202
Concern about the environmental impact of food (i.e., deforestation, waste of water resources, carbon dioxide emissions)	3.71	3.64	0.07	2.24E−06	3.68	0.0189
Concern about the presence of harmful substances that could lead to food poisoning (i.e., salmonella, listeria, etc.)	3.99	4.31	−0.32	0.002173	4.14	−0.0762
Concern about counterfeit food (i.e., actual ingredients are not as stated on the label)	3.77	4.09	−0.32	0.001078	3.92	−0.0821
Sensitivity to purchase by the origin of the Italian and nonimported product	3.69	4.03	−0.34	0.003757	3.85	−0.0894
Concern about chemical contamination	3.43	3.78	−0.35	1.51E−11	3.59	−0.0987
Concerns about lack of sanitation checks during the production process	3.79	4.23	−0.44	1.99E−07	3.99	−0.1097
Concerns about deliberate contamination of the product (i.e., by workers or external people)	3.32	3.84	−0.52	2.68E−07	3.57	−0.1462
Concerns about viruses and food-related diseases (i.e., mad cow disease, avian, and swine flu)	3.42	3.96	−0.54	4.8E−09	3.67	−0.1466
Sensitivity to purchase due to the absence of genetically modified organisms	2.86	3.31	−0.46	9.37E−17	3.07	−0.1484

production). Insects are among the "future foods" that could support this "food" transition, playing a role in the European food market, and the results seem to show that at least some feasible consumers have trust in insect food consumption.

This preliminary consumer study is intended to contribute to the perception of Italian consumers, given the small number of studies dedicated to them. At the same time, the research is limited to a sample of younger consumers with a high level of education, so future research should be oriented toward extending the study to other categories of the respondents' generation and to other generations to assess the main factors that may lead from the consumption of this food to disgust and "foodphobia."

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Part VI
Digitalization: Innovation

Chapter 47
Digital Innovation Ecosystems: A Systematic Literature Review and a New Definition

Irina Gorelova, Francesco Bellini, Adriano Fabbri, and Fabrizio D'Ascenzo

Abstract The rapid development of digital technologies creates digital ecosystems that penetrate into the everyday lives of society. The digital ecosystem is a relatively new phenomenon and has multiple connotations and dimensions in the scientific literature, but it is univocally recognized as a context of the technological execution of both innovation and business ecosystems. The concept of digital innovation ecosystems (DIE) is only partially debated in the scientific literature, so the main objective of this research is to provide a full-fledged definition of the phenomenon under consideration. To reach this goal, an approach based on a broad systematic literature review (SRL) of scholarly studies is adopted. SRL on the definitions and dimensions of DIEs provides evidence of the nature of this rising trend, allowing an in-depth understanding of the dynamics in this domain. The main results of the research are the aggregation and analysis of the various definitions of DIEs, their systematization, and the formulation of comprehensive and shared DIEs.

Keywords Digital innovation ecosystems · Conceptualization · Systematic literature review

47.1 Introduction

Digital technologies are currently the key elements that shape the everyday life of society. Digitalization is becoming an important topic of discourse both in scientific literature and at the governmental, national, and supranational levels. Thus, the United Nations Digital Strategy 2022–2025 aims to create a world in which digital is an empowering force for people and the planet in three directions of change:

I. Gorelova (✉) · F. Bellini · A. Fabbri · F. D'Ascenzo
Department of Management, Sapienza University of Rome, Rome, Italy
e-mail: irina.gorelova@uniroma1.it; francesco.bellini@uniroma1.it; adriano.fabbri@uniroma1.it; fabrizio.dascenzo@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_47

structural transformation, leaving no one behind, and building resilience (UNDP 2022).

In the current dynamic context, innovations are increasingly the result of a network that could present the form of an "ecosystem" (Kolloch and Dellermann 2018) and less and less the result of the action of a single entrepreneur (Hagedoorn 1996); all this poses new challenges to the actors involved in innovation processes (Adner and Kapoor 2010). The concept of "ecosystem" is widely studied in the literature (Christensen and Rosenbloom 1995; Kolloch and Dellermann 2018; Basole 2009) as well as the concept of "innovation systems" (Freeman 1987; Breschi and Malerba 1997), but "innovation ecosystems" have become popular in recent years, and the debate around the ambiguity of the term has been increasing over time (Granstrand and Holgersson 2020). A synthetic way to describe this phenomenon is reported by Dodgson et al. (2014), where "innovation ecosystems" are defined as a range of different ways to define value-creating interactions among different actors; in fact, they can represent a new way to conceive value creation linked to the concept of innovation (Adner and Kapoor 2010).

Digital innovation ecosystems (DIEs), being an inevitable part of the innovation context, lack a coherent theory to synthesize diverse opinions, experience-based insights, and research findings about DIEs (Wang 2020). Therefore, the main goal of this research is to gather evidence from the scientific literature on the definitions of DIEs and their further conceptualization. The gathered evidence could contribute to advancing research in the fields of innovation and digital transformation.

The paper is organized as follows: Sect. 47.2 step-by-step illustrates the research method applied to the study and introduces the research question; in Sect. 47.3, the results of the study are represented; and Sect. 47.4 provides concluding remarks on the study.

47.2 Methodology

A systematic literature review (SRL) is a key tool of an evidence-based approach that enables a researcher to analyze and structure the knowledge existing in the scientific literature for its further practical and scientific use (Tranfield et al. 2003). Following the format of previous SLRs (Durach et al. 2017; Savastano et al. 2019), a six-step review process was carried out in this research, as shown below:

1. Stage one of our research involves the definition of the research questions and keywords. To do so, the keyword combination "digital innovation ecosystem" was chosen; a wildcard was applied to the keyword combination to embrace the cases when the keyword combination was used in the plural. Taking into account all of the above, the main research question (RQ) of the paper is as follows: What is the "state of the art" of the academic literature regarding DIEs?
2. The next step of the study is the determination of the required characteristics of the studies and the inclusion criteria to focus on relevant and rigorous literature

sources only. The authors agreed to study peer-reviewed articles and conference papers written in English, with no limitation on the year of publication or geography of the study. To ensure academic quality, the Web-of-Science (WOS) and Scopus online databases were used in the research; the study was corroborated by supplementary materials identified in Google Scholar, so when the articles were extracted from the Google Scholar database, the authors additionally checked whether the study was subject to peer review.

3. Stage three involves the primary retrieval of a sample of potentially relevant literature according to the keywords and inclusion criteria discussed using the default search field TITLE-ABS-KEY in Scopus, the topic field in WOS, and the above-mentioned keyword combination in the search box of Google Scholar.
4. In the fourth stage of the study, the pertinent literature was selected. PRISMA 2020 checklist was adopted for the stages of identification, screening, and inclusion of papers in this review (Page et al. 2021). Twenty-five articles were chosen for the final examination.
5. The next step of the systematic review process includes synthesizing the literature by applying coding schemes. The coding categories were predefined and corresponded to the aim of the study and its RQ.
6. Finally, the results of the study were analyzed and reported, providing a descriptive overview of the studied literature and discussing thematic findings. The findings of the review process are presented in the next section.

47.3 Results and Discussions

47.3.1 Characteristics of the Studied Literature

As mentioned in the section above, 25 articles were from 451 found in three databases for our research. The first mention of DIE dates back to 2011, but research on the topic has been growing since 2018, peaking in 2020. Such a distribution of the literature may indicate that the DIE phenomenon is just beginning to enter the scientific discourse, even though the studied literature shows in-depth research on this topic.

Regarding the distribution of studies by country, the USA is the leader in DIE research, and Brazil, Germany, and the UK are in second place. Other EU countries represented in the scientific literature are Austria, Finland, France, Italy, Latvia, Poland, Slovenia, Spain, and Sweden. In total, the countries of the EU account for approximately half of the studies.

The articles are almost equally distributed between the sources and their types: journal publications and conference proceedings. The authors believe this may indicate the gradual settlement of the DIE phenomenon into scientific discourse in recent years.

Table 47.1 represents the most used keywords in the studied literature, ranked from 1 to 6, given that other collected keywords have a frequency of 1, which is

Table 47.1 Distribution of the keywords by frequency

Keyword	Frequency	%	Rank
Innovation system	8	9.36	1
Ecosystem	6	7.02	2
Digital innovation	5	5.85	3
Digitalization	4	4.68	4
Industry 4.0	4	4.68	4
Digital innovation ecosystem	3	3.51	5
Digital transformation	3	3.51	5
Ecology	3	3.51	5
Startups	3	3.51	5
Digital ecosystem	2	2.34	6
Innovation community	2	2.34	6
Open innovation	2	2.34	6
Technology	2	2.34	6

explained by the limited range of the studied literature. In addition to the keywords used to retrieve the literature, the most frequently used keywords are predictably connected to the specific elements of the digital innovation domain. However, the sample also included keywords related to the stakeholders of the DIE—startups and innovation community—which will be discussed below.

47.3.2 Definitions of the DIEs

The literature body proposes several DIE definitions presented in Table 47.2. According to the evidence gathered, DIE could be defined as a complex innovation ecosystem of a sociotechnical nature aimed at creating new products and services using digital technologies to create value. Scholars stress the presence of technological (digital) and social (physical) mutually interdependent components; the parts of DIE constantly coevolve, learning how to interact effectively.

47.4 Conclusions

Digital transformation occupies an important place in managerial and scientific discourse. This research discusses the phenomenon of DIEs and their definitions. The systematic literature review on the topic shed light on the state of the art in the scientific discussion on the topic and gave insights into the nature of the DIE that contributed to the formulation of the shared definition of the DIE. The main limitation of the study is a limited literature sample; however, the literature studied represents a significant contribution to the rising scientific discourse on the topic. The

Table 47.2 DIE definitions in the literature

Paper	Definitions of the "DIE" concept
Kolloch and Dellermann (2018)	An innovation ecosystem as a social technological system (actor network) consisting of two inseparable parts: a social system (human actor network) and a technological system (nonhuman actor network)
Suseno et al. (2018)	DIE models the interactions and relationships between organizations and stakeholders, in creating new products and services using digital technologies in order to create value
Wang (2018)	A special type of sociotechnical system
	A complex arrangement of technologies, methodologies, concepts, business application areas, organizations, and institutional contexts; a network of heterogeneous social and technical elements, which coevolve over time
Beltagui et al. (2020)	DIEs account for industry-spanning cooperative and competitive dynamics among firms related to innovations that combine physical and digital elements
Cvar et al. (2020)	A complex system of various actors having different roles, interacting in mutual interdependence, constantly learning how to interact effectively
Wang (2020)	A special type of sociotechnical systems, a dynamic collective of interdependent actors and the resources they draw on to innovate with digital technology
Wang (2021)	A loosely coupled set of autonomous actors (people and organizations who interact without hierarchical fiat) involved in the development and implementation of innovations enabled by digital technologies

DIE digital innovation ecosystems

authors deliberately narrowed the range of literature, concentrating only on the literature that discussed DIEs and no other ecosystems that have a similar nature and connotation, to reveal the characteristics of DIEs as they understood the scholars that use this definition. Thus, the study of the DIE phenomenon at an early stage of its development and the findings of our research represent some interesting theoretical, empirical, and policy implications. Therefore, the theoretical contribution of the present study consists of the conceptualization of the discussion on the common elements of DIE in the scientific discourse, which were previously neglected in the literature. The shared definition of DIEs could raise the discussion in future scientific studies. The managerial implication of this paper resides in the evidence of the role and place of organizations in the DIE environment, which has significant potential to leverage their activity. From an institutional and political viewpoint, the present results can support governments and local administrations in improving their role in the DIE context through research and innovation projects and programs, with the goal of increasing the effectiveness and efficiency of stakeholders' engagement. These outcomes also have a strong social and economic impact on economic development; hence, the development of DIEs prompts advancements in other spheres of life. Future studies on the topic consist of the identification of internal and external context DIE variables and levels of DIE allocation with the following construction of the DIE conceptual model.

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Chapter 48
Smart City and Internet of Things

Angela Carelli, Patrizia Papetti, and Ilenia Bravo

Abstract The aim of the research is the analysis of smart cities as an application of the Internet of Things (IoT): the concept of a smart city/community (SC) can be identified as one of the areas in which IoT technology finds its natural application. According to the Agid, the term SC means the place and/or context where the planned and wise use of human and natural resources, appropriately managed and integrated through the numerous ICT technologies already available, allows the creation of an ecosystem capable of making the best use of resources and providing integrated and increasingly intelligent services (i.e., the value of which is greater than the sum of the values of the parts that compose it). The axes on which the actions of an SC are developed are many: mobility, environment and energy, building quality, economy and ability to attract talent and investments, safety of citizens and city infrastructures, and citizen participation and involvement. Essential conditions are connectivity and the digitization of communications and services. SC is therefore a new conception of urban reality that, through an intelligent direction of the many human activities that take place within it, aims to raise the standards of sustainability, liveability, and economic dynamism of the cities of the future. Specifically, the aim of the research is to analyze the Italian situation and the development prospects of the IoT in SCs, discussing the main present and future applications.

Keywords Smart City/Community (SC) · Internet of Things (IoT) · Applications

A. Carelli (✉) · P. Papetti · I. Bravo
Department of Economics and Law, University of Cassino and Southern Lazio, Cassino, Italy
e-mail: a.carelli@unicas.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_48

48.1 Introduction

A smart city (SC) is an emerging strategy that aims to improve the quality of life of citizens by using the most innovative technologies to support the specific needs of each city. The SC was conceived to address the problems arising from the growing trend towards urbanization. In the future, migration to urban centers will tend to increase. According to UN estimates, the percentage of the population living in cities will increase from the current 55% to almost 70% by the end of 2050. To date, cities occupy less than 2% of the total world territory but produce 80% of the global gross domestic product (GDP) and over 70% of carbon dioxide emissions (United Nations 2020). Cities, therefore, have a strong impact on climate change. The goal of an SC is to respond to these challenges related to urbanization, with the ultimate goal of improving the overall quality of life of citizens.

48.2 SC: Definition and Classification

The basis of the definition of SC is theories on industrial districts (Becattini 1989), clusters (Bagnasco 1977), and technopolises (Shilling and Izzo 2013), which identify three main elements that favor the innovation of a territory (Auci and Mundula 2012): the concentration of different experiences in various fields of knowledge and production; a cooperation network between the actors involved; and the presence of catalysts that facilitate the combination of different capacities and actors. The evolution of the SC concept is also subsequently linked to the following models: the NSI—National System of Innovation (Lundvall 1992), the Regional and Local Innovation System (Cooke et al. 2004), and the Triple Helix (Etzkowitz 2008). The "triple helix" models were later integrated with others, focusing above all on the role of creativity in more sustainable development in an urban context; creativity is therefore seen as a key factor in pursuing both environmental and social sustainability (Gabe 2006).

A SC connects human capital, social capital, and ICT (Information and Communication Technologies) infrastructure to address public issues, achieve sustainable development, and increase citizens' quality of life: the SC is not only a tough technology-based strategy but also requires the deep involvement of the city's human capital to produce its benefits. SCs can be classified according to six main axes or dimensions (Giffinger et al. 2007): smart economy, smart people, smart environment, smart governance, smart mobility, and smart living. These six parameters identify the essence of a SC, which, in addition to being a digital or technologically advanced city, according to Giffinger et al. (2007), is an organic and multifaceted set of physical, economic, intellectual, and social capital.

48.3 Reference Regulatory Context

48.3.1 European Programs

The European Union (EU) has been investing in the SC model for some time. At the European level, there is no specific fund dedicated to smart cities but a plurality of access possibilities to different types of financing. Beyond the programs of the Member States that are based on the integration between national resources and structural funds (ERDF, ESF, and EAFRD), the main programs with directly managed European funds that can finance particular aspects of an SC are as follows:

- Horizon Europe (Agency for the Promotion of European Research, 2021), EU Framework Program for Research and Innovation for the 2021–2027 period. It is the successor to Horizon 2020. The program has a duration of seven years and a total budget of 95.5 billion euros (at current prices), a figure that includes the 5.4 billion euros allocated to the Next Generation EU recovery plan. By supporting research and innovation, Horizon Europe is structured on the following four pillars: Excellence Science, Global Challenges and European Industrial Competitiveness, Innovative Europe, Widening participation and strengthening the European Research Area.
- The European Digital Plan—Digital Europe Program 2021–2027 (European Commission 2021). On March 9, 2021, the European Commission presented a vision and perspectives for Europe's digital transformation by 2030. The Commission has proposed a digital compass for the EU's digital decade that develops around four cardinal points: Skills, Infrastructure, Business, and Government.
- LIFE, the EU flagship program for nature, protection of biodiversity and fight against climate change (CINEA 2021). The general objective of the new LIFE (2021–2027) is to contribute to the transition to a clean, circular, energy-efficient, climate-neutral, and climate-resilient economy.
- Single market program 2021–2027 (European Commission 2020), which will replace in the 7-year period 2021–2027, the activities that have thus far been funded under six different programs, including Competitiveness of enterprises and Small and Medium-sized Enterprises. With 4.2 billion euros over the 2021–2027 period, it provides an integrated package to support and strengthen the governance of the single market. The program protects European consumers and allows many small-sized and medium-sized enterprises to take full advantage of a well-functioning single market, providing support in areas such as food safety, consumer protection, support for small-sized and medium-sized businesses, a more effective single market, and effective European standards.
- Connecting Europe Facility 2.0 (CEF 2.0) 2021–2027, which aims to accelerate investments in the field of trans-European networks and stimulate both public and private investments. The program, worth 33.71 billion euros, aims to fund the development of high-performing, sustainable infrastructure in the fields of

transport, digital, and energy. The budget is divided into three sectors: transport, energy, and digital (Council of the European Union 2021).

48.3.2 Italian Programs

All the initiatives regarding the SC, proposed and implemented at the European level, also find correspondence in Italy, thanks to specific action plans undertaken in part and programmed for the next few years by the Public Administration (PA). They are:

– The Digital Italy 2026 Plan, which is developed along two axes, is in line with the Digital Compass 2030 objectives (MITD 2021): broadband deployment (all EU households will have one GPS connectivity, and all populated areas will be covered by 5G); digitalization of the PA, with the aim that by 2026, 70% of all adults will use digital identity and have basic digital skills; and 80% of public services will be available online. Regarding the digital PA, the main actions are to adopt the "cloud first" principle for at least 75% of central and local public administrations by 2026; to make all public data interoperable, that is, able to communicate with each other safely; and to ensure that 70% of Italians have a digital identity by 2026.
– Italian strategy for ultra-broadband "toward the Gigabit Society" (25.05.21) with both national and EU resources. In this context, the National Federated Information System for Infrastructures (SINFI) was also established, and the procedures for the construction of infrastructures for fiber optic networks were simplified. A public Wi-Fi network is also under development (MITD and MiSE 2021).
– Three-year plan for IT in PA 2021–2023 (Agid and DT 2021). The plan's update is characterized by the following new elements: objectives and expected results related to the NRRP (National Recovery and Resilience Plan) implementation and maximum supervision of digital transformation obligations. The three-year plan for IT in the PA is a summary of the digital transformation in relation to the use of NRRP resources (190 billion euros of which 9.75 billion euros "Digitization, innovation, and security in the PA," of which 6.14 billion is the share for "PA Digitization") and the implementation of the Digital Italy Strategy 2026 plan, focused, on the one hand, on digital infrastructures and ultra-broadband connectivity and, on the other hand, on those interventions aimed at transforming the PA digitally. The plan establishes the evolution and more widespread dissemination of digital services (i.e., electronic identity cards, SPID, pagoPA) and aims to strengthen managerial and digital skills within public administrations.

48.4 Smartness Measurement

Several organizations have drawn up a series of models to evaluate the smartness of a city. The main indices are:

– Desi 2021, the ranking of EU Member States (European Commission 2021). The DESI (Economic and Society Digitization Index) is the tool through which the European Commission has been monitoring the digital competitiveness of the Member States since 2015. Italy's digital competitiveness is significantly lower than in other European states: according to data from DESI 2021, referring to the year 2020, Italy is 20th, with the worst data in Human Capital and Connectivity.
– IMD Smart City Index 2021, IMD is an index that classifies smart cities in the world, created by the Smart City Observatory of the IMD (Institute for Management Development) World Competitiveness Center, in collaboration with SUTD (University of Technology and Design). Singapore (first), Zurich (second), and Oslo (third) are on the podium of the IMD-SUTD Smart City Index 2021, while with reference to our national reality, we unfortunately see Bologna (77th), Milan (81st), and Rome (112th) in the lower-middle part of the ranking. (IMD-SUTD 2021).
– ICity Rank 2021, the ranking of smart cities in Italy elaborated by Forum PA (Forum 2021). ICR 2021 is characterized by the introduction of an indicator that seeks to measure not only the presence but also the ability to communicate and make the tools of digital transformation usable. ICity Rank 2021 puts on the podium the triad of metropolitan cities, Florence, Milan, and Bologna, followed by '*Roma Capitale*' and by medium-sized cities such as Modena, Bergamo, Turin, Trento, and Cagliari (the only city in the South). The gap between northern and southern Italy in digital transformation processes remains wide: two-thirds of the southern capitals are placed in the lowest third of the ranking. The year 2022 will be a crucial year for the implementation of the NRRP, for which the role of urban realities is decisive.

48.5 Conclusions

In the next few years, a development of the SC is foreseeable thanks to the NRRP funds, which allocate over 10 billion euros of investments for the SC and, in particular, for issues such as urban regeneration, sustainability, and digitalization of services. The NRRP missions in which there are elements and objectives related to the SC theme are the following (Risi 2022):

– Mission 5: Inclusion and cohesion with investments in urban regeneration, including the reform of the Integrated Urban Plans (2.5 billion euros), which includes participatory urban planning projects, with the aim of transforming vulnerable territories into smart and sustainable cities;

- Mission 1: “Digitization, innovation, competitiveness, culture,” which promotes, among other things, Mobility as a Service (MaaS) projects, an initiative aimed at creating a sustainable mobility system through the integration of different transport modes through a single digital channel, facilitating travel in urban centers;
- Mission 2: “Green Revolution and Ecological Transition,” which includes various interventions attributable, directly or indirectly, to the network of interventions enabled by smart cities (development of a more sustainable local public transport system with the strengthening of cycling mobility, rapid transport of mass and electric charging infrastructures, smart building projects, smart grid, and strengthening of the electricity distribution network).

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Chapter 49
Digital Transformation in Companies and Human Resources Management

Angela Carelli and Ilenia Bravo

Abstract The last 30 years have seen an evolution in the implementation of ICT (Information and Communication Technologies) in companies. In the first phase, the main use was to support purely operational functions, such as logistics management, inventory organization, and purely administrative tasks. In the second phase, they were used to stimulate the flow of information, making a contribution in the middle management range, up to the third and last phase, which corresponds to the use of technologies as fundamental levers for the definition of strategies in favor of the top management. Therefore, new business models have been developed, and the multisided platform represents the new paradigm for setting business models. In this process of digital transformation in companies, human capital plays a fundamental role. In managing change, it is necessary not only at the team level but also as a single resource. Human resources are a key resource in digital transformation processes, but strategic alignment is necessary to guide the company toward these goals; therefore, e-leadership becomes a key element in the digitalization and innovation processes of companies.

This article analyzes the current digital transformation of companies, identifying new models of human resource management and the new skills needed.

Keywords Digital transformation · Human resources · Digital skills

49.1 Introduction

In the last 30 years, there has been an evolution in the use of ICT (Information and Communication Technologies) within companies, first as a support tool for purely operational functions (logistics management, inventory organization, and purely

A. Carelli (✉) · I. Bravo
Department of Economics and Law, University of Cassino and Southern Lazio, Cassino, Italy
e-mail: a.carelli@unicas.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_49

administrative tasks), then as a tool to stimulate the flow of information, and therefore as fundamental levers for defining corporate strategies in favor of top management.

The aim of this research is to analyze the effects of digital transformation in companies on human resources management. The starting point is the analysis of ICT implementation in companies with reference to the new business models necessary to exploit all the opportunities present on the market. Then the new skills required by the market (hard skills and soft skills) are identified, with the consequent evolution of recruitment and leadership. Finally, the digital transformation process in Italy was examined, identifying the recent incentive tools for the new organizational model capable of integrating digital technologies and managerial approaches.

49.2 Digital Transformation

Digital transformation is a constantly evolving process that uses technology to bring a competitive advantage in operations, marketing, sales, and the production and delivery of products and services. Technology is the sine qua non for the adoption of digital and the introduction of smart working models within organizations.

Digital transformation is a holistic approach that integrates the technology and models of digitalization in all areas of the business to offer customers a better experience and to change the way companies and staff operate.

The foundations of digital transformation can be summarized in the following pillars, linked together (Fracasso, 2018):

– Corporate culture, essential for creating an environment in which change is accepted by the entire corporate ecosystem while maintaining the corporate vision.
– Customer experience, since the ultimate goal is always to ensure a value creation process for customers, planning the buyer's journey processes carefully, and ensuring synergy in the company/customer relationship.
– People and innovation because the company aims to ensure the right human resources within it, capable of promoting the future through proactivity and an ability to transform ideas into concrete actions;
– The main element found in the CEO (Chief Executive Officer) is leadership because the ability to know how to guide and inspire change in every resource is fundamental.

49.3 Business Model Innovation: The Strategic Factor of ICT

The new business models derived from integrations with ICT are more transversal, obtaining more flexibility and efficiency. In addition to the contribution of innovation and the enhancement of existing business structures, the introduction of digital technologies also creates new business models (Muzellec et al., 2015). Examples of successful multisided platforms (MSPs) that reflect the logic of being able to offer value across the board to all users within the network with matchmaking logic, offering services and products that are not in the base, are present in various sectors (Cusumano et al., 2019). The MSP perfectly embodies the new paradigm for setting business models. The main strength of an MSP is its cost-effectiveness because access to the platforms does not involve large costs, either for the customer or for the company. The MSP can be described and represented by the following components (Elia et al., 2020):

- Focus (What): It helps to define the purpose of the platform by defining the why of its existence; it is important to establish mission and vision.
- Side (Who): It groups the category of users participating in the platform and simultaneously helps to define the class of stakeholders.
- Actions (How): These are the set of activities aimed at coordinating interactions between users within the platform, and not only that, because they also encompass all the logic of operation (e.g., matchmaking), thanks to which users can make the most of the full potential of the network, and concern the monetization logics of the platform.
- Driver (Why): Represents the underlying motivation that must entice you to increase participation in the platform; therefore, it is essential to establish an effective driver, such as a magnet that manages to stimulate and entice users' "call to action".
- Governance: A fundamental element in controlling the smooth flow of activities within the platform, as it represents the set of ethical and behavioral rules to be respected to ensure a high level of quality.

49.4 The Impact of Digital Transformation on the HR Function

The structure of the company and the way it is designed are not the only elements involved in the innovation process. To ensure adequate success, it is important that the resources within the company have characteristics that help to create a business ecosystem that is inclined to change. From this perspective, e-leadership is a key element in the digitalization and innovation process of companies (Valdes, 2018) and can be classified according to three types of digital leaders (Kane et al., 2018):

digital investors, digital pioneers, and digital transformers. However, only with the presence of the right human capital can we speak of innovation, because investing only in technological capital and neglecting investments in human resources is counterproductive. The categories of digital knowledge and skills are (Osservatorio delle competenze digitali, 2019): skills for digital citizenship; digital skills of workers; ICT specialist skills; and e-leadership skills. The UNI 11621-2: 2021 standard describes the profiles of professionals in the ICT field, with more precision for the second-generation and third-generation European profiles (UNI, 2021). The European e-Competence Framework (e-CF) 3.0 defines ICT competence as "a demonstrated ability to apply knowledge, skills, and attitudes for achieving observable results." Furthermore, the European framework uses a common and understandable language throughout Europe. The UNI EN 16234–1 standard provides safe guidance in the process of evaluating and selecting human resources and, above all, in the process of training ICT professionals. The e-CF 3.0 (UNI EN 16234-1: 2020) is structured in four dimensions, which represent the different business and human resources planning requirements and complement the guidelines used to define job skill levels. The dimensions are structured as follows (ACCREDIA, 2020):

- Dimension 1 includes five areas of digital skills derived from ICT business processes such as plan, build, run, enable, and manage;
- Dimension 2 includes a set of reference digital competencies for each area, with a generic description for each competence, for a total of 40 identified competencies.
- Dimension 3 indicates the five different levels of ability for each digital competence.
- Dimension 4 presents some examples of knowledge and skills related to the model.

In an increasingly competitive environment, businesses recognize that employees are a major source of sustainable competition.

It is crucial for companies to have unique resources to maintain their competitive advantage (Gözen, 2016). In other words, they must have a skilled workforce, be able to retain it, and use it in line with their business goals. Due to increased global competition, working life has become more skill-intensive, and recruiting and attracting the right candidates at the right time has also become more important and more difficult than ever before (Tong and Sivanand, 2005). In general, recruitment can be explained as the process of attracting, selecting, and hiring the most suitable candidates for vacant positions based on a candidate's individual ownership and person-organizational adaptation (Melanthiou et al., 2015). The development of the new managerial model will therefore require a change in the way managers conceive their role, becoming the orchestrators of a flexible and dynamic behavioral system. In a more dynamic and fluid corporate environment, the very important framing that managers do must take place through their continuous intervention in the organization's behavioral system.

The assumption is that the organization is understood as a system of interdependent behaviors based on specific characteristics of the following elements

Table 49.1 Organization as a system of interdependent behaviors

Behaviour theory	Role of management	Source of managerial power	General principle of managerial action
People devise strategies to achieve their goals based on resources and constraints	Promotion of autonomy in order to make people responsible for the consequences	Power is the ability to influence the issues at stake	Definition of the role in continuous change, according to the actions carried out

Source: personal elaboration from Freeland et al., (2018)

(Table 49.1) (Freeland et al., 2018): Behavior Theory, Role of Management, Source of Managerial Power, and General Principles of Managerial Action.

Regarding the way in which Italian companies are facing and managing digital transformation, the results of the research conducted by the Talent Garden are significant (Sola, 2019). The research is conducted on a sample of over 500 people managers of as many Italian companies and highlights the expected advantages related to the integration of agile approaches within companies: adaptation to change (61%), optimization of time and resources (51%), improvement to coordinate people and manage business processes, for the quality of the final outputs in terms of the effectiveness of the product on the market, and in general for the ability to innovate, the quality of the outputs (30%).

49.5 Conclusions

In the digital transformation process in Italy, companies operate in synergy with the third platform, conceived by the International Data Corporation and characterized by four pillars: cloud computing, big data analytics, mobility, and social business. Considering the three phases of digital transformation strategies, today, Italian companies are in the multiple innovation phase, where cloud, social, big data, and mobility technologies are joined by so-called innovation accelerators, in particular artificial intelligence, the IoT, blockchain, and natural interfaces.

These technologies support companies in creating new products and services through dynamic and immersive interactions with their customers and substantial and innovative reviews of IT and business processes (Assintel, 2020). However, the objectives pursued by the companies according to their geographical positioning are different: new forms of automation in operations and much less on the redesign of the business model for companies in Southern Italy and the islands; redesign of the business model and on the enhancement and monetization of data for companies in the North and Center. The most "virtuous" sectors in the definition and implementation of a digital transformation strategy are finance and PA. The challenges in place for digital transformation are related to the following factors: lack of a single strategy shared at the company level, lack of corporate culture toward continuous change, lack of economic resources, and lack of skills. In relation to this last factor, the Italian government drafted with RCM (Resolution of the Council of Ministers) of July 21, 2020, the National Strategy for Digital Skills (Agid, 2020), whose pillars are education and higher training, the presence of an active workforce, skills development by ICT specialists, the development of basic digital skills necessary to exercise citizenship rights, and conscious participation in democratic life. In the future, Italian companies have a concrete opportunity in their hands to increase their technological efficiency and give a concrete change to the business thanks to the NRRP (National Recovery and Resilience) and the Transition Plan 4.0 (Mise, 2020; Anitec-Assinform 2021).

The funds allocated by the NRRP to Italian companies for investments in digital innovation will favor a very important technological restructuring of national companies. The NRRP is divided into six missions and allocated €40.32 billion for the first and most important mission (digitization, innovation, tourism, and competitiveness). A large part of the funds allocated in the first mission are for the innovation and digital improvement of Italian companies. In percentage terms, this is 60% of the plan's resources provided for in the plan, or approximately 30.6 billion euros.

Considering that, according to the Digital Economy and Society Index 2022, Italy is in the eighteenth position among the EU Member States (European Commission, 2022) and is characterized by some precise elements: the range of beneficiary companies is more extensive; the amount of the tax credit will be variable; and the recognition that companies will enjoy in relation to credit will be over a time horizon of 2021–2022. Therefore, companies are encouraged to define a new organizational archetype and a new cultural and value system capable of integrating digital technologies and managerial approaches. In fact, corporate human capital, as analyzed, is exposed to various challenges that affect all areas of the digital value chain (FUB and COTEC, 2012).

In conclusion, the analysis carried out with particular reference to the European e-CF 3.0 suggests a further element of study. Digital transformation does not have as a side effect a reduction in jobs in our societies, but on the contrary, the transformation of work itself is suggested, with the creation of new opportunities with a view to continuous training of human resources, where the three main proposals for priority intervention are (Osservatorio delle competenze digitali, 2019): strengthening training and updating of the skills of teaching staff; raising awareness that more skilled jobs will increase and less skilled jobs will be replaced by intelligent machines; and stimulating the upskilling of the ICT workforce in companies.

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Chapter 50
"Everything-as-a-Service": The Evolution of the Private Market for Goods into a Public Service Platform

Carlo Alberto Carnevale Maffè, Riccardo Porcu, and Alessio Tola

Abstract In contemporary capitalism, ownership is becoming an economically inefficient and socially unsustainable method of allocation and usage of many market goods. In fact, the digital revolution makes real-time information about resource availability and the preferences of the players involved accessible to market players. This process influences the factors that govern trade, making the provision of services more efficient and socially responsible compared to the sale of products.

Technological innovation, mass-spread connected digital devices, and regulatory development in terms of environmental sustainability are some of the main factors that modify the terms of trade on the goods market and therefore influence the transition towards new forms of fruition services that are not based on selling products, particularly for consumer durables. These phenomena fall under the broad concept of "servitization." The private property of a durable good connected to the Internet, which can be a car or a washing machine, becomes an increasingly inefficient solution compared to its potential use in terms of service, for example, "pay-per-use" mode, provided by the manufacturer or a third party and based on the availability of immediate and timely information on the status of the good itself and the users' demand. From a microeconomic perspective, the breakeven point between purchase and access is rapidly shifting toward the latter. From a macroeconomic perspective, this development can have a significant impact on the labor market and on the productive and financial structure, in addition to taxation and international trade.

Keywords Digital · Sustainable · Innovation

C. A. C. Maffè
SDA Bocconi School of Management, Milan, Italy

R. Porcu
General Directorate of Innovation and IT Security, General Affairs Department, Caligari, Italy

A. Tola (✉)
DUMAS Department, University of Sassari, Sassari, Italy
e-mail: tola@uniss.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_50

50.1 Introduction

In contemporary capitalism, ownership is becoming an economically inefficient and socially unsustainable method of allocation and usage of many market goods. In fact, the digital revolution makes real-time information about resource availability and the preferences of the players involved accessible to market players. This process influences the factors that govern trade, making the provision of services more efficient and socially responsible compared to the sale of products.

Technological innovation, mass-spread connected digital devices, and regulatory development in terms of environmental sustainability are some of the main factors that are modifying the terms of trade on the goods market and, therefore, are influencing the transition towards new forms of fruition services that are not based on selling products, particularly for consumer durables; these phenomena fall under the broad concept of "servitization."

50.2 The Choice Between "Purchase" and "Use": The Role of Digitalization

The private property of a durable good connected to the Internet, which can be a car or a washing machine, becomes an increasingly inefficient solution compared to its potential use in terms of service, for example, "pay-per-use" mode, provided by the manufacturer or by a third party and based on the availability of immediate and timely information on the status of the good itself and the users' demand. From a microeconomic perspective, the breakeven point between purchase and access is rapidly shifting toward the latter. From a macroeconomic perspective, this development can have a significant impact on the labor market and on the productive and financial structure, in addition to taxation and international trade (Kohtamäki et al. 2020; Huikkola and Kohtamäki 2018).

Servitization, which is accelerated by digitalization and regulatory changes, has an increasingly deeper impact on different market areas. The technological obsolescence of goods (e.g., smartphones, computers, and cars in retail markets, but also robotics and automation in the industrial field) facilitates servitization because demand is subject to strong information asymmetry, compared to supply, on the efficient lifecycle duration of these goods.

The most obvious case is that of software: until a few years ago, it was sold as a "product" within an End-User Licence Agreement; currently, it is always more offered under the "SaaS" (Software as a Service) model, provided on cloud by world's leading companies. This model is also well established in markets characterized by a high incidence of maintenance and technological updating costs, such as installation and real estate markets, where, in addition to traditional leases, you can now find "full-service" packages that often include consumables, support, and maintenance, and sometimes even a specific-result bond, not only a best-endeavors obligation, as a guarantee for the tenant for a certain level of availability and productivity, set in advance on a "service level agreement" (Sklyar et al. 2019).

If goods require financing for consumers, the differential between the cost of capital borne by the supply side and the cost of capital borne by the demand side can alone account for a large part of the commercial margins of the "as a service" supply.

Currently, the conveyance of the property of a durable good that falls under the consumer credit criteria could have interest rates an order of magnitude higher compared to those accessible to major companies, which go to financial intermediaries; this is due to the information asymmetry about the customer's use of the good. However, if these asymmetries are not only reduced but even reversed by Internet of Things technologies and artificial intelligence, it will be convenient for a manufacturing company to sell goods within a service level agreement, whose duration and binding conditions can vary. Through this, the company is able to remotely manage its product and optimize its use, both from an energetic and ecological perspective, ensuring the maximum service life and the proper disposal and/or reuse of the good.

50.3 Servitization: A Possible Model for Consumer Staples?

The transition to a "circular economy" model for high environmental impact durables can be faster and more effective if there is no transfer of ownership but only possession. This is because recovery and reuse processes are much more efficient on the supply side and because suppliers' reputational risks are higher than those of individual consumers. In spite of the pauperistic theses, therefore, servitization could be a way to continue the consumerization of the economy without proportionally increasing the environmental impact, indeed reducing it from the outset, even with the same employment of energy sources.

Since services are normally characterized by a higher share of labor in value-added formation, servitization can also foster the creation of new jobs and certainly require new skills, favoring professional mobility, including cross-sectoral mobility.

Looking at the net present value, we can see that benefits from profiling customer behavior are frequently bigger than the "one-off" markup derived from the sale. The highest capital absorption associated with the "as a service" model can be mitigated by the securitization of service-level agreements that, thanks to their stable cash flow, can sustain considerable leverage.

The servitization model is developing even for consumer staples such as food. Consider, for example, a weekly subscription for food supply (above all fruit and vegetables) or periodic deliveries—on a discount—from major e-commerce companies. Therefore, the "shopping list" model has been established due to the development of home delivery for grocery, household, and personal care products. Driven by the logistical constraints introduced by the pandemic crisis, there has been a boom in food delivery, which is just one of the clearest examples of servitization.

Servitization can also have a significant macroeconomic impact in areas affected by fiscal asymmetries between consumption and production. Fuel taxation partially cuts car-sharing company expenses but entirely affects the end user; the same is true for car loan amortization. The lowering trend of the corporate tax rate can potentially be a factor that hastens the servitization process. On the one hand, servitization can lower the tax on consumption for the demand side and theoretically can also lead to the emergence of the submerged black economy because it is largely based on transparent and verifiable digital data (Sjödin et al. 2019).

On the goods market, digitalization not only gradually pushes the focal point toward services, even for the exchange relationship on traditional services markets—which, let us recall, makes up between 70% and 80% of the gross value added to Western economies—but also, technology shifts the balance between different players, acting as a disintermediating factor. The most obvious example can be found in the distribution, which has always been one of the major components of the entire service macrosector: e-commerce. Driven by the pandemic, e-commerce has expanded its field of reintermediation both in different product categories and in terms of penetration and frequency of use among increasingly large consumer groups.

Changes in consumer behavior and business models, along with the evolution of digital technologies, have fostered the rise of new services monetized via subscription approaches. The so-called "subscription economy" exhibits the diffusion of business models based on recurring customer relationships. Within that framework, rather than purchasing goods, users subscribe to services, such as ongoing digital services and consumption-based models. Especially during the pandemic, business models based on subscriptions have shown higher resilience to uncertainty, and the "Subscription Economy Index" (SEI), published by the Subscribed Foundation, measures the growth in the volume of business for subscription-based products and services. The SEI is based on anonymized, aggregated, system-generated activity on the billing service provided by Zuora, a software platform, and is intended to be indicative of the direction of the subscription economy as a whole.

Over the past decade, the SEI has grown 4.6 times faster than the S&P 500, which represents more traditional, product-based businesses (compound annual growth rates for the 10-year period were 17.5% vs. 3.8%, respectively; see Fig. 50.1). In 2021, while companies in the S&P 500 began to recover from 2020 lows, subscription businesses in the SEI continued to thrive, outpacing traditional businesses with 16.2% revenue growth compared to 12% for the S&P 500 (Figs. 50.1 and 50.2).

If we also consider the impact that the trend of reusing second-hand goods—that is widespread among young people and fueled by new digital platforms that allow us to overcome the fragmentation of the supply—has on distribution models, now progressively growing even for those goods that were hitherto left out (such as clothing and accessory products), a deep evolution is becoming increasingly evident and no longer dismissible.

That the services' share of total consumption is growing structurally is nothing new. The rise of disposable incomes, manufacturing, and distribution process improvements has enabled consumers and suppliers to allocate an increasing share of value to an increasingly diverse range of services. This has led, in recent decades, to a gradual but steady increase in the share of services in the economies of developed nations. The traditional model that attributes a "primary" role to farming, a

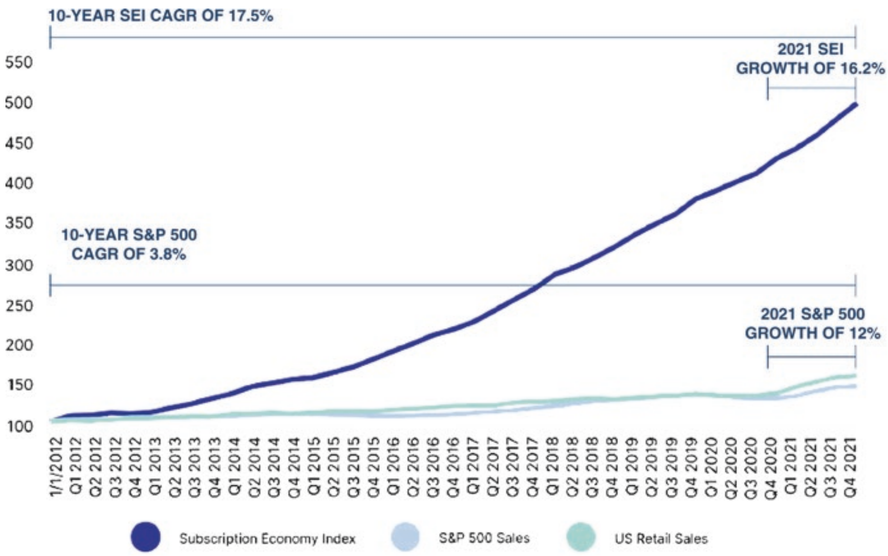

Fig. 50.1 The subscription economy index level versus S&P 500 and US retail sales. (Source: Subscription Economy Index 2022, Subscribed Foundation)

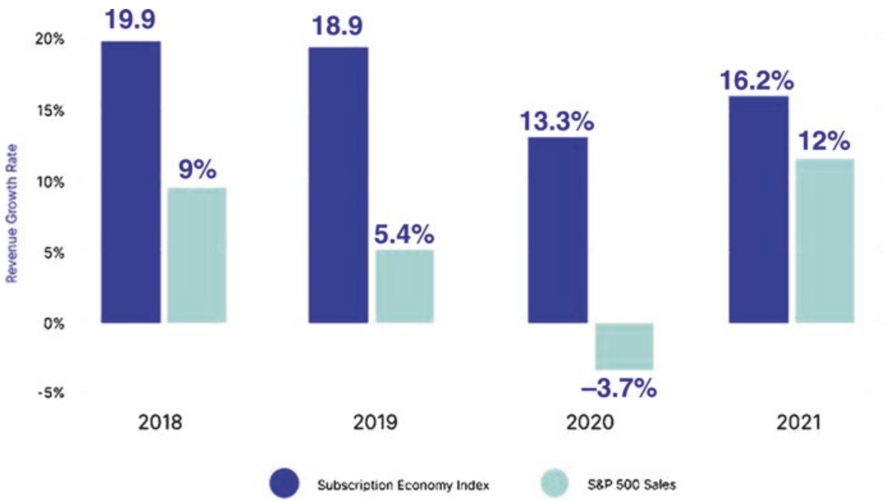

Fig. 50.2 Subscription economy index versus S&P 500 sales annual revenue growth. (Source: Subscription Economy Index 2022, Subscribed Foundation)

"secondary" role to manufacturing, and relegates services to a "tertiary," or residual, role is now clearly outdated. The services market is not homogeneous either in its economic nature or in its social and technological manifestations: cross-sector dependencies with public administration, industry, agriculture, and manufacturing, as well as other areas of production, are multidirectional and increasingly complex.

It is therefore essential to no longer look at services as a stand-alone *commodity category* but as a transversal exchange model across the different economic sectors: from farming to manufacturing, servitization should not be a new ATECO code (the Italian version of the NACE, the European classification of economic activities) but a new, completely different criterion for economic interaction between supply and demand. This is becoming increasingly true, even for the traditional three-sector model.

These "embedded services" for the most technologically advanced industrial goods (machinery and equipment of Industry 4.0) are not properly included in traditional accounting, but they are often reduced under the spare parts supply entry. Separate the service share from the good, or even revert this relation, requalifying spare parts supply and consumables as part of the services—which is already happening in many different areas, just think about what happened for the supply of office machinery, which was among the first to test full service pay-per-use—would bring out the true economic structure of the underlying exchanges. Moreover, the increased investment in digital processes in manufacturing and farming creates added value for the primary and secondary sectors, which is often hidden by official statistics. This is because companies have now incorporated part of the costs by adding technological specialists to their stuff and not buying those services from third party as they used to do before. To give an example, a wine company that yesterday could just add a Controlled and Guaranteed Designation of Origin label for its products has now started to hire digital specialists in charge to guarantee to consumers the traceability and the environmental impact of the supply chain. Statistics show that this service share is embedded in the product price, but it is actually part of a different economic area, from which we could start to think of new value configurations.

50.4 Conclusions

As we have seen, the availability of digital data and the possibility of elaborating on it in real-time can change the terms of trade in the goods market. Unlike the private property of a product, digital data do not constitute a competitor product: sharing them does not reduce the benefit for users; indeed, it often increases it. Even if informative content can have some specific and temporary rivalry features, in most situations, shared data, if properly normalized and anonymized, brings relevant positive externalities. This phenomenon is at the root of the European Union directives on digital data, which promote a new, superior balance between privacy protection and the enhancement of non-personal data.

The new concept of the product/service must lead the commodity sciences to an adequate reflection on the issues of the digital transition.

The ways in which the performance of products is evaluated and valued increasingly involve issues related to customer satisfaction and the same concept of product and service quality.

It is necessary to have rules and metrics adapted to the new context, overcoming the logic of the past and creating instead a productive and normative framework that, albeit evolving, must certainly be attentive to the dynamics of change.

We need some "policy recommendations" on the subject of digital servitization, both on the regulatory front—to ensure adequate consumer protection but at the same time incentivize private investment in legally protected intangibles—and on the technical-methodological front—with new product metrics and statistics that allow us to correctly measure these new phenomena, which today end up "drowned" in an inadequate classification as hybrids between products and services.

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Chapter 51
Supply Chain 4.0: Lean Six Sigma, Industry 4.0 Technologies and Circular Supply Chain Applied to an Italian Hospital Case Study

Cristina Ciliberto, Fabrizio Majorana, Katarzyna Szopik-Depczyńska, and Giuseppe Ioppolo

Abstract The aim of the paper is to present a circular supply chain 4.0 in the healthcare sector of an Italian hospital through the implementation of Lean and Six Sigma techniques to reduce waiting times and improve processes in the surgical unit. Lean Six Sigma methodology is preliminary to a good implementation of Industry 4.0. Before digitalizing and robotizing, it is necessary to improve efficiency both in terms of Lean waste and in terms of variance and efficiency for Six Sigma to be able to "feed" Industry 4.0 with a product that is already optimized and ready for digitalization. The methodology adopted is based on a literature review and a case study. The results show a dramatic increase in the average number of surgery interventions and that the joint adoption of Industry 4.0 technologies, circular economy strategies, and Lean Six Sigma methodologies enables a circular supply chain.

Keywords Lean Six Sigma · Supply Chain 4.0 · Digitalized Supply Chain · Circular Supply Chain · Industry 4.0 · Healthcare

C. Ciliberto (✉) · G. Ioppolo
Department of Economics, University of Messina, Messina, Italy
e-mail: cristina.ciliberto@unime.it

F. Majorana
CEO at Six Sigma Management Institute (SSMI), Europe, UK

K. Szopik-Depczyńska
Department of Corporate Management, Institute of Management, Faculty of Economics, Finance and Management, University of Szczecin, Szczecin, Poland

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_51

51.1 Introduction

There are many similarities between the healthcare sector and the industrial sector, and consequently, the healthcare world could also benefit from that broad and consolidated disciplinary corpus that we could call operations management, which has determined and made possible the exceptional and simultaneous development of the efficiency and effectiveness of the industrial sector in recent decades.

A potential performance improvement could and should be exploited in favor of our health system, as well as to guarantee greater safety in new situations, albeit exceptional, such as that due to COVID-19. To qualify the main and unavoidable difference between healthcare and industry, it is necessary to underline that in all business-to-consumer sectors, the most important aspect is not only to prevent diseases or treat them when they occur but also to do so by generating a satisfying customer experience.

Even in the healthcare sector, as in the industrial sector, the quality of the service provided to patients depends on a large jumble of decisions that are intertwined with each other and that we can group, in very aggregate terms, according to the object of the decision, in the *configuration choices* and *system management choices*.

By *configuration choices*, we mean all those choices that determine how the hardware (physical structure) and software (organizational structure) of the system are made. Since the modification of the physical or organizational structure of a complex organization such as that operating in the healthcare sector requires high investments and equally long timescales, configuration decisions are typically medium- to long-term decisions, delegated to strategic and setting choices.

Management choices, on the other hand, are medium- to short-term decisions typically made with a given configuration.

Therefore, what we have defined as *configuration choices* belongs to the *strategic or business level*.

Management choices typically belong to the operation and process levels.

The dawn of Industry 4.0 technologies, environmental issues such as the need to reduce energy consumption and the spread of health emergencies such as the COVID-19 pandemic have greatly modified the business environment and the business approach of enterprises (The Global Risks Report, 2021).

On the other hand, the importance of the implementation of the Lean Six Sigma methodology before the introduction of Industry 4.0 technologies in a company must be highlighted.

Therefore, the objective of this paper is to demonstrate the power of Lean Six Sigma with the help of Industry 4.0 emerging technologies in an Italian hospital through the presentation of a case study. The paper is organized as follows: Section 51.2 reviews Lean Six Sigma, Industry 4.0, and the circular supply chain in general. Then, the section turns to Lean Six Sigma and the circular supply chain in healthcare specifically to understand their scope of application in this research area. Section 51.3 concerns the methodologies applied; Section 51.4 presents a case study of an Italian hospital; Section 51.5 introduces the results and discussion; and Sect. 51.6 concludes with future perspectives.

51.2 Literature Background: Lean Six Sigma, Industry 4.0, and Circular Supply Chain

Optimization of processes is a transversal choice that can be carried out both by implementing different methodologies, such as Lean techniques, Six Sigma, or Lean Six Sigma, and by introducing Industry 4.0 technologies.

Lean tools are focused on defining value and eliminating waste, whereas according to Harry and Schroeder (2000), Six Sigma is "a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction." Hence, Six Sigma aims to eliminate variability and achieve a high level of quality.

On the other hand, Lean Six Sigma is a methodology of business improvement that is focused on the maximization of shareholder value by improving quality, speed, customer satisfaction, and costs. These benefits are achieved by joining tools and principles from both Lean and Six Sigma (George 2003). Process improvement, customer satisfaction, and better financial results are achieved through the implementation of Lean Six Sigma by eliminating waste and variation adopting the define, measure, analyze, improve, and control (DMAIC) approach (Cherrafi et al. 2016; Salah et al. 2010).

Antony et al. (2022) suggest a sand cone model of Lean Six Sigma evolution from Lean Six Sigma 1.0 to Lean Six Sigma 4.0. Lean Six Sigma 4.0 is more technologically enabled.

Gupta et al. (2020) consider that traditional information systems cannot successfully keep up with the growing amount of data that companies are being involved in today. This exponential growth of data pushes toward the implementation of new technologies (Tissir et al. 2022). Conversely, Lean Six Sigma is based on data analysis to solve complex problems. Thus, Industry 4.0 technologies such as big data, cyber-physical systems, and the Internet of Things can be treated as an infrastructure of Lean Six Sigma.

According to Ghobakhloo (2020), Industry 4.0 currently not only refers to the manufacturing industry but also supports the digital transformation of both industrial and consumer markets with the onset of smart manufacturing and digitalization of delivery channels. Thus, protagonists of the digital era are not only industries and producers but also end-users such as consumers and patients, among others.

Another aspect to take into consideration is the archetypic shift of organizations after implementing Industry 4.0 technologies toward a circular economy (Rajput and Singh 2019). Enterprises are adopting emerging technologies in *circular supply chains* to concentrate on restorative and regenerative features to enable the industrial system to reshape the concept of "end of life" (Heyes et al. 2018; de Sousa et al. 2018; Farooque et al. 2019). Thus, Lean Six Sigma is technologically enabled to meet the needs of the circular economy of an enterprise by boosting the environmental performance at various levels of the supply chain.

Circular supply chain management is a new field of study in the literature that investigates technologies and methods that allow the implementation of "circularity" in industry (Canning 2006).

51.2.1 Lean Six Sigma and Circular Supply Chain in the Healthcare Sector

The healthcare sector is increasingly adopting the Lean Six Sigma methodology, typically used in the industrial sector for its continuous improvement of services. Although Lean and Six Sigma are different methodologies, they operate well together in the healthcare sector (Henrique and Godinho Filho 2018). Lean Six Sigma provides a hands-on framework for continuous improvement in healthcare by monitoring costs, improving quality, and supplying better healthcare services (Sohal et al. 2022).

Govindan and Hasanagic (2018) identified the healthcare sector as one of the areas in which circular supply chain management could facilitate production and service management. Circularity implies that the product disposal phase becomes the starting point of a new phase for a brand-new product. Therefore, it increases the number of product end-users.

51.3 Materials and Methods

This section presents the methodology adopted in the study. It is based on a mixed approach, characterized by a detailed literature review and a case study of an Italian hospital.

First, objectives, research questions, keywords, and search databases were determined. Regarding the objective and the research question, the article aims to understand the scope of the main topics: Lean Six Sigma, Industry 4.0, and circular supply chain and their peculiarities in general. Then, Lean Six Sigma and circular supply chain are reviewed in healthcare specifically to understand their scope of application in this field.

In terms of databases, Google Scholar, Scopus, and Elsevier were chosen to implement the research. Peer-reviewed journal articles, books, and non-academic research, such as international reports available online were considered. Subsequently, the following keywords were used: "Lean Six Sigma," "Supply Chain

4.0," "Digitalized Supply Chain," "Circular Supply Chain," "Industry 4.0," and "Healthcare."

Then, the study draws on process information and primary data from a real anonymized project carried out in an Italian hospital. The Lean Six Sigma methodology adopted in the case study is outlined.

51.4 Case Study

The case study focuses on the optimization of waiting times and the improvement of processes in the surgical unit of an Italian hospital.

The goal of the project is fulfilled through the implementation of the Lean Six Sigma methodology and the management of end-to-end activities that take the patient from the hospital ward to the surgical unit and vice versa.

51.4.1 Problem Statement

A consistent number of surgical interventions were delayed, and planned surgical interventions were postponed.

In this context, customer dissatisfaction, long waiting times, postponement of planned surgical interventions, and waste of time and resources were some of the main reasons to intervene.

51.4.2 Methodology Steps

"Recognize" Phase In this initial phase, the deployment of the Lean Six Sigma methodology among employees was carried out. In this respect, a customized course was held to deploy Lean Six Sigma culture and philosophy to train people and make them aware of the cultural change they were going through.

"Define" Phase A cross-functional project team was created, led by two black belts, with the objective of using the DMAIC six-sigma breakthrough methodology to reduce waiting times and improve process efficiency. Process mapping activities were started, and all the internal processes between the hospital wards were officially defined, including the processes that flow internally from the outside to the hospital and the processes that make the reverse path going from the hospital outwards. The efficiency was calculated for the first time, and it will serve in the future as one of the key indicators to check the quality of the processes.

"Measure" Phase This activity allowed us to identify eight milestones essential for planning data collection and the development of solutions:

1. Medical examination before surgery.
2. Patient in the preoperating room.
3. Entrance to the operating room.
4. Start induction of anesthesia.
5. Patient ready for surgery.
6. Surgical incision.
7. Suture.
8. Exited from the operating room.

Each of these milestones was monitored through the entrance and exit times. In this phase, historical samplings, hospital flow observations, entry forms, metric calculations, efficiency, total times, cycle times, lead times, and Takt times are carried out. A list of fundamental metrics impacting the times (critical to delivery, costs [critical to cost]. and quality [critical to quality]) of the services/treatments made available is also defined (Fig. 51.1).

To conclude, it is essential to have a baseline of the performance of the process, since it is this measure that will allow us to verify whether the improvement actions have brought benefits. For this reason, seven indicators within the operating block are identified, and their performance is measured. The seven indicators are classified as in Table 51.1.

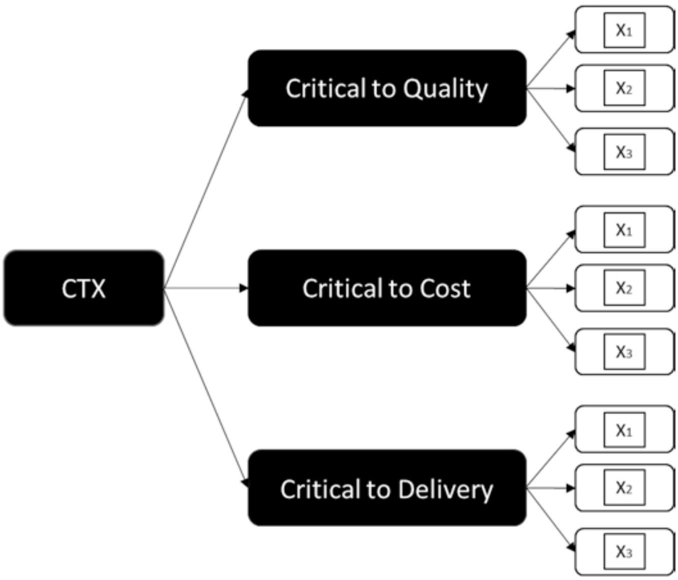

Fig. 51.1 Fundamental metrics to be identified

Table 51.1 Classification and description of the previously identified indicators

ID	Indicator	Acronym	Description
1.	Raw utilization	RU	Ratio between the sum of the time patients occupy the operating room and the total time available, expressed as a percentage
2.	Start time tardiness	STT	Difference between the incision time of the first intervention of the day and the scheduled time of the beginning of the first intervention, expressed in minutes
3.	Over time	OT	Difference between the last patient's exit time from the operating room and the programmed SLOT end time, expressed in minutes
4.	Under utilization	UT	Difference between the programmed SLOT end time and the patient's exit time from the operating room, expressed in minutes
5.	Turn over time	TOT	Difference between the time of entry into the operating room of the next patient and the time of exit from the operating room of the previous patient, expressed in minutes
6.	Lead time	LT	Total time spent by the patient in the operating block
7.	Patient operation efficiency	POE	Number of patients who entered the operating block by surgery/number of operations performed

"Analyse" Phase The analysis phase consists of evaluating how the identified metrics impact the various processes and if there is a degree of correlation between them. This activity will be preparatory to the improvement phase and will allow us to focus on high-leverage metrics.

Measurements of the causes of volume variability, seasonality, percentiles, and statistical trends are carried out through simulators, Pareto diagrams, scatter diagrams, Ishikawa diagrams, and regression analysis.

"Improve" Phase The improvement phase aims to find the tools and technologies that allow the three types of metrics—Critical to Quality, Critical to Cost, and Critical to Delivery—to reach a higher quality level. In this phase, the statistical design of experiments is adopted as a smart method of analysis.

The objectives of the improvement are based on four fundamental principles:

- Small batches to manage.
- Connected and communicating processes.
- Setting the takt time.
- General coordination.

The strategic objective is the fluid scheduling of elective surgery.

Three improvement tools that aim to improve the management of all the processes of the operating block have been developed.

All of them are computer-based tools supported by cloud computing, a paradigm that empowers "utility computing," that is, the leasing of computing resources (computational power, storage, and related networking resources) in real-time with negligible interaction with the provider.

1. Planning of the operating rooms: the objective of this improvement tool is the early planning of surgical interventions to optimize the planning and execution of activities inherent to the processes of the operating block.
2. Plan Matrix: The aim of this second tool is to monitor the deviations between the critical phases of the operative flow to create a continuous improvement loop within the entire operating block. This tool, based on a live monitor, allows us to identify, categorize, and eliminate all possible causes of delays, errors, and non-conformities that may arise within the operating block.
3. Surgical intervention checklist: This third tool is focused on the anticipation of the collection of important information regarding the patient to optimize and reduce the stay of the patient within the operating block.

"Control" Phase The control phase, on the other hand, is used to implement monitoring software and tools so that there is constant attention to preserving the quality levels achieved.

51.5 Results and Discussion

The main managerial results derived from the project were in terms of management's approach to Lean Six Sigma and the need to adopt Industry 4.0 technologies to support it. The application of Lean Six Sigma has to be preliminary to Industry 4.0 implementation in a company. Then, Lean Six Sigma for continuous improvement made senior management aware of the importance of employee involvement in the cultural change an organization is going through. The preparatory training for employees was essential to prepare the staff for a culture of continuous improvement as well as to learn how to design processes and how to interpret metrics.

Better utilization of resources, reduced operational costs, reduced waiting times for patients and therefore improved customer service are crucial factors for the long-term sustainability of a hospital. In this case study, the following was observed:

- Reduction of delays associated with patient preparation activities.
- Risk reduction in the surgical process through the implementation of predefined safety standards.
- Reduction of non-value-added times for anesthetic activities.
- An increase in the number of surgical interventions in the period between 2019 and 2020 (Fig. 51.2).
- The operating block was able to optimize activities and achieve a 13.2% increase in productivity in the number of surgical interventions.

Hence, key lessons to be learned are related to the first phase (recognition) and the last phase (control) of the project:

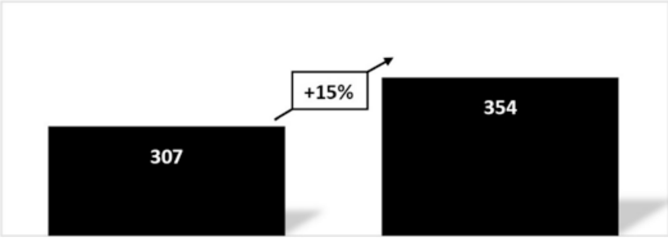

Fig. 51.2 Number of average surgical interventions per operating room in the period 2019–2020

1. In the recognition phase, the deployment of Lean Six Sigma culture is acknowledged as an essential part of the improvement process.
2. In the control phase, improvement is documented, and the implementation of Lean Six Sigma in a sustainable way with training and with the management of improvement projects from the inside of the organization has led the hospital to grow in a logic of continuous improvement.
3. The implementation of Industry 4.0 technologies, such as cloud computing, proved the importance of technological support. In this respect, plans for further implementation of Lean Six Sigma and information technologies are arranged. Management software that will lead to the automation of metrics control is under consideration.
4. A circular supply chain focused on zero waste is implemented.

However, it may be required for a black belt, after a given time, to recontrol the process to guarantee that improvement actions are correctly operating.

51.6 Conclusions and Future Perspectives

Hospitals are increasingly struggling to provide high-quality services to patients despite facing different issues in the last few years, such as the COVID-19 pandemic and the need to become environmentally friendly.

In the case study, an Italian hospital with the aim of improving its waiting times for surgical interventions is introduced. Through the Lean Six Sigma method and new technologies, a dramatic improvement in efficiency is achieved. The number of interventions and overall productivity are increased, and a reduction in waiting times is achieved.

The case study illustrated within the paper offers interesting insights into the goodness of Lean Six Sigma in hospitals and the feasibility of creating Supply Chain 4.0, which is therefore enabled by emerging technologies (Chen et al. 2022).

This kind of supply chain in the service sector of hospitals, in light of the case study, can also become circular in the sense that it is focused on eliminating waste. In the specific case we dealt with, wastes are intended as long waiting times for surgical interventions, a lack or reduction of productivity, and, therefore, circularity is given by the standardization of the process's duration in flows with no wastes and employee training. Future work must focus on the meaning of circularity in hospitals and its interaction with the implementation of Lean Six Sigma.

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Chapter 52
Digital Innovation in the Healthcare System: Integration Between Blockchain and Artificial Intelligence

Roberto Leonardo Rana, Pasquale Giungato, Mariararosaria Lombardi, and Caterina Tricase

Abstract One of the major problems associated with healthcare is protecting patient privacy, as sensitive data can be disclosed carelessly. Implementing a digital healthcare system that uses blockchain (BC) technology could help improve the security of this information. BC can be integrated with other digital tools, such as the Internet of Things, big data, information and communication technology, and artificial intelligence (AI), expanding its fields of application. The present paper provides an overview of the opportunities offered specifically by the combination of BC and AI. To do this, the authors conducted a systematic literature review using the Web of Science and Scopus. The meta-data were reported in a Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram, showing that among the 168 articles identified, only 21 were effectively included according to the authors' criteria. The findings revealed growing attention to this topic over the last 2 years, above all among Indian and American scholars, and the opportunity to ensure the security and privacy of patient data and to improve the diagnosis, prevention, and treatment of diseases. These preliminary results are strategic to fill the gaps in research and to provide useful information to policymakers for supporting the digital transition of this system.

Keywords Digital innovation · Blockchain · Artificial intelligence · Healthcare system

R. L. Rana (✉) · M. Lombardi · C. Tricase
Department of Economics, University of Foggia, Foggia, Italy
e-mail: roberto.rana@unifg.it; mariarosaria.lombardi@unifg.it; caterina.tricase@unifg.it

P. Giungato
Department of Chemistry, University of Bari Aldo Moro, Taranto District, Bari, Italy
e-mail: pasquale.giungatol@uniba.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_52

52.1 Introduction

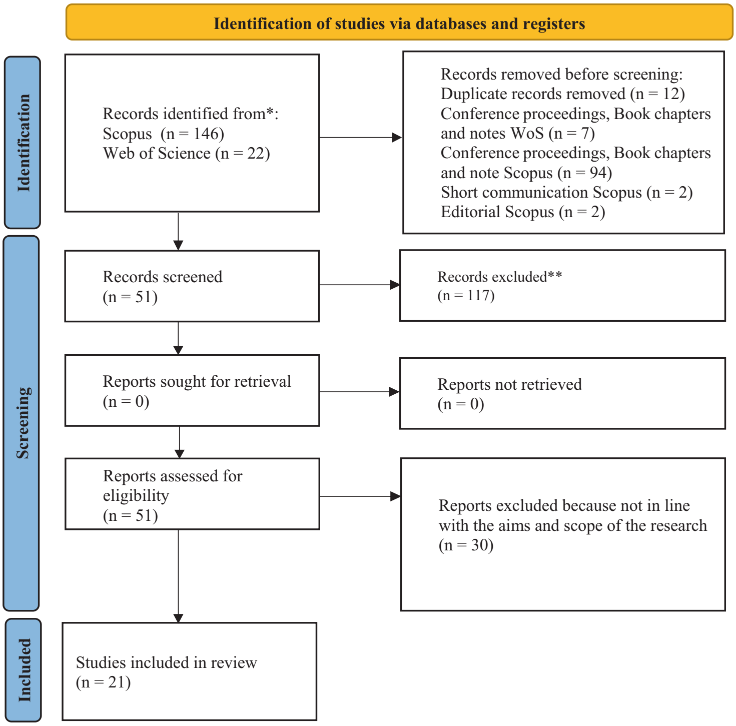
The digitalization of the economy involves many countries and organizations moving to new business models. Widespread innovation technologies such as blockchain (BC), artificial intelligence (AI), big data, and the Internet of Things are synergistically fostering the production of goods and services and the sharing of useful information among actors in a supply chain. Specifically, in the healthcare system, where there are problems associated with the protection of patient privacy, BC assures the storage and sharing of health data thanks to a decentralized network, protecting data integrity and access security because of smart contracts among parties (Jaber et al. 2021). Similarly, AI helps to analyze and interpret medical data, identify and manage diseases, and generate proactive predictions for clinical diagnosis, prognosis, health-related discovery, etc. (Fetjah et al. 2021). Their applications reduce costs and increase the efficiency of healthcare services. In light of these premises, the present paper aims to explore the opportunities offered by the integration of these emerging technologies in a framework applied to the healthcare system through a systematic literature review (SLR). Using the indexed databases Web of Science and Scopus, as well as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram, the authors identify and evaluate the most important studies published until April 2022. Finally, this study could provide useful information to academic scholars and policymakers about the gaps to be deepened in research and the main elements that have to be taken into account to support the digital transition of this system.

52.2 Materials and Methods

The authors conducted an SLR, a quantitative methodology for collecting and examining the most important studies in a certain field (Snyder 2019). Furthermore, the authors used the PRISMA model to "*account for an evidence-based minimum set of items*" (Page et al. 2021). The authors carried out a structured TITLE-ABS-KEY search in Scopus (Elsevier-indexed database) and Web of Science (Clavirate-indexed database) because of their reputation and high quality in the field of academic research. The authors limited the literature review to peer-reviewed articles and reviews published until April 21, 2022. Regarding the keywords, the authors decided to use the following search terms: "Blockchain" AND "artificial intelligence" AND "healthcare", "Blockchain" AND "artificial intelligence" AND "E-health", and "Blockchain" AND "artificial intelligence" AND "health care". Moreover, the data collected were systematized in a Microsoft Excel sheet, including authors' names, articles' titles, abstracts, corresponding authors' nationalities, publishing journals, year of publication, and DOI (i.e., digital object identifier).

As previously stressed, these meta-data have been reported in a PRISMA diagram (Fig. 52.1). Then, the selected papers were analyzed in terms of their content to ensure their eligibility for the SLR.

Figure 52.1 shows 168 records identified for data extrapolation. The authors excluded most of them according to selected criteria. Thus, they eliminated 117 papers because they were duplicate records ($n = 12$), conference proceedings, books or book chapters and notes ($n = 101$), and editorial or short communication ($n = 4$). Consequently, the authors screened and examined 51 papers (three in WoS, 36 in Scopus, and 12 in common). At the end of this phase, they included 21 articles for in-depth review, excluding 30 because they were not in line with the aims and scope of the review.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation to ols.

Fig. 52.1 Preferred reporting items for systematic reviews and meta-analyses diagram, elaborated by the authors using Page et al. (2021)

52.3 Results and Discussion

The earliest article was published in 2018 (one article), and the latest articles were published in the first 4 months of 2022 (two articles). Scholars' interest in the subject has increased since 2018, with the peak reached in 2021 (12 articles). Figure 52.2 summarizes the research timeline.

Regarding the corresponding authors' geographical affiliations, India and the USA comprise the most scholars (52%), followed by China and Korea (24%) and the remaining countries (24%).

In detail, the selected papers can be clustered principally into four main groups. In the first group, studies have focused on the importance of integrating BC and AI to fight against the coronavirus pandemic. Indeed, decentralized BC-based pandemic detection and an assistance system model, with the addition of machine learning (ML), a branch of AI, mainly reduce risk management. This approach provides both pandemic information and future predictions in real time that are useful for the diagnosis, treatment, and therapy of patients affected by COVID-19 (Fusco et al. 2020; Egal et al. 2021; Jabarulla and Lee 2021; Nguyen et al. 2021). Other papers can be clustered considering the integration of BC and AI in a specific medicine field: Krittanawong et al. (2022) for providing precision cardiovascular medicine; Xie et al. (2021) for managing chronic diseases; Kumar et al. (2020) for using novel symptoms and cases for lung cancer patients; and Mamoshina et al. (2018) for biomedical research. The third group includes works where AI and BC are integrated into a framework, model, method, platform, or architecture system, which improves the healthcare system. Alruwaili (2020) proposes an *architecture system* for generating a smart contract and avoiding access and usage of unauthorized patient data by external users. The *framework* of Chamola et al. (2022) generates a singular systematic report containing all essential information related to patient health history, useful for doctors in the ongoing diagnosis and treatment of patients.

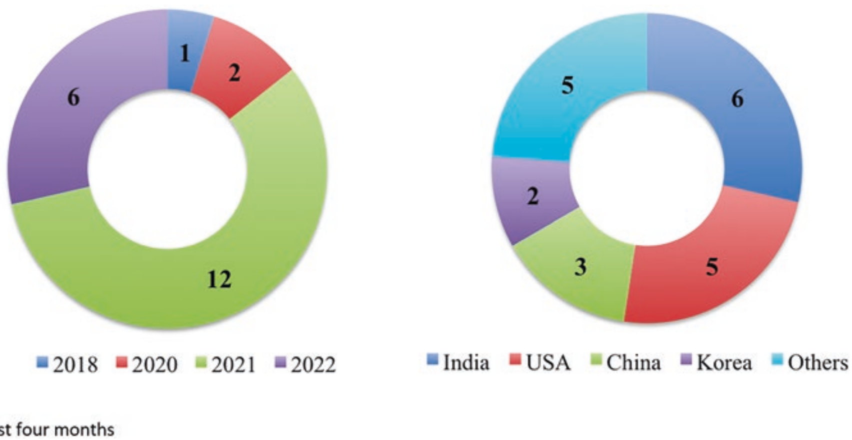


Fig. 52.2 Research timeline and geographical corresponding authors' affiliation

Chang et al. (2021) present a BC-based federated learning *method* characterized by an adaptive differential privacy algorithm (AI) to overcome problems such as data privacy, malicious attacks, and service quality and create a smart healthcare system. Fetjah et al. (2021) describe an integrated *architecture* that, using BC, creates smart contracts that ensure the security and privacy of patient's data, while using ML, diagnoses medical problems more efficiently. Gupta et al. (2021) proposed a BC-based secure and intelligent drone communication architecture underlying a 5G communication network and AI techniques in telesurgery, disinfection of infected areas, medicine delivery, and on-the-move health monitoring. Gupta et al. (2021) developed a BC and AI-empowered telesurgery *system* toward 6G, which is a self-manageable, secure, transparent, and trustable system for telesurgery or robotic surgery. Additionally, Hassan (2021) proposed a *system* where BC and AI are integrated into the Internet of Medical Things industry to provide better results in diagnosis, prevention, treatment of the patient, patient rights, patient autonomy, security, and equality. Jennath et al. (2020) propose a *platform* powered by BC to cater to the requirements for building a trusted AI ecosystem with provenance. Kim and Huh (2020) define an information security BC AI *framework* where medical information can be verified and personalized services used in real time. The last and fourth groups of papers consider the miscellanea of topics. For instance, Kuo et al. (2020) stress that to overcome the critical issue of BC, it is important to adopt a decentralized BC-based AI method that does not share patient-level data or have a central coordinating node. McBee and Wilcox (2020) sustain the same concept, highlighting that decentralization avoids the risk of alteration of data sets and servers and data loss and therefore potentially real and trustworthy outcomes. Tagde et al. (2021) underline the benefits coming from the integration between BC and AI: for instance, improved service efficiency, reduced costs, and democratized healthcare. Nevertheless, Khatri et al. (2021) emphasize that this fusion needs additional research to determine the accuracy and validity of the prediction by AI.

52.4 Conclusions and Future Perspectives

This study has revealed the considerable potential to enhance the quality of health services thanks to the joint utilization of BC and AI. In particular, the SLR has shown that (1) this topic is new, and only a limited number of articles have been published to date, (2) interest has been growing in the last 2 years, and (3) papers can be clustered into four main groups. In particular, the group that includes papers on an integrated BC and AI framework, model, method, platform, or architecture system is the largest.

The main limitation of this research is linked to the choice of keywords: probably a different selection would have identified other important articles regarding BC and AI combination. Nevertheless, these preliminary results are strategic to guide researchers in identifying other critical aspects of this topic and to encourage policymakers to promote the use of these technologies in the medical field.

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Chapter 53
Bibliometric Analysis and Topic Modeling of the Literature on Artificial Intelligence in Healthcare

Fabrizio D'Ascenzo, Andrea Rocchi, Francesca Iandolo, and Pietro Vito

Abstract In the last 5 years, there has been accelerated growth in scientific production on the subject of artificial intelligence and healthcare by scholars of the most diverse disciplines. Recently, the scientific corpus has been enriched with considerable literature reviews ranging from the overview of large collections of scientific documents to the recognition of the state of knowledge on specific aspects (e.g., in the medical field, ophthalmology, cardiology, nephrology, etc.). Following a bibliometric analysis of the literature on the subject, conducted on a vast collection of scientific contributions, we also searched for the "latent" themes in the semantic structures of these documents, identified the relationships between them, and recognized those most likely to be investigated in the future. The methodological approach is located in the scientific fields of relational bibliometry and content analysis. The results of the bibliometric analysis are presented in terms of interactive maps of the association of the contributions based on bibliographic coupling and, subsequently, the co-occurrence of author keywords.

Keywords Healthcare · Artificial intelligence · Bibliometric analysis · Topic modeling

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F. D'Ascenzo · F. Iandolo · P. Vito
Department of Management, Sapienza University of Rome, Rome, Italy

A. Rocchi (✉)
Department of Communication and Social Research, Sapienza University of Rome, Rome, Italy
e-mail: andrea.rocchi@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_53

53.1 Introduction

The complex set of concepts and technologies that are generally referred to by the term "Artificial Intelligence" (AI) is one of the most relevant and dynamic fields of application in healthcare. AI and health evoke two areas of impetuous evolution whose boundaries are widening with a frequency that does not seem risky to define daily. The combination of these two worlds, which at first glance seem to be far removed from each other, is increasingly closer and more natural. Thus, it has given rise to a new field called "Health AI" (Jung and Pfister 2020; Martinho et al. 2021). In the spiral of reciprocal interdependencies between the growth in demand for collective and individual health – also driven by recent pandemic events – and the acceleration of the processes of digitization of socioeconomic activities, the entire world of healthcare is, in fact, taking on new and rapidly evolving physiognomies, so much so that Topol (2019), in the subtitle of his book dedicated to Deep Medicine, introduces the reader to how "Artificial Intelligence can make healthcare human again." The applications of computer systems capable of carrying out tasks that normally require human intelligence for healthcare activities are many, and both the web and the scientific literature propose basic taxonomies, for some of which it is possible to refer to Wang et al. (2021) and Bohr and Memarzadeh (2020).

In recent years, in fact, the convergence of the evolution of AI with the increase in health data availability and processing power has given rise to a new class of AI solutions that are beginning to have a significant impact on all aspects of healthcare (Garg et al. 2021; Househ et al. 2021; Saxena et al. 2021). These solutions are based on advanced techniques of machine learning and deep learning, natural language processing, and computer vision able to process and interpret huge amounts of data (big data), all developed starting in the 1950s, ideally in response to the famous question "can machines think?" of Turing (1950) and explored in some aspects in the following years (the ability of a machine to play checkers better than its programmer (Samuel 1959), that of learning to make decisions (Quinlan 1986) and many others). In the healthcare sector, big data originates from different sources (e.g., electronic health records [EHR], wearable devices, patient-generated data, etc.) to support clinicians and decision-makers in various areas, such as precision medicine, risk prediction and prevention, drug discovery and development, and robotic process automation in administrative and managerial tasks. The healthcare sector is one of the most data-intensive sectors and, at the same time, one of the least digitized sectors (Secinaro et al. 2021; Shen et al. 2021). In recent years, however, there has been a growing interest in the use of AI solutions in healthcare, mainly driven by three factors:

- The exponential increase in data availability is due to the growth of EHRs and other digital health initiatives.
- The rapid evolution of AI technologies, in particular deep learning.
- There is a need to address some of the main challenges facing the healthcare sector, such as rising costs, chronic disease management, and drug development.

Precision medicine is one of the most promising applications of AI in healthcare (Seyhan and Carini 2019; Ahmed et al. 2020). AI can be used to analyze large amounts of data (genomic data, patient medical records, clinical trial data, etc.) to identify patterns and correlations that can help develop more personalized treatment plans for individual patients. In the past, precision medicine was limited by a lack of data and computing power. However, recent advances in AI and machine learning have made it possible to process large amounts of data quickly and accurately. As a result, precision medicine is now being used to develop more personalized treatment plans for individual patients.

There are many other potential applications of AI in healthcare (e.g., disease risk prediction, drug development, robotic process automation, clinical trials), and it is clear that the health sector is at the beginning of an AI-powered transformation that will have a profound impact on the way care is delivered and managed.

53.1.1 Why Another Bibliometric Review on AI and Healthcare Life?

In recent years, there has been an explosion of interest in bibliometric reviews. These reviews use quantitative methods to analyze the scholarly output of individuals, institutions, or entire fields of study. Bibliometric reviews can provide valuable insights into patterns of research productivity, emerging trends, and areas of potential impact. However, they are also time-consuming and expensive to produce. As a result, there is a need for careful justification when proposing a new bibliometric review. In this paper, we argue that there is still value to be gained from additional bibliometric reviews, particularly when they are designed to address specific research questions. We believe that well-designed bibliometric reviews can complement traditional narrative literature reviews and contribute to our understanding of the current state of scholarship in a given field.

A bibliometric review is a quantitative assessment of the scholarly literature in a given field. It is similar to a traditional literature review, but it goes beyond simply summarizing and critiquing the existing research. Bibliometric reviews also analyze the relationships between different pieces of research, identify trends and patterns, and assess the overall state of the field.

Despite their popularity, bibliometric reviews have been criticized for a variety of reasons. First and foremost, their approach is commonly challenged for being too basic and not taking into account significant elements such as publication bias. Second, their findings are frequently contested on the grounds that they are too broad and not precise enough to be useful to practitioners. Finally, the manner in which these evaluations are conducted is frequently attacked for being inefficient and time-consuming.

Despite these criticisms, bibliometric reviews can be a valuable tool for researchers and practitioners alike. When used correctly, they can provide insights into the latest trends and developments in a particular field of research. Additionally, they can be used to identify gaps in the literature and inform future research directions. Overall, bibliometric reviews can be a useful addition to the literature on AI and healthcare.

A "free" search on the Web conducted without claiming to be exhaustive yields numerous reviews of the literature on the topic under examination, including several dozen conducted with bibliometric methods. Among these are those complete with a searchable full-text, necessary to identify the databases and the software used, the research questions they answer, and the limitations posed to the construction of the set of reference documents (Table 53.1).

Our bibliometric review differs from others in two key ways. First, we cascade bibliographic coupling and the cooccurrence of keywords (Iandolo et al. 2021). This allows us to identify not only which papers are citing each other but also which keywords are being used in conjunction with each other. Second, we use a combination of manual and automated methods to identify the relationships between papers. This ensures that our results are both accurate and comprehensive.

53.2 Materials and Methods

53.2.1 Methods

In the early days of information science, people looked for ways to organize and make sense of the rapidly growing body of knowledge (De Solla Price 1965). Among the methods conceived, we find bibliographic coupling (Kessler 1963), cocitation analysis (Marshakova-Shaikevich 1973; Small 1973), and the co-occurrence of keywords or words in abstracts and/or full texts. All can be used to identify groups of papers on similar topics, as well as relationships between different fields of research. Bibliographic coupling of documents is a measure of the similarity between two documents based on the number of references they share in common. Bibliographic coupling has been used to study a wide range of topics, from the history of science to the spread of ideas. It is a powerful tool for understanding the structure of knowledge, and it continues to be used by scholars all over the world. There are three main types of bibliographic coupling: content-based, cocitation, and network. Cocitation coupling measures the similarity between two documents based on the number of times they are cited by other documents. Keywords or word co-occurrence coupling measures the similarity between two documents based on the topics they discuss. Each of these methods has its own strengths and weaknesses, and all three can be used to complement each other to create a more complete picture of document similarity.

Our method consists of using bibliographic coupling in two successive phases to identify homogeneous networks of scientific papers and subsequently characterize these networks in terms of topics mainly dealt with through the co-occurrence of the authors' keywords.

Table 53.1 Some previous bibliometric reviews about AI and Healthcare

Article reference	Publication Year	Years considered	Publications considered	Keywords searched	Bibliometric software(s) used	Database(s) used
Sohn et al. (2018)	2018	2012–2017	7324	Precision medicine & al.	KnowledgeMatrix plus, Gephi and VOSviewer	WoS
Gu et al. (2019a, b)	2019	2000–2017	4820	AI & chronic diseases	HistCite, CiteSpace, MS Excel	WoS
Gu et al. (2019a, b)	2019	1992–2017	3085	IT and Health	HistCite, CiteSpace, NetDraw, and NEViewer, SATI	WoS
Gupta and Katarya (2020)	2020	2010–2018	1240	Social media-based surveillance systems that predict the disease in real-time	Systematic SLR	IEEE, ACM digital library, ScienceDirect, PubMed
Hussien et al. (2021)	2021	2016–2020	941	Blockchain technology in the healthcare industry	R	WoS e Scopus
Islam et al. (2021)	2021	2020–2021	1697	AI applications in COVID-19	Vosviewer, R	WoS
Saheb et al. (2021)	2021	Any period	585	Ethics of artificial intelligence in healthcare	Vosviewer	Scopus
Secinaro et al. (2021)	2021		288	“Artificial intelligence” OR “AI” AND “healthcare” with a focus on “business, management, and accounting”, “decision sciences”, and “health professions”.	Systematic SLR	Scopus
Wang et al. (2021)	2021	al 2020	8444	Digital/healthcare/covid	Vosviewer and CiteSpace	Scopus

53.2.2 Tools

VOSviewer is a free, open-source software application for overlaying and visualizing sets of bibliographic data, such as journal article authors, coauthors, and citation networks. Developed by scholars at Leiden University in the Netherlands (van Eck and Waltman 2010, 2014), VOSviewer has been designed to be used with a variety of different data sets and can be customized to suit the needs of specific research projects. In addition to its visualization features, VOSviewer also offers a number of analytical tools that can be used to examine relationships between different data sets. VOSviewer offers various options for customizing the visualizations. One option is to overlay the visualization with additional information. For example, users can overlay a map of the world onto their network visualization. This can be helpful for understanding the geographic relationships between nodes in the network. Other overlays include node labels, node sizes, and more. In addition to overlays, VOSviewer also offers options for changing the colors and shapes of nodes and edges. This allows users to create visualizations that are both visually appealing and informative.

53.2.3 Data

On May 21, 2022, the query "artificial intelligence" and healthcare was researched on Web of Science (Clarivate) in the field "Topic," which searches title, abstract, author keywords, and Keywords Plus (words or phrases that frequently appear in the titles of an article's references but do not appear in the title of the article itself). The results were then refined, excluding non-English contributions but without limiting them to specific types of publications, given the freshness of the scientific debate on the topics. A total of 2164 contributions were obtained and extracted to be used for our analyses. A couple of descriptive analyses follow (Fig. 53.1).

53.3 Results and Discussion

The result of the bibliographic coupling of the 2164 scientific publications making up our sample is summarized by the map in Fig. 53.2. The parameters used for the construction of the map were the following: Normalization method: Association strength; Layout: Attraction 2, Repulsion 0; Clustering: Resolution 1.00, minimum cluster size 100. With these parameters, the clustering algorithm returns seven clusters whose sizes are between 566 (contributions) of the first group and 103 of the last.

- Cluster 1 (red): Ethics, Big Data, Digital Health. (Healthcare Sciences and Services, Medical Informatics, Computer Science) https://bit.ly/3mbGkd5

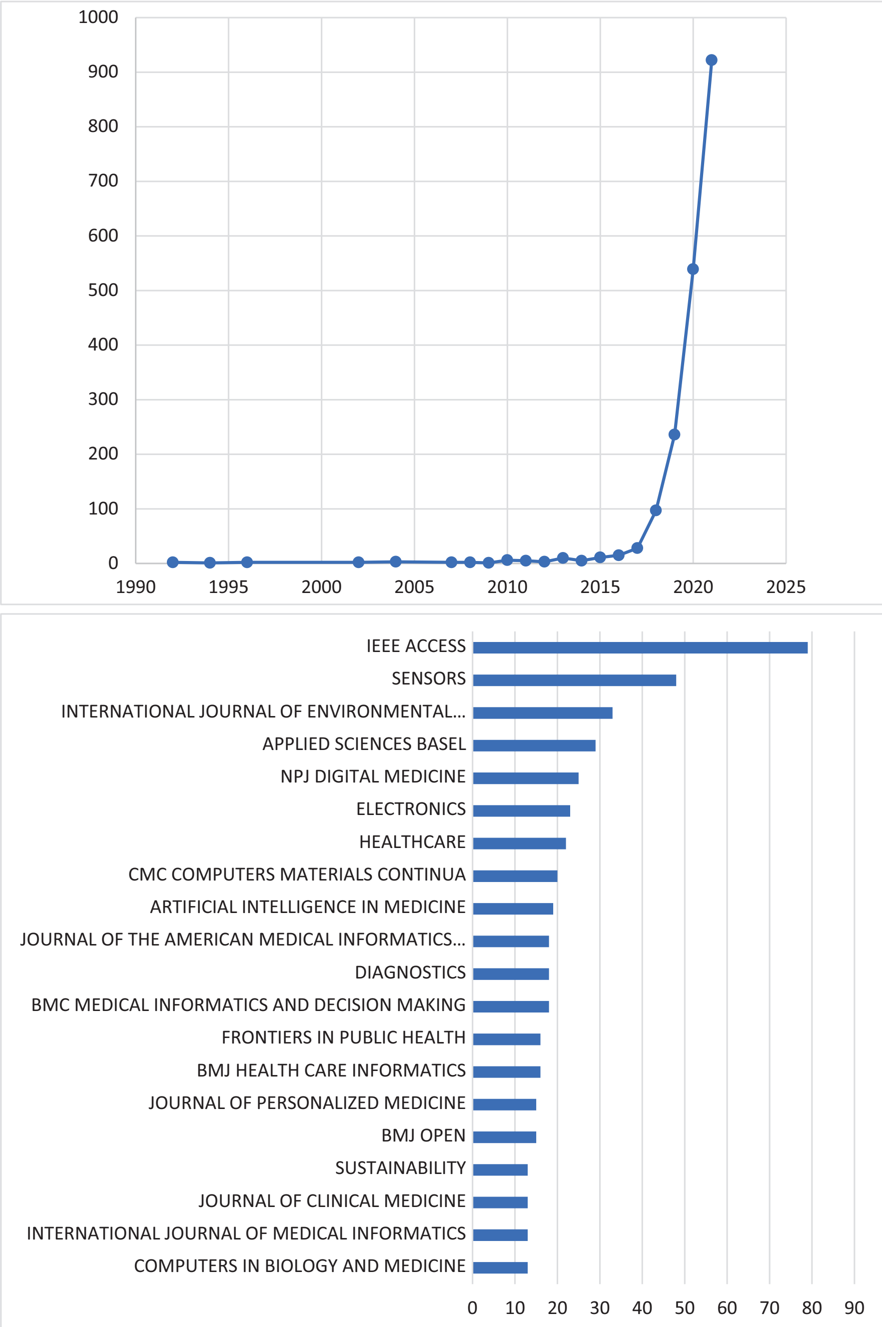

Fig. 53.1 Documents by year and by source. (Sources: Authors' elaboration based on data retrieved from Web of Science)

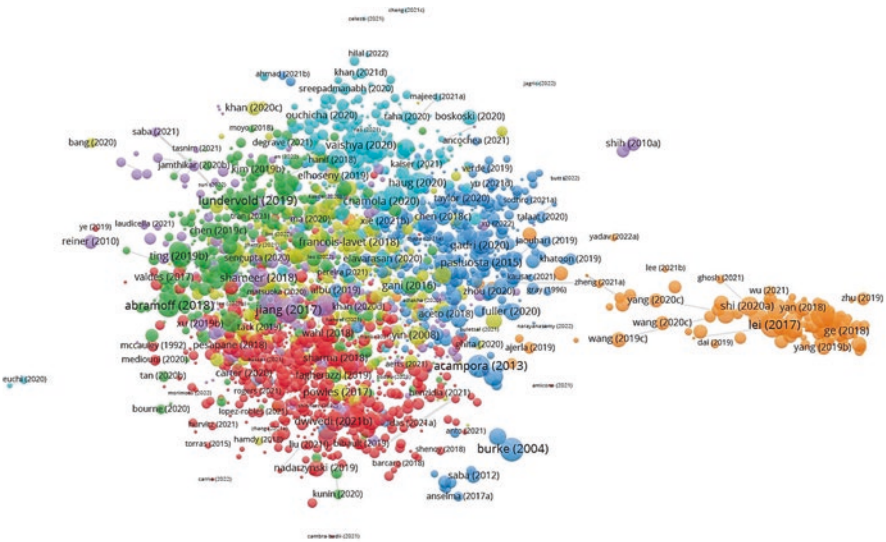

Fig. 53.2 Bibliographic coupling of the sample

- Cluster 2 (green): medical imaging, convolutional neural network/s, telemedicine (medicine, general and internal; computer science, information systems) https://bit.ly/3ap2dDa
- Cluster 3 (blue): internet of things, blockchain, big data (computer science, information systems; engineering, electrical and electronic; telecommunications) https://bit.ly/3x46hQM
- Cluster 4 (…): natural language processing, big data, explainable artificial intelligence (computer science, information systems; medical informatics) https://bit.ly/3GJiOgQ
- Cluster 5 (…): big data, neural network/s, digital health (cardiac and cardiovascular, healthcare sciences and services) https://bit.ly/3Md10vN
- Cluster 6 (…): covid-19, internet of things, convolutional neural network/s, diagnosis, big data https://bit.ly/3x4Mi4y
- Cluster 7 (…): electronic skin, flexible electronics, wearable electronics, sensors, tactile sensor/s https://bit.ly/3m9iHSm

The characterization of the clusters in terms of topics mainly dealt with in each of them through the determination of the frequency of the keywords used by the authors required the preliminary identification of the contributions contained within each cluster and subsequent analysis in Vosviewer. The keywords of the emerging authors in each cluster are shown in Table 53.2.

The static representations of the bibliometric maps relating to the authors' keywords are omitted for the sake of brevity as summarized in Table 53.2. In correspondence with each cluster, however, we have indicated the web page containing the interactive (zoomable and navigable) version of the relative map. All the maps are displayed in the "clean" version, that is, cleaned of terms indicating the same concept (e.g., "healthcare" and "health care" or "artificial intelligence" and "AI").

Table 53.2 Most frequent keywords (topics most frequently dealt with) in each cluster

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Ethics	Medical imaging	Internet of things	Natural language processing	Big data	Covid-19	Electronic skin
Big data	Convolutional neural network/s	Blockchain	Big data	Neural network/s	Internet of things	Flexible electronics
Digital health	Telemedicine	Big data	Explainable artificial intelligence	Digital health	Convolutional neural network/s	Wearable electronics
Chatbot/s	Big data	Medical services	Covid-19	Precision medicine	Diagnosis	Sensors
Medical informatics	Neural networks	Cloud computing	Data mining	Cardiology	Big data	Tactile sensor/s

53.4 Conclusions

In addition to the natural limitations of bibliometric analysis methodologies (the dependence of the results on search strategies in bibliographic databases, meaning not only the formulation of the queries but also the series of possible limitations to the construction of the sample of bibliographic references to be analyzed, e.g., but not limited to, the type of publication, the reference time extension, etc.), which have been poorly highlighted in the existing reviews examined, this work highlights further limitations.

While this bibliometric review of the literature on AI and healthcare allows us to identify some privileged areas of attention by scholars of different disciplines (this is the case, e.g., of ethics in the disciplinary field "healthcare science & services" or "Internet of Things" in the computer science, information systems area) from another reveals the limits of hard clustering techniques, as demonstrated by the presence of some keywords in several groups (one for all, the keyword "big data").

The numerous existing reviews (structured, bibliometric, systematic, etc.) must be integrated by reviews based on topic modeling techniques, which make it possible to identify topics, historical trends (classical and emerging topics), and associations between the documents and to predict, on a probabilistic basis, which scientific fields will be most likely to see development in the future.

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Part VII
Digitalization: Circular Economy and Sustainability

Chapter 54
The Role of Multistakeholder Platforms in the Path Toward Circular Economy (CE) Transition in Europe

Francesca Frieri, Marco La Monica, Grazia Barberio, and Laura Cutaia

Abstract The strength of the circular economy (CE) is stakeholder engagement in fostering synergies along different production chains and CE stages to reduce waste, maximize product value, and increase loop closure. The transition to CE requires the participation of various players, in line with the quadruple helix approach, including enterprises, trade associations, institutions, central and local public administration, education, research and innovation institutions, and citizens, but clear governance is needed. Multistakeholder platforms (MSPs) facilitate dialogue and interaction between actors and create an innovation ecosystem where knowledge, ideas, good practices, perspectives, criticalities, and expectations on CE can be shared. Starting from a national case study, the Italian Circular Economy Stakeholder Platform (ICESP), an analysis of selected platforms with similar characteristics to ICESP has been carried out. The main focus of this study is to understand the role that the platforms have in the reference country, the objectives, the governance, the stakeholders involved, and the main results. Despite similar main goals, platforms can act as hubs for the CE and/or as service providers, with, thus, some differences in the organization, activities, and stakeholders they involve, as well as in the results they achieve.

Keywords Circular economy · Multistakeholder and digital platforms · Innovation ecosystems · Stakeholder engagement · Network governance

F. Frieri (✉)
University School for Advanced Studies IUSS, Pavia, Italy
e-mail: francesca.frieri@iusspavia.it

M. La Monica · G. Barberio · L. Cutaia
Department of Sustainability, ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Rome, Italy
e-mail: marco.lamonica@enea.it; grazia.barberio@enea.it; laura.cutaia@enea.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_54

54.1 Introduction

The circular economy (CE) transition requires a shift from competition to cooperation between organizations and a turning away from individual gain for the sake of a common benefit. It requires the participation of various actors, each of whom has a specific role to play, in line with the quadruple helix approach (Carayannis and Campbell 2009), including enterprises, trade associations, institutions, central and local public administration, education, research and innovation institutions, and citizens. All stakeholders shall act together to identify and overcome the operational challenges of the shift toward CE through innovative solutions.

Given the importance of stakeholder cooperation, multistakeholder platforms (MSPs) can act as enablers for the fastest CE transition. The goal of this study is to analyze and compare platforms of stakeholder cooperation with similar characteristics to the Italian Circular Economy Stakeholder Platform (ICESP) operating in different European countries.

The first section of this paper is dedicated to a literature review, where the purpose and role of MSPs are explained. Then, the methodology used for the selection of platforms similar to ICESP and the analysis of the database (DB) used for the study are described. Finally, the case studies will be explored, investigating their contribution in shaping national and international policies, the relationships they facilitate between different stakeholders, the projects they support, and the documents with which they contribute to the dissemination of these issues.

54.2 Review of the Specialized Literature

MSPs are defined by Steins and Edwards (1999) as "decision-making bodies (voluntary or statutory) comprising different stakeholders who perceive the same resource management problem, realize their interdependence for solving it, and come together to agree on action strategies for solving the problem." Even if MSPs can be very different, the generic objective of an MSP is to encourage the empowerment and active involvement of stakeholders in the search for solutions to shared problems (Faysse 2006). The identification of stakeholders is the basis for MSPs (Grimble and Wellard 1997); they can be defined as those who have a stake in a certain decision, either as individuals or representatives of a group. Stakeholders can be actors who influence a decision, who can influence it, or who are affected by it (Hemmati 2002).

CE platforms gather stakeholders who perceive the same resource management problem; their systemic collaboration is required to create an innovation ecosystem where actors support sustainable innovation by cooperating and sharing expertise and by activating virtuous and intensive knowledge flows (Etzkowitz and Ranga 2015; Romano et al. 2014; Carayannis and Campbell 2009). Web technologies and digital platforms facilitate opportunities for value creation in innovation ecosystems because they make the process of knowledge creation, assimilation, and diffusion (Romano et al. 2014) more effective and rapid (Del Vecchio et al. 2020).

CE platforms pursue goals for which collaboration between stakeholders is fundamental; they are hubs to share good practices, innovative solutions, and knowledge so that innovation can spread between stakeholders and the operation challenges of CE can be identified and overcome together. Moreover, stakeholder engagement is crucial in the decision-making process for including their needs in policies.

ECESP, the European Circular Economy Stakeholder Platform, is a great example of how a vibrant community can develop circular solutions together, transferring knowledge, sharing experiences and creativity and connecting organizations big and small. It is an initiative of the European Commission and the European Economic and Social Committee created to promote the transition to CE.

54.3 Materials and Methods

54.3.1 ECESP DB

The study began with the construction of a dataset including the 167 CE networks/platforms collected on the ECESP website. The ECESP DB is built with the active participation of stakeholders according to a common standard. Then, the ECESP publishes the platforms submitted according to internal assessment criteria. When presenting the platform, each submitter needs to specify different features: the *platform type* (e.g., national or regional, research, and innovation, etc.), which gives information on the objective and the focus of the platform; the *country* where the network operates; *the language of the contents;* the *key area* of interest of the platform (e.g., secondary raw materials, production); the *sector*, to identify which are the specific sectors the platform addresses (e.g., recycling, awareness raising, etc.); and the *scope* (e.g., EU, international). Starting from this standard, the dataset used for this study was created and analyzed (Annex I). Each platform/network can be defined with more than one possible attribute for each data category (platform type, country, language, key area, sector, and scope), so the total number for each category is higher than the number of analyzed platforms (167), and the total sum-up closes at more than 100%.

54.3.2 Selection of the Case Studies

Since the goal is to compare ICESP with other similar experiences and to understand the way they operate, filters with the specific features recorded for ICESP were applied to the dataset. In particular, ICESP is categorized on the ECESP DB as a platform type "national or regional", and the key areas addressed are all five possible key areas (production, consumption, secondary raw materials, waste management, and innovation and investments). The scope is "national," while sectors are not specified, so no filter was applied to this category. The filter application reduces the DB to four platforms (ICESP included): the Polish Circular Hotspot, the Romanian Circular Economy Stakeholder Platform, and State of Green (Denmark).

54.3.3 Additional DB

Two additional platforms have been analyzed, not available in ECESP DB but presented during the last ECESP annual conference 2022 and available on the web: "Circular Economy Portugal" and "SRIP – Circular Economy" (Slovenia). These two have been selected for their similar standards used by ECESP.

The selected case studies cover different European geographic areas.

54.3.4 Case Study Analysis

Starting from available information on the web, the comparative analysis was performed according to criteria (e.g., goals, stakeholders, governance, activities, and results).

54.4 Results and Discussions

The analysis of the ECESP platform database is presented in Annex I. As outlined in the previous section, a comparative analysis of six platforms (case studies) has been carried out, as fully presented in Annex II. The main results are presented in Table 54.1.

54.5 Conclusions and Future Perspectives

The analysis of the platforms revealed that even if the sample was selected to have similar characteristics, there are differences in the way they are organized and in the approach and activities they carry out to facilitate CE. Despite similar main goals, platforms can act as hubs for the CE and/or as service providers, with, thus, differences in the organization, activities, and stakeholders involved, as well as in the results they achieve.

Table 54.1 Case study analysis

Platform	Goals	Stakeholder	Governance	Activities	Results
ICESP	Promote knowledge sharing, dialog and synergies between actors and initiatives.	Quadruple helix stakeholders.	Promoted by ENEA. President, technical coordinator, ECESP linking. WG coordinators' committee, Member's Assembly (161 organizations).	Web platform; GP six WGs (with 800 experts from 280 organizations).	WGs position papers; proposals for national CE strategies.
Polish Circular Hotspot	Find innovative, practical and scalable solutions through the stakeholders' experiences.	Local and nationwide governments, business big and small, and universities and scientists.	Promoted by INNOWO. Public–private platform.	Development of strategies and roadmaps, networking, case studies sharing.	Reports; analysis of CE polish National Strategy, polish circular week.
ROCESP	Promote knowledge sharing, fostering dialog and synergies.	Quadruple helix stakeholders.	Founded by IRCEM. Same organization as ICESP.	Web platform, GP DB, 11 advisory groups.	Thematic WS; annual reviews on CE European and national documents.
State of Green	Give the example and inspire other countries in their journey toward sustainable development by sharing Danish experience.	More than 600 Danish businesses, agencies, academic institutions, experts, and researchers.	Public–private partnership owned by the Danish state, three Danish business associations. Eight directors.	Connection between users and solution providers; R&D projects.	Production of white papers; participation to CE programs and projects, events organization.
SRIP-Circular Economy	Increase efficiency and competitiveness of the Slovenia economy in the transition toward CE.	Entrepreneurs, educational and research institutions, nongovernmental organizations, and other interested parties, state. Annual membership fee.	Managed by the chamber of commerce and industry (Štajerska region). Program and technological council, steering committee, assembly of members.	Creation of value chains in breakthrough fields; technology transfer; project consultancy; public consultation.	Five value chains in breakthrough technological fields established in 2022, WS and conferences.
Circular Economy Portugal	Being a pole for the CE advancement, supporting the business community, government and civil society.	Professionals who work together as a multidisciplinary collective. To become a member the payment of a fee is needed.	There is a board of directors, an advisory board, and the statutory auditor.	Project and activities in four areas: Feeding and composting, awareness and training, reuse and repair and policies analysis.	Analysis for the European Union. Creation of a CE network.

CE circular economy, *DB* database, *WG* working groups, *GP* good practice, *WS* workshops, *ROCESP* Romanian Circular Economy Stakeholder Platform, *INNOWO* Institute of Innovation and Responsible Development, *ENEA* National Agency for New Technologies, Energy and Sustainable Economic Development, *ICESP* Italian Circular Economy Stakeholder Platform, *IRCEM* Institute for Research in Circular Economy and Environment

All platforms have the goal of facilitating CE development, but they take different approaches: the Portuguese platform is configured as a top-down platform/organization that works to support businesses and institutions when they request it. The Danish platform works to facilitate the transition of other countries by promoting their practices, organizations, and solutions; their objective is to inspire other countries on their journey toward CE by sharing Danish knowledge and expertise. SRIP-Circular economy works to make Slovenia more competitive and provide technical services such as project consultancy and technology transfer. On the other hand, the Italian and Romanian platforms are configured as a network, providing the service of being a convergence point for national stakeholders to inspire each other and share their knowledge. The Polish platform aspires to facilitate the global community, business, cities, and governments transition to CE through practical and scalable solutions. The difference also reflects on the stakeholders involved; the Slovenian, Romanian, Italian, and Polish platforms engage local and national administrations, research institutes, and enterprises, while in the case of Portugal, the network is made of professionals who give their expertise and provide a service to support national development, enterprises, and start-ups. Additionally, in the case of Denmark, members of the platforms are experts who provide and inspire innovative solutions. Members have to pay a fee in the case of Portugal and Slovenia. For the organization, the Italian and Romanian platforms were both founded by national research centers, and they both organize their activities through working groups (WGs), each of which operates on a specific topic. Additionally, the activities of the other platforms are carried out according to the focus area of interest, but the separation between WGs is not made explicit.

Except for Portugal and Slovenia, all platforms gather good practices and case studies of CE; they all produce documents and report on CE topics and on their activities (Slovenia excluded); all of them, except for Portugal, promote events and initiatives for the promotion of the activities and raising awareness. Poland, Portugal, and Slovenia give their support to create innovative business models. Portugal is the only organization that develops projects and, together with Slovenia, conducts project consultancy activities.

For the platforms contributing the most to the development of national and local policies, it seems that the Italian and Romanian realities, also given their close relationship with ECESP, are the ones carrying out more activities with this objective together with Poland. These three platforms are the ones that, according to the analysis of their website, have the mission to find innovative solutions together for the sake of circular transition and do not pursue any economic benefit.

This consideration is, however, limited because of the data available on the internet, so further insights should be provided before drawing definitive conclusions. Further activities could be aimed at creating synergies, links, and other collaborations between platforms and fostering the “network governance” approach that ECESP has recently investigated.

Annex Section

Annex I: ECESP Dataset Analysis

Platform Type

The most frequent platform type is "knowledge community" (approximately 41%), followed by "national or regional" (36.5%), "interdisciplinary exchange" (30.5%), and "research and innovation" (27.5%). Then, it follows "education or training platforms" (23.4%), "sectoral" (20.4%), "interest group" (16.2%), "other" (12.6%), and CSO (10.2%). Table 54.2 summarizes these data.

Country

Looking at the countries where those platforms/networks are in action, the majority are classified as "EU" (41 platforms; 24.6%), addressing the European Union in general. Considering the single country, Germany is the one where CE platforms are most frequent (23 platforms; 13.8%); the Netherlands follows with 17 platforms and then Spain and Belgium (15 platforms). For Italy, there are nine CE platforms working to facilitate the transition in its territory.

Language of Original Content

As expected, the majority of the platforms (65.9%) produce their content in English; the second language for frequency is German, with 27 platforms (16.2%). Then, it follows French (12%), Spanish (8.4%), Dutch (8.4%), and Italian (6%).

Table 54.2 Platform type (frequency and percentage)

Platform type	Frequency	Percentage
Knowledge community	68	40.7
National or regional	61	36.5
Interdisciplinary exchange	51	30.5
Research and innovation	46	27.5
Education or training platform	39	23.4
Sectoral	34	20.4
Interest group	27	16.2
Other	21	12.6
CSO	17	10.2

Sources: Data elaboration from the ECESP website. (ECESP website. Available at: https://circulareconomy.europa.eu/platform/en. Accessed 10 June 2022)

Key Area

For key areas, the frequency distribution is similar across the categories, with “Innovation and investments” being slightly higher than the other areas (67.1%). Then, it follows “waste management” (56.3%), “production” (55.7%), “consumption” (48.5%), and “secondary raw materials” (48.5%).

Sector

Table 54.3 shows the sector categories more frequently classified by platforms on the DB, with the frequency and the percentage. The other sectors are not shown in the table because they have a frequency of <12%. The most frequent sectors addressed by the platforms are “awareness rising” (21%) and “circular action for climate neutrality” (20.4%), which likely express the priorities felt by the CE platforms. Then, it follows the “recycling” sector (18.6%), B2B services (16.8%), and “circular design,” “construction, buildings, and infrastructure,” “digital solutions,” and “waste management and secondary raw materials” (12.6%).

Scope

More than half (54.5%) of the 167 platforms/networks of the DB have the goal of acting on a “national” scale. Approximately 33% of them act at the European level and 18% act at the regional level. Table 54.4 shows the scope with frequencies higher than 10%.

Table 54.3 Sector (frequency and percentage)

Sector	Frequency	Percentage
Awareness raising	35	21
Circular action for climate neutrality	34	20.4
Recycling	31	18.6
B2B services	28	16.8
Circular design; construction, building and infrastructure; digital solutions; waste management & secondary raw materials	21	12.6

Sources: Data elaboration from the ECESP website

Table 54.4 Scope (frequency and percentage)

Scope	Frequency	Percentage
National	91	54.5
EU	55	32.9
Regional	30	18
International	29	17.4
Global	19	11.4
Cities	18	10.8

Sources: Data elaboration from the ECESP website

Annex II: Case Study Analysis

ICESP (Italian Circular Economy Stakeholder Platform)

Goals

It is set up as a network of networks that aims to be the place where national initiatives, experiences, challenges, perspectives, and expectations on CE converge. The platform wants to express in one voice "the Italian way for circular economy."[1] The ICESP objective is to promote knowledge sharing, dialog and synergies between actors and initiatives around Italy, and to map the Italian CE good practices.

Stakeholders

ICESP engages stakeholders who want to contribute to the transition to a CE and who represent their sector, from business and trade associations, institutions, public local and national administration, research and education, civil society, and the third sector. All participants must approve and sign the ICESP Charter, with which they engage to actively participate in the activities and the WGs and to promote ICESP and its objectives.

Governance

ICESP is the ECESP mirroring Italian Platform promoted by ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development), which was part of the ECESP Coordination Group 2017–2020 and is now represented in each ECESP leadership group (LG). The role of ENEA is to transfer the knowledge and information coming from the ECESP coordination groups to the ICESP stakeholders and to share Italian good practices gathered on ICESP around Europe. The platform is composed of a president, a technical coordinator, an ECESP interface, a WG coordinators' committee and the member's Assembly. The Assembly gathers once a year to approve the activities realized in the previous one, plan the activities for the next year, evaluate the proposed changes of the WGs, approve the annual report, ratify the entrance of new members, and decide on the disqualification of inactive members.

[1] ICESP website. Available at: https://www.icesp.it/ (accessed: 10 June 2022).

Activities

The exchange of information and good practices is facilitated by a web platform. ICESP operates with seven WGs, each of which focuses on a specific matter: research and eco-innovation, knowledge sharing and education, regulatory and economic instruments, tools for measuring CE, sustainable and circular value chains, circular cities and territories, good practices and integrated approaches, and promotion and communication.

Results

Each WG sets its goals, action plan, and expected results; moreover, it produces different documents and reports on the thematic activities carried out. The latest published document (May 2022), for example, is about policy and governance instruments. It also organizes events to promote and share the activities and results obtained by the WGs.

Polish Circular Hot Spot

Goals

The mission of the platform is to support the global community, businesses, cities, and governments in the transformation toward CE. It does that by promoting cross-sectoral and supraregional cooperation as well as cooperation between administration and business. The final goal is to find innovative, comprehensive, practical, and scalable solutions that will help in the transition toward circularity through the experiences, knowledge, and resources of stakeholders.

Stakeholders

The stakeholders involved are local and nationwide governments, large and small businesses, universities, and scientists. All stakeholders are listed on the Polish Circular Hotspot website, divided by companies, NGOs, local governments and experts, and by sector.

Governance

Public–private platform. The project was initiated by Institute of Innovation and Responsible Development (INNOWO), which is a member of Circular Action Hub, a network of nongovernmental organizations cooperating to "improve the situation of society and environment's condition."[2]

Activities

The activities of the platform address different industries, including construction, packaging, electronics, food, plastics, transport, energy, and textiles. Among the activities carried out by the hotspot, in cooperation with their partners, there is the development of strategies and roadmaps to identify specific issues, including legislative ones, and to plan possible solutions; connecting businesses to create a network with partners inside and outside Poland; creating a DB where circular innovations, case studies, and programs are shared; creating workshops on CE and circular procurement for public institutions; supporting entrepreneurs to develop innovative circular business models; supporting cities that want to become more circular by helping them identify problems and create solutions; and creating workshops and training for anyone interested in CE. They also promote the Polish Circular Week to encourage Polish people to be more aware of their resource use.

Results

Together with INNOWO, it produced the reports "Circular Construction in practice," dated May 2019, and "Plastics in a closed-loop economy," dated May 2020. For the Polish National Strategy, the platform dedicates a part of its website to identifying the areas where actions need to be taken for the transformation toward CE: sustainable industrial production, sustainable consumption, bioeconomy, and new business models. The goal set for the coming year is to publish the Circularity Gap report to promote the "Circle Festival" in four cities simultaneously (Amsterdam, Glasgow, Oslo, and Warsaw). Moreover, they want to develop the Circle City program and make the first scan of the Polish city.

[2] Polish Circular Hotspot website. Available at: http://circularhotspot.pl/ (accessed 10 June 2022).

ROCESP (Romanian Circular Economy Stakeholder Platform)

Goals

The ROCESP platform aims to promote the dissemination of knowledge, dialogue, cooperation between actors, and the integration of initiatives at the Romanian level. It "is a platform configured as a network of networks whose purpose is to create a point of national convergence on initiatives, experiences, critical issues, perspectives, and expectations on the CE."[3]

Stakeholders

The platform brings together all actors who want to contribute to the development of CE in Romania. ROCESP members are local and central public administration institutions, academic, research and innovation institutions, companies, professional associations, and civil society representatives. The network counts thus far 130 organizations and 21 social enterprises. All members must comply with the ROCESP Charter, where common objectives, structure, area of interest, and operational tools are defined.

Governance

The ROCESP platform was founded in 2020 by the Institute for Research in Circular Economy and Environment (IRCEM) "Ernest Lupan" as part of the ASIST project to be a national interface of ECESP. IRCEM shares with ROCESP stakeholders the information obtained with participation in the ECESP Coordination Group and shares with ECESP the Romanian CE good practices. The organization of the platform includes a president, a technical coordinator, an ECESP interface, a WG coordinators' committee, and the member's Assembly. The Assembly gathers once a year to approve the activities realized in the previous year, plan the activities of the next year, evaluate the proposed changes of the WGs, approve the annual report, ratify the entrance of new members, and decide on the disqualification of inactive members.

Activities

ROCESP operates through a web platform that facilitates the exchange of information and good practices. The activities are carried out by 11 advisory groups (AGs), each of which focuses on a specific theme and has specific objectives and expected

[3] ROCESP website. Available at: https://rocesp.ro/ (accessed: 10 June 2022).

results. All groups pursue common objectives applied to the specific area they focus on: they examine the support mechanisms capable of mobilizing the potential of the areas, identify the key elements of the reform of the legislation on the focus topic they have, stimulate knowledge and the dissemination of good practices in the fields, develop a regulatory framework on the topic at the national and European levels, develop instruments for measuring circularity, and create opportunities for collaboration between stakeholders. The AGs are the following: Social and collaborative economy; Urban and territorial development; Energy and energy efficiency; Food, Agriculture, Bioeconomy; Textiles and technical textiles; Air, Water, and Soil; Electrical, electronics and home appliances; Materials, Goods, and Packaging; Mobility and transport; Education and training for the CE and Socioculture and tourism. On the platforms, there are 37 good Romanian practices mapped.

Results

All groups are expected to promote thematic workshops, produce an annual review of information with reference to the most important European and national policy documents on the circularity of materials, goods and packaging, and identify the different themes of intervention, determinants, needs, barriers, and potential solutions offered through case studies and good practices collected and analyzed. Moreover, they produce different documents on the topics they focus on.

State of Green

Goal

The goal of the platform is to set an example and inspire other countries in their journey toward sustainable development by sharing the Danish experience.[4]

Stakeholders

It is a knowledge hub that gathers more than 600 Danish businesses, agencies, academic institutions, experts, and researchers who share their expertise and solutions on green transition in four areas: energy transition, water management, green cities, and CE.

[4] State of Green website. Available at: https://stateofgreen.com/en/ (accessed: 10 June 2022).

Governance

Nonprofit, public–private partnership owned by the Danish state, and three leading Danish business associations, founded in 2008. The patron of the platform is His Royal Highness, Crown Prince Frederik of Denmark; then, there is a board of directors composed of eight members.

Activities

On the platform, it is possible to contact solution providers who are the stakeholders who can help solve the user's green challenge and to find inspiration among approximately 1400 featured cases, R&D projects, policy initiatives, products, or services. Solution providers and solutions are available for each focus area and different countries. State of Green also organizes, facilitates, and promotes events, plans, and hosts international delegation visits to Denmark, presents the Danish vision at international exposes and conferences, and communicates about Danish green solutions and know-how on social media and in the press.

Results

They produce several white papers with a focus on methods, tools, and state-of-the-art solutions for different green sectors in Denmark and around the world; the latest publication, "Energy renovation of buildings" was published on May 24, 2022. Moreover, they participate in relevant programs and projects aimed at accelerating the global green transition.

SRIP: Circular Economy

Goals

The ultimate objective is to increase the efficiency and competitiveness of the Slovenian economy in the transition toward CE and to make Slovenia a CE hub "that will set the reference standard for top professionals and foreign investors through its knowledge, R&D infrastructure, breakthrough technologies, and services, as well as its regulatory support environment."[5] The specific goals of the platforms are establishing a long-term public–private partnership, improving the material efficiency index/productivity from 1.07 (2001) to 1.5 (2020), establishing new value chains with closed material flows, and promoting new business models.

[5] SRIP – Circular Economy website. Available at: https://srip-circular-economy.eu/ (accessed: 10 June 2022).

Members of SRIP – Circular Economy will also contribute to the fulfillment of the goals of the Slovenian Smart Specialization Strategy (S4), that is, "to boost Slovenia's competitiveness in global markets by increasing the added value per employee, the share of knowledge-intensive and high-tech exports in total exports, and overall entrepreneurial activity."[6]

Stakeholders

The platform connects Slovenian entrepreneurs, educational and research institutions, nongovernmental organizations, and other interested parties together with the state. It counts thus far 84 members. To become a member, it is necessary to pay an annual membership fee that is different depending on the size of the enterprise and the organization (local community, NGOs, R&D institutions).

Governance

It is managed by the Chamber of Commerce and Industry of the Štajerska region of Slovenia, which is a voluntary connection within the business community with the goal of enabling economic growth and development in the country. The co-founders are the National Institute of Chemistry and the University of Maribor, Faculty of Chemistry and Chemical Engineering. Investment is co-financed by the Republic of Slovenia – first and foremost the MGRT (Ministry of Economic Development and Technology) and the SVRK (Government Office for Development and European Cohesion Policy) – together with the European Union under the European Regional Development Fund. It is organized in a program council, a steering committee, a technological council, and the assembly of the members.

Activities

The activities carried out by the platform are in line with the S4 focus area for the transition to CE. The areas addressed are sustainable energy, biomass and alternative raw materials, secondary raw materials, functional materials, processes and technologies, and circular business models. In these fields of focus, they create verticals/value chains that focus on the development of technological fields and products. These are supported by the horizontal network of IT, internationalization, and the development of human resources and common services. The platform provides different services, including technology transfer, business and project consultancy, integration of knowledge and research infrastructure sharing, development of

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[6] SRIP – Circular Economy website. Available at: https://srip-circular-economy.eu/ (accessed: 10 June 2022).

activities in collaboration with state institution representatives, promotion of members, and provision of content related to CE through workshops, public consultations, and conferences.

Results

The SRIP Action Plan reveals that in 2022, the number of established value chains in breakthrough technological fields was five, the same number registered for 2018; 36 are the new high technology-intensive products and services export oriented in 2022 (compared to eight in 2018). The number of participating companies increased from 42 in 2017 to 62 in 2022, while the number of new product categories/companies increased from 0 (2017) to 10 (2022). The annual range of investments in R&D slightly increased in the years: €3 billion (2017), €3.1 billion (2018) and €3.4 billion (2022). The platforms gather several CE projects in Slovenia.

Circular Economy Portugal

Goals

Circular Economy Portugal (CEP) is an organization that promotes the transition toward CE in Portugal. The aim of CEP is to be a "dynamic pole for the promotion of the CE, supporting and inspiring the business community, government bodies, and civil society in Portugal."[7]

Stakeholders

A network of experienced professionals who work together as a multidisciplinary collective. To become a member, the fee is €20, and to join as a company or organization, the fee is variable.

Governance

CEP is organized with a board of directors, an Advisory Board, and the Statutory Auditor.

[7] Circular Economy Portugal website. Available at: https://circulareconomy.pt/ (accessed: 10 June 2022).

Activities

CEP develops different projects and activities in four areas: feeding and composting, awareness and training, reuse and repair, and analysis and policies. All developed projects are available on the website, with information on the date, partner, support, promoter, or client. CEP carries out consultancy activities for municipalities, companies, and third-sector organizations that want to take circular approaches. They take courses for public and private organizations on CE and provide services to cities to increase their circularity and sustainability. They evaluate the circularity of organizations to help them identify opportunities for advancement. CEP also supports those who want to make their business more circular, by creating an action plan with precise objectives, supporting public and private entities conducting research and analysis on different topics, and spotting international and national good practices.

Results

Among the projects in the area "Analysis and Policies," they conducted an analysis for the European Union "Industrial Waste Management and Recycling of Secondary Raw Materials" (2020) or the latest "Making the business case for packaging reuse systems" (2021), a study with the aim of evaluating the expansion potential of packaging reuse systems and inspiring companies and policymakers. CEP created "Pioneiros Circulares," a network made of start-ups, SMEs, and social economy organizations whose activities focus on sustainable reuse, repair, and upcycling. The role of CEP in the network is to represent its members in public policy discussions and support them with knowledge, visibility, and advice. The network promotes the sharing of good practices, experiences, and opportunities between the members and has the goal of accelerating the transition to a CE. CEP realized different interesting publications, such as the "Opinion on Action Plan for the Circular Economy" (2017) and the "Response to the public consultation on the New Circular Economy Action Plan Roadmap" (2020). On the website, activity reports for 2018, 2019, and 2020 are available.

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Chapter 55
Green Smart Manufacturing: Potentials and Limits Toward Industry 5.0

Raffaella Taddeo, Veronica Casolani, and Alberto Simboli

Abstract In recent decades, progressive industrial digitalization has provided companies with an increasing capability to improve the efficiency of processes and quality products. In the recent frameworks of Industry 4.0, the pursuit of greater efficiency in the use of material, energy, and human resources assumes increasing importance in achieving the three goals—environmental, economic, and social—of sustainability. Even if the issue is widely debated, the mechanisms by which these technologies are applied from a life-cycle perspective, how they interact with each other, and how they produce effects on sustainability remain to be explored. The article aims to contribute to filling this gap by investigating the role played by so-called *smart technologies* in the context of *green manufacturing*. The study, through a critical analysis of the most recent scientific literature, provides a systematization of the technologies and solutions in the various stages of an ideal product life cycle, highlighting their operating interactions and potential effects in terms of sustainability, toward the future paradigm of Industry 5.0.

Keywords Green manufacturing · Smart technologies · Digitalization · Industry 4.0 and 5.0 · Sustainability

55.1 Introduction

Manufacturing companies are currently experiencing an important phase of renewal. The drive toward innovation requires, on the one hand, to give their processes timeliness, operational flexibility, and adaptability and, on the other hand, to achieve greater environmental efficiency and, more generally, the well-being of workers,

R. Taddeo (✉) · V. Casolani · A. Simboli
Department of Economic Studies, University “G. d’Annunzio” of Chieti-Pescara, Pescara, Italy
e-mail: r.taddeo@unich.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_55

stakeholders, and society. The first of these trends can be summarized in the concept of “smart manufacturing,” a form of production integrating manufacturing assets with ICT-based technologies (Kusiak 2017). The concept of “green manufacturing,” often used as synonymous with clean manufacturing, environmentally conscious manufacturing, environmentally responsible manufacturing, sustainable manufacturing, or sustainable production (Sangwan and Mittal 2015), appeared in the literature from the early 1990s. It describes a systematic and integrated approach for reducing the environmental impact associated with the production of goods, optimizing the use and selection of resources and technologies, and improving the overall efficiency. Although the two fields of research (and innovation) have emerged separately, more recently, thanks to the intensive use of integration technologies, they have found great potential for interaction, leading to the development of the concept of “green smart manufacturing” (GSM) (Váncza et al. 2020). GSM has progressively found wide support from governments of many countries, and there has been a significant increase both in research activities and industrial applications. Even if the theme is widely debated, the mechanisms by which these technologies are applied from a life-cycle perspective and how they produce effects on the three dimensions of sustainability remain to be fully explored.

55.2 Theoretical Background

Recently, following pandemic events, the issue of business digitalization has become increasingly relevant; it is considered one of the events that most accelerated the adoption of emerging technologies by companies (Amankwah-Amoah et al. 2021). Digitalization, however, starts much earlier; it denotes the partial or total conversion of elements, activities of the organization, and their value chain through integrated digital platforms and emerging digital technologies such as mobile and visual connectivity, cloud computing, robotics, smartphones, artificial intelligence, blockchain, additive manufacturing, 3D printing, and the Internet of Things (IoT) (Soto-Acosta 2020).

In the literature, the concept of digitalization is increasingly associated with that of Industry 4.0 (Skender and Ilker 2019); the latter is, in fact, characterized by the widespread application of digital technologies in an interconnected way between the production and management departments and outside companies. Oztemel and Gursev (2018) recommend the following definition: “*Industry 4.0 is a manufacturing philosophy that includes modern automation systems with a certain level of autonomy, flexible and effective data exchanges that support the implementation of production technologies of next generation, innovation in design and more personal and more agile production, as well as customized products*”. This definition clearly indicates the presence of automation implementations (Machine To Machine - M2M, Internet of Things - IoT) with autonomous decision-making skills (smart factories), effective data exchange (Enterprise Resource Planning - ERP, Cloud), innovation support, and the invention of future generation technologies (augmented reality), as well as more personal use of data (mobile systems, big data). All those mentioned fall within the “enabling technologies” and represent the pillars of the so-called Fourth Industrial Revolution, which has already found more advanced forms of development, such as the Digital Factory, the Smart Factory, the Virtual Factory, and cloud manufacturing (Salierno et al. 2021). The integrated and joint use of these technologies, although they have already been known and applied for many years, is therefore gradually and radically transforming the entire industrial paradigm from the man–machine relationship to the manufacturing process to relationships with suppliers and customers in each stage of the supply chain and, more generally, with society and the environment (Rüßmann et al. 2015).

55.3 Methods

The study, through a critical analysis of the most recent scientific literature, provides a systematization of technologies and solutions in the various stages of an ideal product life cycle, highlighting their operating interactions and the potential effects in terms of economic, environmental, and social sustainability. Figure 55.1 summarizes the analytical model of the research. A combined search was carried out on the Scopus scientific database (Elsevier 2022) on the subject of Smart Manufacturing, with the following keywords: Green Manufacturing, Smart Technologies, Digitalization, Industry 4.0. After selection based on abstract analysis, 328 articles were recognized. They were used for the first phase of the study: identifying the smart technologies adopted in the various stages of the life cycle. On this basis, those articles were further selected (37), which dealt with the themes of smart manufacturing in relation to sustainability. They were subjected to a critical analysis to highlight possible interactions between the two issues.

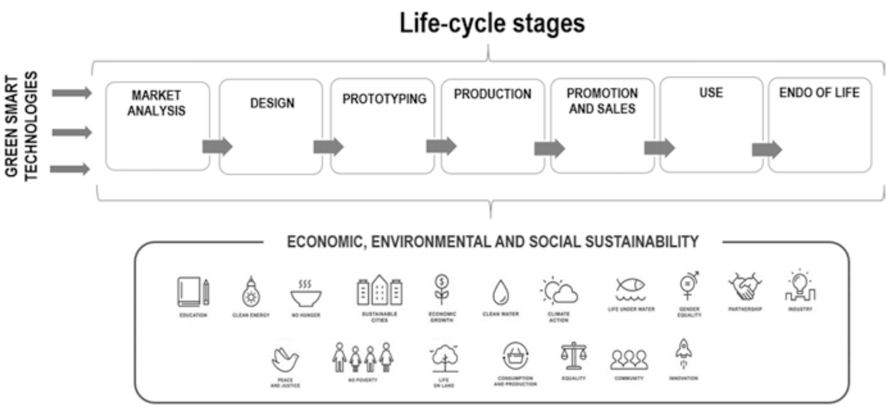

Fig. 55.1 The analytical model of the study

55.4 Results

Interesting results emerged from the analysis of the scientific literature, both in terms of the applicability and diffusion of smart technologies and their possible interactions with sustainability issues. They are described below.

55.4.1 Diffusion/Application of Smart Technologies

The analysis was conducted with a "life-cycle" perspective, aimed at representing the degree of applicability of the most widespread smart technologies in their various stages: market analysis, design, prototyping, production, sale, use, and end-of-life. Table 55.1 summarizes what emerged from the literature.

It can be noted how the degree of applicability of smart technologies is now very high; all phases of the life cycle are affected, but above all, there are increasingly significant spaces for synergistic interaction (standardization of languages, sharing of data, controls, and feedback in real-time), with potential logistical-production advantages and in relations with the end customer. It is also interesting to note how some of them are increasingly destined to play the role of integration technologies (e.g., IoT and big data analytics). In particular, it is noted that future studies could identify strategies to increase competitiveness through the combined use of enabling technologies of Industry 4.0 (Cricelli and Strazzullo 2021).

55.4.2 Smart Technologies and Sustainability

Many studies have revealed that digitalization can help achieve the 17 Sustainable Development Goals, divided into (1) economic, (2) environmental, and (3) social dimensions. From the analysis of the literature, it clearly emerges that these technologies can have a positive impact on (1) business profitability through material flow optimization, time-to-market reduction, space optimization, efficient use of resources, waste reduction, and lower inventory costs (Kayikci 2018). The use of artificial intelligence and data analytics can also offer customized professional development schemes or learning programs based on employee experience (Joshi et al. 2018). It is also widely accepted that digitalization can facilitate the transition toward (2) a circular economy. In fact, it allows the development of more efficient processes (reducing the use of resources and emissions) and, at the same time, provides transparent access to production and use/consumption data (e.g., monitoring and control systems in real time). In this direction, Cagno et al. (2021) use the ReSOLVE framework, which proposes six areas of action for the implementation of the circular economy: regenerate, share, optimize, loop, virtualize, and exchange. Vishnevsky et al. (2021) affirm that an additional positive environmental effect of

Table 55.1 Application of smart technologies in the life-cycle stages

Smart technologies		Life-cycle stages						
Name	Description	Marketing	Design	Prototyping	Production	Sale	Use	End of life
Internet of things	Network of devices that contain electronics, software, actuators, and connectivity that allows these objects to connect, interact and exchange data	X		X	X		X	
Big data analytics	Use of analytical tools in order to manage the flow of data and transform it into a productive and usable source of information	X			X	X		
Artificial intelligence	Field of knowledge that consists in placing computers/ machines in the position to acquire the ability to perceive and process input information, in order to perform in a similar way to human intelligence					X		X

(continued)

Table 55.1 (continued)

Smart technologies		Life-cycle stages						
Name	Description	Marketing	Design	Prototyping	Production	Sale	Use	End of life
Cloud computing	Technology that allows to use, via remote server, software and hardware resources (such as mass memories for data storage)	X						X
CAD	Software technology to support technical drawing and design		X					
Virtual reality	Computer-generated interactive experience that takes place within a simulated environment		X		X	X		
Augmented reality	Use of smart devices that add some virtual elements to the physical reality, in multimedia format		X					X
Simulation	Integration of IT tools aimed at the virtual reproduction of all aspects of a system with the aim of reprocessing data and improving decision-making							X

(continued)

Table 55.1 (continued)

Smart technologies		Life-cycle stages						
Name	Description	Marketing	Design	Prototyping	Production	Sale	Use	End of life
CAE	Computer software for simulating the performance of a product, component, or material			X				
Additive manufacturing	A manufacturing method capable of creating a physical object by printing layer by layer from a three-dimensional digital design or model			X	X			X
Autonomous robot	Autonomous, flexible, communicative, and cooperative industrial robots				X			X
Digital twin	Digital replication of physical assets, processes, systems, and devices				X			
Blockchain	Shared and immutable register that facilitates the transaction registration process and the traceability of assets in a commercial network						X	

digitalization is dematerialization. Moreover, (3) one of the essential indicators for assessing the social sustainability of production technologies concerns working conditions. The changing work environment and the integration of ICT in Industry 4.0 show some potential for the creation of sustainable value in the social dimension (Stock 2018). Possible benefits can be expected for better employee integration and inclusion, job enrichment, more effective worker education, and better work-life balance. Negative impacts could occur in terms of job replacement or simplification and in terms of controllability and complete transparency of work by those who could lead to the exploitation and extortion of employee performance.

55.5 Discussion and Conclusions: Toward Industry 5.0

From the analysis conducted, it clearly emerges that the possible areas of interaction of digital technologies in the field of GSM are multiple and operate "vertically," that is, in terms of greater material-energy efficiency of the production phases in which they are implemented, and "horizontally", as integration technologies, to support the collection, analysis, and sharing of data on the basis of a process, company and/or supply chain, improving company performance in terms of economic, environmental and social sustainability. These operational potentials find full integration in the future paradigm of Industry 5.0. (Lu 2021). To give a precise overview of Industry 5.0, the European Commission (2021) published a report entitled *Industry 5.0. Toward a sustainable, human-centric and resilient European industry*, it recognizes the power of industry to achieve societal goals beyond jobs and growth to become a resilient provider of prosperity by making production respect the boundaries of our planet and placing the well-being of the industrial worker at the center of the production process. The report explains how Industry 5.0 complements the existing Industry 4.0 paradigm, highlighting research and innovation as driving factors for the transition to a sustainable, human-centered, and resilient European industry. Industry 5.0 shifts the focus from shareholder value to stakeholder value, with benefits for all stakeholders, attempts to capture the value of new technologies by providing prosperity beyond employment and growth, respecting the borders of our planet, and places the well-being of the worker at the center of the production process. Industry 5.0 will also be characterized by an expanded vision, going beyond the for-profit production of goods and services. This broader scope constitutes three fundamental elements: human centrality, sustainability, and resilience. *Human centrality* includes responsible innovation, which places basic human needs and interests at the heart of the manufacturing process. It is necessary to ensure that the use of new technologies does not undermine the fundamental rights of workers, such as the right to privacy, autonomy, and human dignity. *Sustainability* means reducing energy consumption and greenhouse gas emissions, avoiding the depletion and degradation of natural resources, and guaranteeing the needs of future generations. *Resilience* refers to the need to develop a greater degree of robustness in industrial production, preventing disruption and ensuring that it can provide and support critical infrastructure in times of crisis.

To conclude, geopolitical changes and natural crises, together with the COVID-19 pandemic, have highlighted the fragility of the current approach to globalized production, which should instead be balanced by developing sufficiently resilient strategic value chains, adaptable production capacities and flexible business processes, especially where value chains meet basic human needs, such as health care or security.

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Chapter 56
The Use of Unmanned Aerial Systems in Environmental Monitoring

Giuseppe Tassielli, Bruno Notarnicola, Pietro A. Renzulli, Maurizio De Molfetta, and Donatello Fosco

Abstract Environmental monitoring plays a central role in diagnosing the impacts on the climate and other environmental receptors. Today, most monitoring and data collection systems are based on a combination of ground measurements, surveys made by sensors mounted on manned aerial platforms, and satellite observations. Each of these systems has space-time constraints that could be overcome with the use of drones.

In this context, remotely piloted aircraft systems, also called drones or unmanned aerial systems (UAS), have considerable potential to radically improve environmental monitoring.

This paper intends to provide an overview of the various fields of UAS use in the context of environmental monitoring. The recent advances in sensor technology are highlighted by analyzing the different types of instruments on the market and their characteristics, including their use.

Then, the various applications in which drones can be used are explored, indicating the strengths and limitations encountered thus far by the use of this technology.

Keywords Environmental monitoring · Drones · UAS

56.1 Introduction

Environmental monitoring plays a central role in diagnosing the impacts on climate and other environmental receptors. Today, most monitoring and data collection systems are based on a combination of ground measurements, surveys made by sensors mounted on manned aerial platforms, and satellite observations. Each of these

G. Tassielli (✉) · B. Notarnicola · P. A. Renzulli · M. De Molfetta · D. Fosco
Ionian Department of Law, Economics and Environment, University of Bari Aldo Moro, Bari, Italy
e-mail: giuseppe.tassielli@uniba.it; bruno.notarnicola@uniba.it; pietro.renzulli@uniba.it; maurizio.demolfetta@uniba.it; donatello.fosco@uniba.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_56

systems has space-time constraints that could be overcome with the use of drones. In this context, remotely piloted aircraft systems, also called drones or unmanned aerial systems (UAS), have considerable potential to radically improve environmental monitoring. However, the use of this technology is still not widespread in environmental monitoring since various issues arise at the operational level that limit its application.

At the same time, we can see how the use of drones for the management of industrial sites, with specific reference to companies that deal with waste treatment and disposal, is constantly increasing. Nonetheless, there is still a clear gap if we compare this kind of use to the application of UAS for infrastructure inspection activities in the construction, energy, telecommunications, or mining fields, sectors in which drones have been applied more frequently and for a longer time. The use of drones in the field of environmental monitoring is certainly more recent but already shows a considerable variety of applications that require specific intervention protocols.

The aim of this work is to provide a state-of-the art view on the use of drones in environmental monitoring.

56.2 Materials and Methods

For this research, a selection and analysis of scientific publications were carried out using both the Scopus and Google Scholar portals, using the following terms both individually and in combination as keywords useful for finalizing the search: "UAV," "environmental monitoring," "remote sensing," "UAS," "drones," "environmental survey," and "monitoring of contaminated sites." The time range used refers to the years from 2010 to 2022 to exclude any applications prior to 2010, a period in which the sector was still in the experimentation phase using drones as simple vectors without sensors. The publications found and selected, as reported above, were then further screened with respect to the topics of the present research, namely, the application of UAS-based systems to environmental monitoring. After this last screening, we moved on to an in-depth analysis of the selected publications.

56.3 Results

The ever-increasing use of drones in environmental monitoring is evidenced by evaluating the number of publications on this topic in the time period from 2010 to 2022. From a first overview of the most popular instruments mounted on drones for environmental monitoring, we have the use of optical, multispectral, and hyperspectral devices that acquire data in the visible, thermal, and infrared fields. Ample space is dedicated, especially from 2019 onwards, to the application of light detection and ranging (LIDAR) systems dedicated to monitoring the territory through the acquisition of high-definition three-dimensional models useful for advanced territorial management. An important operational contribution to the world of surveying through UAS systems is then provided by the use of ground penetrating radar (GPR) and magnetometers, tools frequently applied for monitoring the subsoil in different scenarios and with various purposes, ranging from archaeological research to the identification of underground infrastructures to determine their precise positioning, from the search for cavities and tunnels to the identification of ferrous materials buried underground.

Among the main fields of application of UAS systems is the search for airborne pollutants in the atmosphere through aerosol counting instruments, particle counters, and various types of sensors (tunable diode laser absorption spectroscopy [TDLAS], non-dispersive infrared [NDIR], electrochemical sensors, photo ionization detector [PID]) for monitoring a wide range of traceable pollutants in an airborne state, especially at certain types of sites (Sliusar et al. 2022).

In addition to these applications extensively dealt with in scientific literature, there is also the monitoring and sampling of water in lakes, maritime, or marshy environments, in which the difficult practicability enhances the versatility of drones. For this last class of use, there is the presence of scientific literature starting from 2018 onwards, so we could define this last use together with the monitoring of airborne pollutants among the most recent uses in the panorama of applications described thus far. The types of applications described above, which differ substantially in the type of sensor used, the type of survey workflow applied, and, in some cases, the type of drone chosen as the vector for the sensors, are operationally inserted in scenarios such as:

- Monitoring of air quality in outdoor environments.
- Search and localization of illegal landfill sites.
- Monitoring of marine, coastal, wooded, or any other protected areas.
- Monitoring of protected species, such as antipoaching control, observation of animal movements, and so on.
- Control of the state of erosion in river or torrential waterways.
- Control of coasts in terms of verifying the erosion of the dunes, the advancement of the coastline, etc.
- Monitoring of areas with significant hydrogeological risk, both for mapping reasons and in the phase of emergency situations, for example, to define the extent of a flood or to very quickly estimate the damage caused or procurable from a mudslide.

Each of these applications requires well-defined workflows based on different phases of approach to the operational situation. Below, three application cases will be examined in detail through the use of different sensors chosen from the aforementioned applications.

56.3.1 Optical Monitoring for the Spatial Analysis of Landfill Sites

A waste collection site, from aggregates to hazardous or nonhazardous special waste, often extends over fairly large surfaces whose orography is not always regular. Sometimes the orographic variations in altitude represent an obstacle to the fluid practicability of spaces for monitoring or survey purposes. In this regard, one of the most widespread uses of UAS is spatial analysis, that is, the definition of the spatial properties of a site through orthophoto framing using optical, graphic, or photogrammetric media produced via drones.

The spatial properties to be monitored may concern the identification of mass accumulations in areas of definitive or temporary waste abandonment, for which it is essential, for example, to know the volumes, the control of the angles and the state of conservation of the landfill slopes, the control of the conservation state of the capping in areas with definitive coverage, the control of the correct installation of the closing covering for areas with temporary coverage, the optical monitoring for the control of any leachate leak points, the colonization of some areas by animal species, and the onset of dangerous situations due to collapses or subsidence (Azimov et al. 2020). All these aspects, whose analysis is defined precisely as spatial analysis, can be framed, studied, and correctly managed through high-resolution outputs produced via drones. The same concepts are applicable not only to landfills but also to quarries and mining sites, which are characterized by considerable extensions that can be quickly and precisely monitored via drones. The image below represents a wide view of a specific sector falling within a much larger landfill site. From this photo, taken nadirally, that is, with the camera forming an angle of 90° with respect to the horizontal axis of the drone, we can evaluate various technical elements for subsequent logistical and operational evaluations (Fig. 56.1).

56.3.2 Monitoring of a Riverbed by Scanning with a LIDAR System and Reconstruction of a Three-Dimensional Model

The LiDAR system falls into the category of sensors defined as "active," that is, those sensors whose principle of reading and producing the data consists of a first defined emission phase and a subsequent reading phase of the message in return. LiDARs can be mounted on drones but also on fixed-wing aircraft, airplanes, helicopters, and cars, or worn by specialized operators for monitoring roads and tunnels. The opportunity to mount LiDARs on drones derives precisely from the versatility of UAS systems that are able to intervene in inaccessible places if traveled on foot or by car but with management and operating costs generally lower than a classic aircraft such as an airplane or a helicopter. The LiDAR survey maps the environment in the direction in which the emitter is oriented (if downwards, the

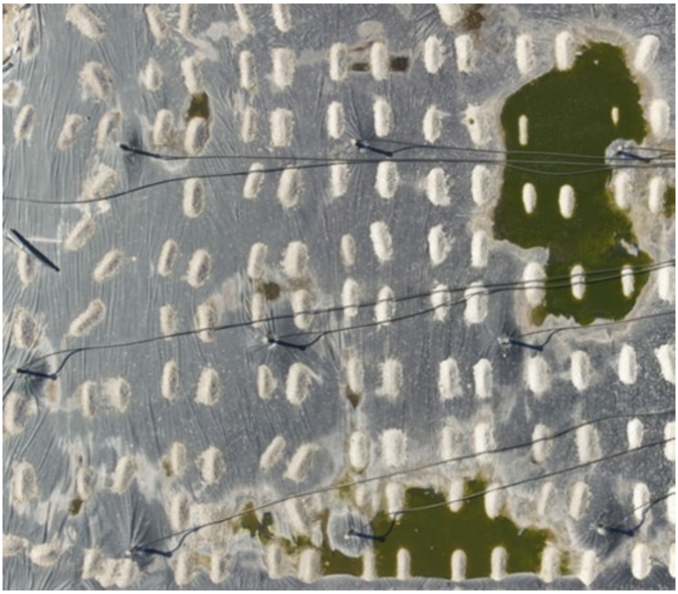

Fig. 56.1 Nadiral photo for identifying technical elements in a specific landfill sector

LiDAR will map the environment below the drone), providing what is called a point cloud at the end of the survey.

The point cloud is the representation of an object or a scenario through points. By processing the point cloud using specific management software, it is possible to geo-reference and reconstruct the textures and arrive at a three-dimensional model that is perfectly and totally representative of the real state of the detected places. The survey of the riverbed, conducted in this way, allows us to have a three-dimensional model, which can be defined as quoted and whose measurements obtained through specific software correspond to the real measures; this output is useful for monitoring the erosion state of the riverbed or for the calculation of the lowering volumes, referring to the debris that the watercourse carries and deposits in the loops or at other specific points (Messinger and Silman 2016). This kind of survey also makes it possible to map the depth of the riverbed, the presence of any unauthorized infrastructure, the flow rates, and any other element necessary for the targeted and conscious management of that specific portion of the territory in terms of ordinary and predictive maintenance (Fig. 56.2).

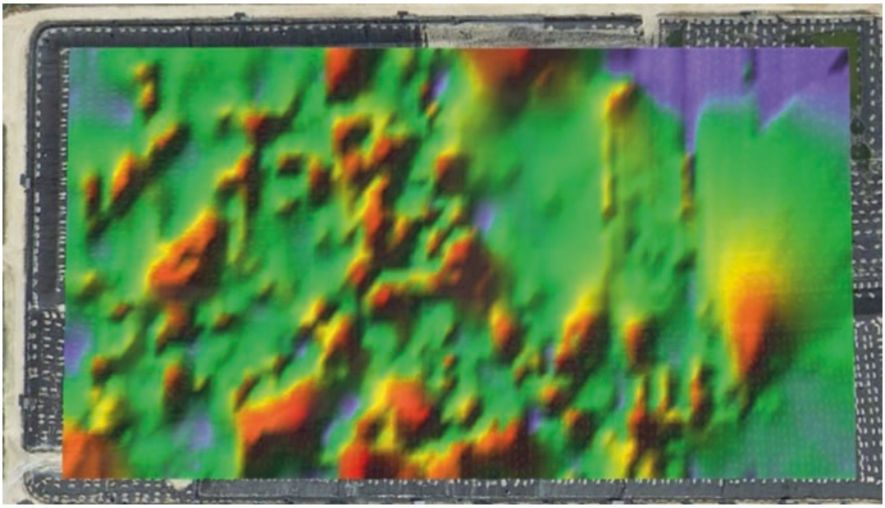

Fig. 56.2 Graph of the representation of methane concentrations using a chromatic scale on orthophoto map support

56.3.3 Monitoring Aimed at Detecting Fugitive Emissions of Methane from Landfills

One of the most recent applications of UAS systems dedicated to environmental monitoring is the survey aimed at identifying the presence of airborne pollutants with contextual quantification of the concentrations in which they are present. This activity can be carried out with different types of instrumentation that involve the use of electrochemical sensors, PID, NDIR, TDLAS, and more (Allen et al. 2019). The example of use described below consists of measuring the concentrations of methane contained in biogas escaping from fugitive emissions using a sensor with TDLAS technology, that is, a technology that uses the emission of a laser beam having a precise frequency and which, by measuring the return laser beam, reflected by the landfill soil, by means of a special receiver, calculates the delta between the emitted and the reflected beam, translating it into methane concentration. Figure 56.2 shows an example of a map graphic product created through the postproduction of a dataset obtained from the UAS system and TDLAS sensor containing the methane concentrations detected on a portion of the landfill (Tassielli et al. 2021).

56.4 Conclusions

The overview illustrated has highlighted that there are increasingly more applications of drones (and the monitoring technology they transport) for environmental monitoring.

The increasingly frequent application of various survey methods and the considerable scientific literature are evidence of repeated experimentation activities in the field that are allowing the standardization of certain parameters with a consequent improvement in the monitoring activity via drones as a whole.

The issue mainly highlighted by the overview appears to be the absence of standardized and well-defined protocols that could guide the operators from the preliminary stages of desk study and survey design to the implementation phase of the activity on the field and to postprocessing and critical analysis of the data produced.

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Part VIII
Tourism: Innovation

Chapter 57
Eco-Innovation in Tourism: An Overview of a Promising Field of Research

Pasquale Del Vecchio, Giustina Secundo, and Antonello Garzoni

Abstract This paper aims to contribute to the debate on sustainable tourism from the perspective of eco-innovation. Focusing on the challenges of sustainability in tourism, both for companies and destinations, this paper provides a critical reading of the literature on eco-innovation in tourism to derive a state-of-the art and depict roots for the future development of the research. As a complex and integrated system of products and services, tourism is an industry with a large impact on the environment and local communities, and for this reason, it is called on to implement sustainable strategies of development and growth. The challenges of sustainability in tourism can benefit from eco-innovation as a driver for reducing its impacts on the environment, thus contributing to the implementation of a circular economy. Framed in these premises, this paper presents the results of a critical review identifying the main trends structured into (1) energy efficiency and smart mobility; (2) governance, key performance indicators, and socioeconomic performances; (3) industrial ecology and eco-certifications; (4) rural development and circular economy; and (5) intangibles and knowledge-based enablers. Implications arise for theory and practice in terms of eco-innovation strategies and enablers, servitization, and digital transformation.

Keywords Eco-Innovation · Sustainable tourism · Circular economy · Eco-Design · Green tourism experience

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P. Del Vecchio (✉) · G. Secundo · A. Garzoni
Department of Management, Finance and Technology, University LUM Giuseppe Degennaro, Casamassima, BA, Italy
e-mail: delvecchio@lum.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_57

57.1 Introduction

The recent pandemic emergence due to COVID-19 has increased the attention of public opinion on sustainable tourism by highlighting the need for radical change in the management of tourism companies and destinations (Chang et al. 2020). This trend is associated with the growing interest reserved by policymakers and citizens toward the Sustainable Development Goals of the United Nations (United Nations 2015), as well as with the popularity of issues such as ecological transition and the circular economy.

In the meantime, there is a greater awareness of the impact that tourism can have on the environment and local communities (Hamaguchi 2020). In representing an opportunity for the economic growth of territories with tourist vocation in terms of gross domestic product (GDP) and employment, tourism is also identified as one of the most polluting industries (Sun et al. 2021). In this direction, several recent reports (i.e., Ernest and Young (2021); Booking.com 2022) have registered a growing interest in tourism demand for sustainable tourism experiences.

The tourism industry, businesses, and destinations are also called to explore the opportunities associated with the embracement of a sustainable development strategy. From this perspective, eco-innovation can represent an opportunity for innovating sustainable tourism by creating positive and emotional journeys and tourism consumption experiences. In 2015, the European Commission defined eco-innovation as follows: "changing consumption and production patterns and market uptake of technologies, products and services to reduce impact on the environment."

Research on eco-innovation has investigated its micro (i.e., Kiefer et al. 2021), meso (i.e., Mazzoni 2020), and macro (Hazarika and Zhang 2019) perspectives, moving toward industrial and organizational settings (Yan et al. 2022). Eco-innovation has also been demonstrated to be a useful lens for the analysis of innovation performance at the regional and country levels (Rama et al. 2022). Eco-innovation has also been considered a managerial practice supporting the servitization of firms' business models (Munodawafa and Johl 2019), and in this direction, it is aligned with the debate on digital transformation and data-driven value creation processes (Bag et al. 2022). All this debate makes the topic of eco-innovation a promising paradigm for the sustainability challenges that are interesting to tourism. However, while eco-innovation is largely recognized as a useful approach for achieving sustainable development growth in manufacturing and other complex industries, the debate on eco-innovation in tourism results is under-considered (Wang et al. 2020). These premises highlight the relevance of eco-innovation in the current debate on tourism and destination management. However, while this can be intuitively proven, the literature on the meaning and implications of eco-innovation in tourism is still fragmented. Some reviews have been conducted on the topics of eco-innovation and tourism, but they have been more focused on the technical or managerial issues of eco-innovation, with a limited exploration of their implications in tourism management. Accordingly, eco-innovation in tourism is far from being fully achieved, which is the main motivation behind this preliminary research study.

Moving from this premise, the paper presents the results of a critical review of the literature on eco-innovation in tourism aimed at providing answers to the following research questions: *How is the literature on eco-innovation in tourism developing? What is its thematic focus? What are the implications for future research?*

The remainder of the paper is structured as follows: Sect. 57.2 describes the research methodology and the phases of the study; in Sect. 57.3, findings are presented in terms of bibliographic trends and thematic areas of specialization; and in Sect. 57.4, conclusions recall evidence collected and areas for future research.

57.2 Methodology

This paper is based on a critical and qualitative literature review as a useful approach for deriving a deeper comprehension of the state of the debate on a certain topic (Cortellazzo et al. 2019); moreover, a critical literature review is considered a suitable approach for discussing and evaluating the state of the art, for identifying areas of specialization and for future research investigations (Saunders and Rojon 2011). The review has been conducted with the aim of identifying and including the most relevant contributions associated with the topics of eco-innovation and tourism. The study consisted of three main phases related to (1) research design, with the identification of research gap, the definition of research questions, and the planning of the research activities; (2) review analysis, with the extraction of the paper from Scopus database according to the keywords "eco-innovation" and "tourism" and including only articles and book chapters, the definition of criteria for their analysis (in terms of content analysis, thematic specialization, methodological approach, results, and implications), cleaning and preliminary check; and (3) research writing, in terms of statistics, content analysis, and the definition of a conceptual framework.

The original sample extracted from Scopus included 31 papers. After a preliminary screening aimed at verifying the thematic coherence of papers, a final sample of 25 items was identified by excluding conference proceedings and book series.

57.3 Results and Discussions

The final sample included in the analysis was composed of 25 documents, including 21 articles and four book chapters. Trends in terms of the timing of publication, subject areas, authors and geography, keyword recurrence, and thematic clusters of specialization are provided. Regarding the timeframe (Fig. 57.1a), publications cover a period of 9 years (from 2013 to 2022), showing a fluctuating increment of published papers from 2016 with a peak in 2019. Considering the average number of papers published during the whole period, interest in the topic remains limited (a maximum of five papers in 2019). For the subject areas, Scopus allows us to identify seven clusters (Fig. 57.1b).

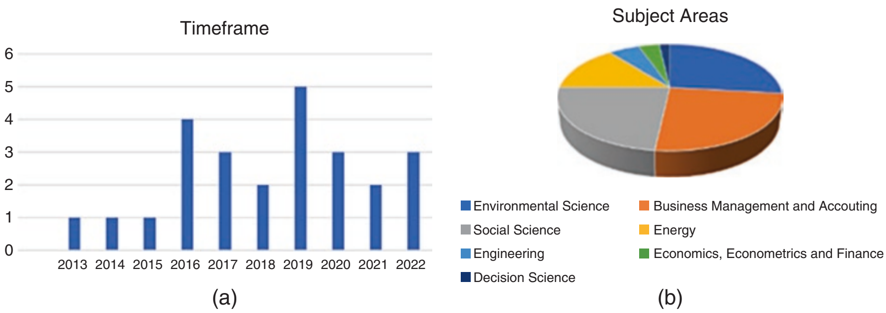

Fig. 57.1 (**a**) The publication trend and (**b**) the subject area of the papers included in this review sample

Considering that the same paper can be included in different areas, the sample highlights the following clusters: Environmental Science (15 papers), Business Management and Accounting (14 papers), Social Science (13 papers), Energy (8eight papers), Engineering (three papers), Economics, Econometrics and Finance (two papers), and Decision Science (one paper).

Other information can be derived about the publication venue. Journals with more than two papers published are only Sustainability (five papers) and Journal of Cleaner Production (two papers). The remainder of the sample results are located in journals and books with a prevalence of managerial and technical issues and without a clear specialization in tourism management. Additionally, the authorship results are very dispersed, while for geographic specialization, the sample shows the leadership of Spain (eight papers), followed by China (five papers), Taiwan (three papers), Italy, Mexico, and the UK (with two papers).

Focusing on the thematic areas of specialization, important evidence arises from the analysis of keywords offered by Scopus. The sample presents more than 200 keywords with a very large coverage of issues and perspectives. However, considering a recurrence higher than two, the keywords most frequently used are Eco-Innovation (14), Innovation (11), Sustainability (six), Ecotourism (five), Sustainable Development (five), Tourism (five), Hospitality (four), Sustainable Tourism (three), and Tourist Destination (three). Additionally, in this case, the sectorial focus results are marginally interested in the research being demonstrated to be included more in the context of the application of the single study than as a primary focus. A deeper analysis of the research areas included in the sample is presented in Table 57.1, where highlights of the key contributions of the paper are reported.

Table 57.1 Research areas of eco-innovation in tourism

Research area	Paper	Main contributions
Energy efficiency and smart mobility	Sun et al. (2021)	Econometric evaluation of the tourism and ecological innovation on carbon emissions and ecological footprint in Turkey
	Robaina and Madaleno (2019)	Literature review on eco-innovation in tourism and implications in terms of shift toward renewable energies
	Buijtendijk et al. (2018)	Evaluating the effectiveness of a collaborative approach to production in a Dutch travel industry through actor network theory
	José-Luis et al. (2021)	Energy efficiency as driver for cost saving strategy and the implementation of eco-innovation – Quantitative analysis of data.
	Wei and Lihua (2022)	Analysis of short- and long-term relationships about carbon emissions ASEAN countries' tourism – Quantitative data collection with interviews.
	Amendola et al.	Integrated methodology for urban mobility and sustainable tourism mobility – Case study
Governance, key performance indicators, and socioeconomic performances	Pikkemaat et al. (2019)	Literature review on eco-innovation in family firms and SMEs, consumer-driven innovation, mechanisms of governance.
	García-Pozo et al. (2016)	Quantitative analysis on employees' productivity and impact of eco-innovation in Spain. Analysis of seven good practices with a focus on financial and socioeconomic indicators
	Martínez-Pérez et al. (2015)	Social capital and networking as drivers for knowledge exploitation for the eco-innovation in Spanish company – Survey
	Wu et al. (2019)	Hierarchical framework for sustainable tourism based on three critical dimensions related to socioeconomic, socioenvironmental and eco-efficiency value – Structural modeling
	Vidickienė et al. (2020)	Transformative tourism development through policies of regional development – Survey
Industrial ecology and eco-certifications	Lucchetti and Arcese (2014)	Literature review on the meaning and opportunities of application of industrial ecology for tourism management
	Tang et al. (2019)	Exploration of the dilemma tourism innovation and ecological participation – Pressure state response model
	Miret-Pastor et al. (2011)	Qualitative review for the conceptualization and measurement of eco-innovation supported by three environmental certifications (ISO 14001, EMAS, and Eco-label)

(continued)

Table 57.1 (continued)

Research area	Paper	Main contributions
Rural development and circular economy	Jeong and Ramírez-Gómez (2017)	Eco-design and eco-innovation for the protection of water and rural areas and the development of a rural-housing in a case study reservoir area under tourism and mass tourism
	Chen et al. (2022)	Rural community as eco-innovation suitable context and opportunity for developing an educational program in coherence with SDGs – Case study
	Alonso-Almeida et al. (2016)	Literature review suggesting the opportunity of deepening the implication of eco-innovation and circular economy for tourism through the exploration of eco-innovation typologies and empirical cases
	Liu et al. (2017)	Small farms into the rural areas as educational institutions and attractor for tourism development
Intangibles and knowledge-based enablers	Chung et al. (2019)	Analysis of the impact of green technologies on CSR and reputation of museums. Technology based innovation for reducing footprint – Lean square method
	Bell and Ruhanen (2016)	The role of opinion leaders and change agents in influencing the adoption of eco-innovation – Interviews
	Pace and Miles (2019)	Impact of KIBS and client interactions on firms' absorptive capacity and role of business partnership in the adoption of eco-innovation
	Wang et al. (2020)	Analysis of the dynamic capabilities managers' attitudes and stakeholders' engagement – Square structural equation modeling
	Avellaneda-Rivera et al. (2020)	Open innovation as stakeholders' involvement as knowledge-based opportunity for eco-innovation in tourism – Quantitative data analysis
	Velázquez-Castro et al. (2016)	Identification of eco-adopters and enablers of eco-innovation in the Mexican hotels – Quantitative data
	Velazques-Castro et al.	Structured literature review on eco-innovation in service, business process analysis and modeling

57.4 Discussions and Conclusions

The brief review of the literature contributes to the understanding of the state-of-the art of eco-innovation in tourism. The critical review based on a final sample of 25 papers demonstrates that the debate on eco-innovation in tourism is still fragmented and far from the achievement of a consolidated and systemic view. Specifically, it has been possible to verify that the large debate on eco-innovation, fluorescent in the recent literature, has marginally interested the community of scholars in the field of tourism management. In this direction, the thematic areas of specialization cover different issues, including (1) energy efficiency and smart mobility; (2) governance, key performance indicators, and socioeconomic performance; (3) industrial ecology and eco-certifications; (4) rural development and circular economy; and (5) intangibles and knowledge-based enablers. In confirming the fragmentation of the research field, this large noun of topics is coherent with the versatility of eco-innovation and with its relevance from micro, meso, and macro perspectives, and at the same time, it allows us to highlight the need for further studies in the tourism field. Accordingly, implications for future research can be identified at different levels. First, it is necessary to achieve a clear understanding of what eco-innovation can mean in tourism, both for companies and destinations, and how it can support tourism in the achievement of sustainability issues. By considering the nature of complex industries based on the integration of products and services, it could be useful to understand how eco-innovation can allow sustainable results to be achieved in terms of servitization and value co-creation. Considering the digital transformation that has interested tourism, it could also be interesting to understand how digital technologies such as big data, artificial intelligence, virtual and augmented reality, and blockchain can be adopted as an eco-innovation strategy in tourism destination management.

Further areas of speculation on eco-innovation in tourism could be identified in the different definitions of sustainable tourism by focusing on the circular economy, green tourism, slow tourism, etc. Each of them could suggest exploration with a plurality of methods, including quantitative and qualitative studies.

The paper presents several limitations. From the methodological point of view, some limitations can be identified in the qualitative nature of the review, in the single database considered, and in the criteria for exclusions adopted. Despite the rigor and references supporting the choices in this direction, for the actuality of the issues, it is not possible to exclude that some promising contributions could be missed. In the same direction, the keywords (such as "eco-innovation" and "tourism") adopted for the selection of papers from the Scopus database could represent another limitation characterizing the current version that could be overcome in the future development of the research. Despite all of them, the authors hope that the evidence collected can contribute to the achievement of a greater awareness of the opportunities for eco-innovation in tourism and inspire the future work of scholars and researchers in tourism management.

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Chapter 58
Innovative Approaches for the Digitalization of Tourism Businesses

Carlo Amendola and Marco Savastano

Abstract Over the last few decades, tourism has changed profoundly, and at the same time, both the types of travel and the profiles of travelers have changed. Due to the COVID-19 pandemic, tourism was one of the sectors that paid the highest price in economic terms, not only in the lockdown period but also in the following months in which, in correspondence with the first reopening, consumers associated a high perception of risk to travel, many giving up planning their own departures. The entire supply chain of the tourism industry has been affected, from the hoteliers of the largest and most renowned structures to small Bed & Breakfasts, from guest houses to hostels, from restaurateurs to suppliers, and from operators to tour guides and museums. This work aims to investigate new dimensions of post-COVID-19 tourism by including some innovation factors, such as the alternatives offered by smart working to tourists and to the citizens of large cities in which many hotels are placed. The research work highlights how the digitalization of tourism services has thus far changed the information-decision-making process that leads to the choice of travel, its experiential and post-experiential phases, and how in the new post-pandemic normal, it can change the way of living the vacation, traveling, and ancillary services connected to them.

Keywords Digital transformation · Tourism businesses · COVID-19 pandemic · Decision-making · Value proposition · Consumer behavior

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C. Amendola (✉) · M. Savastano
Management Department, Sapienza University of Rome, Rome, Italy
e-mail: carlo.amendola@uniroma1.it; marco.savastano@uniroma1.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_58

58.1 Introduction

The diffusion and widespread use of information and communications technology tools, as well as that of social media, has triggered strong behavioral changes in tourists and has influenced the way they plan a trip, the way they face travel, and how they behave after their experience. Large digital platforms have made it possible to move from a standard product to a personalized experience by digitalizing the process and aggregating several service providers (Vescovi et al. 2010). We can summarize the main use of pre- and post-technologies in two macro-areas:

1. *Search for information*: Tourists look for what to do on site, where to eat, what to see, etc. The most interesting technologies are Metasearch (Trivago, skyscanner.net) (Vescovi 2019), Online Travel Agencies (OTAs), Experience Marketplace, and Hotel Networks. These companies allocate huge investments to support very aggressive marketing and commercial activities (Dall'Ara 2017).
2. *Generation of information* (information posting): the main feature of the 2.0 tourist is the generation of information. This macro-area includes all the social networks that are the main vehicle for the generation of content before, during, and after the trip. Tripadvisor, in this context, is the most used platform and the one in which tourists place the most trust (www.formazioneturismo.com). Additionally, Instagram is used to collect and show travel memories, especially among millennials and Generation Z users.

Given these premises, a clearer understanding of the digital business strategies to exploit the new characteristics of the tourism sector created both by the digital economy and the COVID-19 pandemic is timely and needed. Therefore, the present paper presents an empirical investigation to highlight some significant patterns in this wave of innovation.

58.2 Synthetic Review of the Literature on the Subject

Companies in the tourism sector are now called upon to compete in an increasingly complex and articulated global market (WTTC 2021). The digitalization of hospitality businesses is not only strategic in the relationship with customers but also represents an important efficiency tool in the management of structures (Benevolo and Grasso 2018). The evolution of new technologies can represent a disruptive element to overcome the constraints arising from the small size of accessing management programs and software (Corigliano and Baggio 2017). ERP (Enterprise Resource Planning) management systems, software for the efficiency of profitability linked to customer relations, for example, Customer Relationship Management, Property Management System solutions in the cloud version, and Channel Manager, can be integrated with online marketing platforms, which are easy to customize and have low investments, allowing considerable economic advantages for businesses

(Vescovi 2019). The concept of innovation in the tourism sector goes beyond mere aspects related to technology, as it is also accompanied by the ability of operators to innovate in terms of business models and environmental and social sustainability (Dall'Ara 2017). Artificial intelligence, the Internet of Things (IoT), blockchain, and big data analytics are changing both the supply structure and the dynamics and behavior of demand, simultaneously creating new opportunities and challenges for companies and policymakers (Corigliano and Baggio 2017).

58.3 Materials and Methods

The technological innovations promising to have disruptive effects on the tourism market mainly concern the areas of entertainment, comfort during travel, robotics, and information (big data, machine learning, artificial intelligence, and social networks play an increasingly central role) (Rossi 2018). The COVID-19 pandemic, in addition to the significant impact on social life and economic activities, has stimulated many accommodation facilities to a digital transformation, crafting new models of work organization, with extensive use of remote working, smart working, and virtual teams (Hepburn et al. 2020). This research is focused on gathering information on the level of awareness of companies, the importance of digitalization, impacts generated, potential, threats, benefits, and difficulties encountered in the implementation of 4.0 technologies in the tourism sector (Amendola et al. 2022). To achieve this objective, the study presents an online survey based on a questionnaire consisting of 10 multiple choice items, with a sample of 195 companies in the sector operating on the national territory, in the period January–April 2022.

58.4 Results and Discussions

As a result of the digital transformation process, companies often have found themselves pushed to change their business model and adapt to the speed of technological transformation. The sample consists mainly of large companies, with a number of employees greater than 250 units and a yearly turnover of more than 50 million euros (48.32%), followed by medium-sized enterprises and small and micro enterprises (see Fig. 58.1).

To understand and analyze the level of awareness regarding digitalization and the impact it has on the organization, the items were designed to provide a clearer vision of the phenomenon. When asked about the perceived level of digitalization within their organization, 58.12% of the sample answered that they have a high level of digitization, 31.08% an average level and only 10.80% declared that they have a low level of digitization (see Fig. 58.2). Therefore, most companies have adapted to the ongoing transformation by taking a proactive attitude toward change.

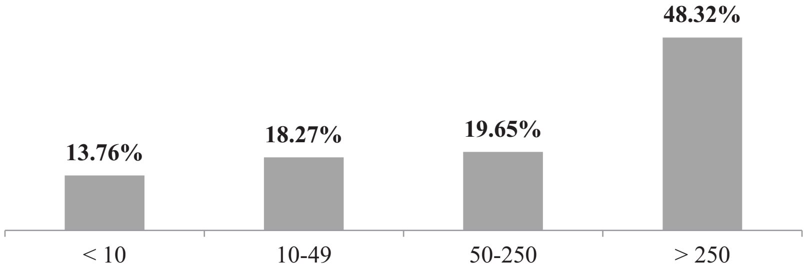

Fig. 58.1 Size classes of the companies in the sample

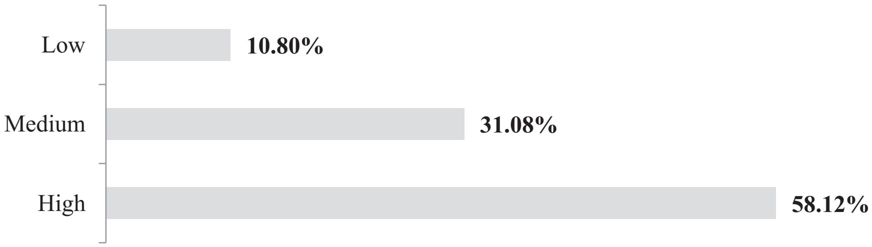

Fig. 58.2 Degree of digitalization of companies

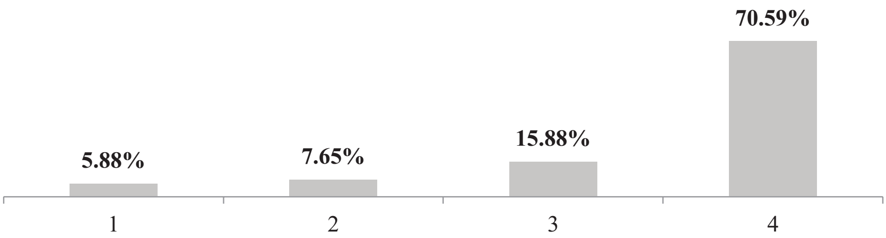

Fig. 58.3 Measurement of the impact of digital transformation in the tourism sector

When asked to what extent the digital transformation had influenced the sector in which they operate, 70.59% of the sample replied that digitalization has a strong impact on the tourism sector (level 4) (see Fig. 58.3); for 5.88% of the sample, digital transformation has a medium-high impact (level 3). The remainder of the sample had low or very low incidence levels. Companies, therefore, express a positive opinion on their situation and are well aware of the changes brought by digitalization.

Moving on, therefore, to defining the level of investments dedicated to digitalization both in the present and in the future, from Fig. 58.4, it is evident that the majority of the sample made significant investments in digitalization, while the remainder, on the other hand, shows a more prudent if not downright disinterested approach to the subject.

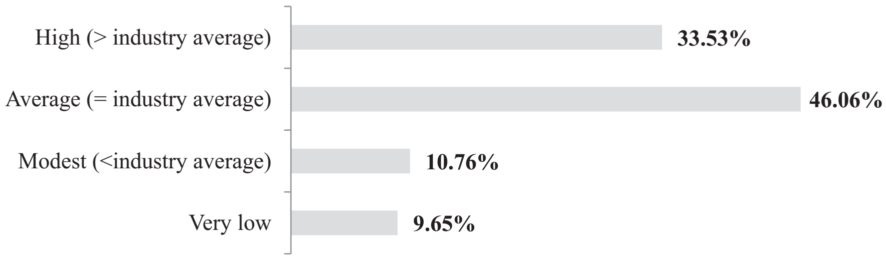

Fig. 58.4 Level of investments in innovation and digitalization supported by companies in the sector

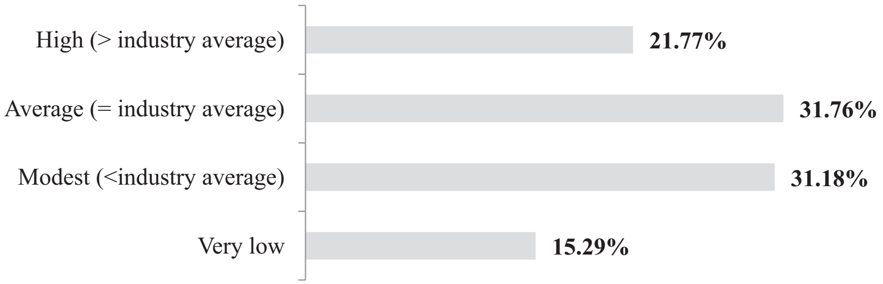

Fig. 58.5 Level of investments in digitization of companies in the sector over the next 3 years

With regard to the forecast on the investments that the companies in the sector intend to make over the next 3 years, the situation is shown in Fig. 58.5. The data show that companies that intend to invest in digitalization in the future are much higher than companies that do not want to invest or that want to allocate only those strictly necessary. This highlights how companies have completely internalized the trend of change.

Furthermore, digital transformation induces companies to implement policies aimed at the adequate management and training of human resources (such as upskilling or reskilling) capable of dealing with this phenomenon. The analysis of Fig. 58.6 shows the strategies implemented by companies to keep up with the technological and cultural changes taking place. This further confirms the contribution of Tortorella et al. (2021), who found that higher employee involvement has a positive mediating effect on the relationship between Industry 4.0 adoption and operational performance improvement.

To better understand the phenomenon, companies were asked to what extent Industry 4.0, and more generally digitalization, has influenced their evolution. Using the Likert scale, almost half of the sample (49.06%) stated that their organization has been highly influenced by digitalization, for 20.65% the effects are quite high, 17.65% register a more moderate level, for 5.88% the effects are still relatively scarce and only 6.76% declared a nil influence (see Fig. 58.7). These results are in line with the evidence presented by Stentoft et al. (2021).

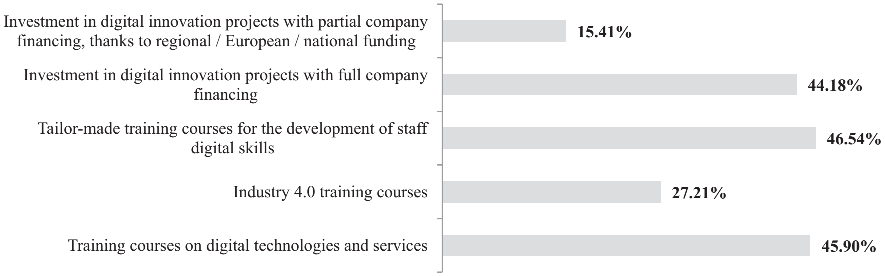

Fig. 58.6 Digital innovation projects carried out by companies

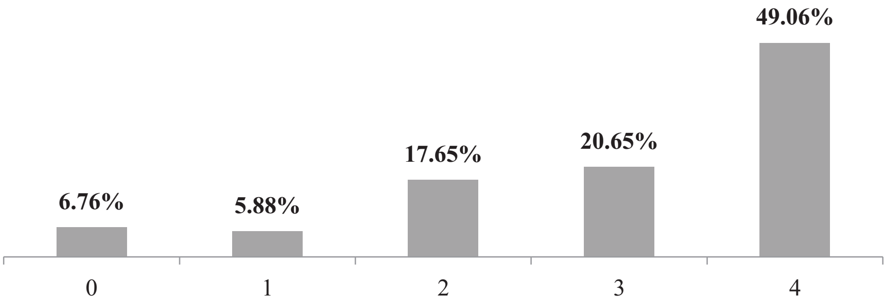

Fig. 58.7 Effects of Industry 4.0 (and more generally of digitalization) on companies in the sector

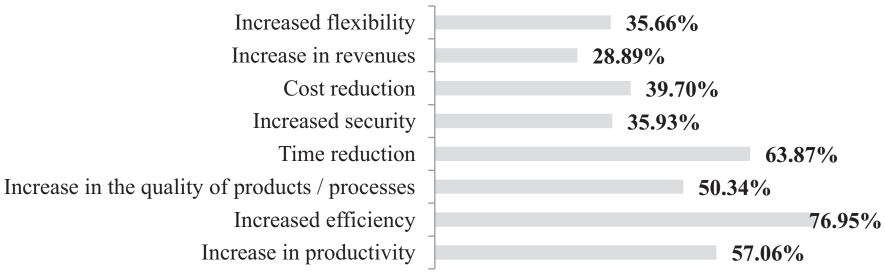

Fig. 58.8 Main benefits brought by the digital transformation

Finally, analyzing the potential benefits and criticalities encountered following the implementation of digital technologies, Fig. 58.8 shows the potential benefits that can be obtained from the new technologies. However, the technological leap in addition to the innumerable benefits also brings various challenges. In fact, there are difficulties in finding highly qualified professionals, as well as a lack of human resources prepared at an operational level (see Fig. 58.9).

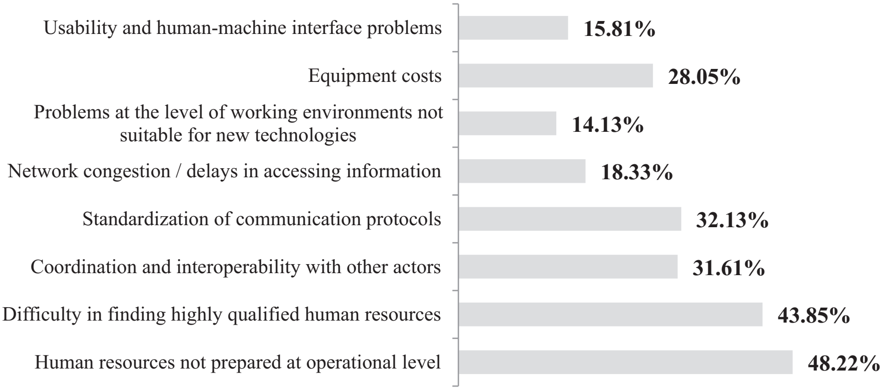

Fig. 58.9 Main challenges and criticalities of the digital transformation

58.5 Conclusions and Future Perspectives

Today, business players are oriented toward consumer satisfaction and the development of user-friendly touchpoints, often through digital platforms as a virtual place where supply and demand will easily meet their needs (Ruggieri et al. 2018).

This study focuses on the level of awareness of companies regarding the digitalization process and on their degree of maturity in this area. Digital transformation has affected the evolution of business models, with particular regard to digital and social media marketing channels, modifying consumer segments and value propositions (Ronchi and Ciancia 2019). It is not just a question of building a lasting relationship over time with customers but of ensuring that loyal customers report positive experiences to other consumers, especially through the Web, and thus make it possible to acquire new customers (Gabetti Property Solutions 2020).

The findings of this study can inform both tourism operators and policymakers about interesting opportunities brought by the digital transformation of the sector to successfully invest their resources and make the right decisions according to the new needs brought by the changes characterizing this turbulent scenario. However, this work can be considered an exploratory phase and therefore also faces some limitations. For instance, a limitation lies in having considered only companies operating in the Italian market.

A comparison with companies from other countries would make it possible to better evaluate both the transformation of business models and the needs of international travelers. Thus, future studies could include an expanded sample of companies operating in international markets to have greater objectivity and awareness of the topic of interest.

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Part IX
Tourism: Circular Economy and Sustainability

Chapter 59
A Framework for Carbon Footprint Assessment in the Tourism Sector

Teodoro Gallucci, Rossana Strippoli, Giovanni Lagioia, Carlo Ingrao, Vera Amicarelli, and Annarita Paiano

Abstract Climate change and global warming are currently among the most important challenges we face. For this reason, greenhouse gas (GHG) emission assessments have become the research topic of many studies. One of the indicators that best allows us to determine the environmental impacts of anthropogenic activities is the measurement of the carbon footprint (CF). The tourism industry, in this context, is the cause of negative environmental impacts and represents approximately 8% of global GHG emissions. Therefore, the purpose of this preliminary study is to provide a framework through ISO 14064-1:2018 standards that aims to: (1) define the main environmental pressure in a Mediterranean micro destination between Monopoli (BA) and Fasano (BR) municipalities in the Apulia region; and (2) enhance and promote the sustainable tourism growth of this area through the assessment, monitoring, and reduction of the CF of the organizations involved. The main results show the difficulty in choosing a suitable functional unit for the tourism industry that combines all the organizations that belong to the micro destination, as well as the obstacle in obtaining accurate data. Future research studies will provide an assessment of the GHG emissions of the tourism organizations involved in the examined area.

Keywords Carbon footprint · Tourism · Low-carbon tourism organizations

T. Gallucci · R. Strippoli (✉) · G. Lagioia · C. Ingrao · V. Amicarelli · A. Paiano
Department of Economics, Management and Business Law,
University of Bari Aldo Moro, Bari, Italy
e-mail: teodoro.gallucci@uniba.it; rossana.strippoli@uniba.it; giovanni.lagioia@uniba.it; carlo.ingrao@uniba.it; vera.amicarelli@uniba.it; annarita.paiano@uniba.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_59

59.1 Introduction

Climate change and global warming are currently among the most important challenges we face. Carbon footprint (CF) can be defined as "the quantity of GHGs expressed in terms of CO_2-e, emitted into the atmosphere by an individual, organization, process, product, or event from within a specified boundary" (Pandey et al. 2011). It is considered a sustainable development indicator since it allows us to determine the environmental impacts of anthropogenic activities causing climate change (Rico et al. 2019). In this context, the travel and tourism sector represents approximately 8% of global greenhouse gas (GHG) emissions (Koçak et al. 2020). However, this sector generated huge benefits for the economic growth of a country; in fact, in 2019, according to the World Travel & Tourism Council (2021), this industry generated 10.4% of the global gross domestic product. In accordance with Filimonau et al. (2013), there is a need to develop a specific and innovative methodological approach for CF assessment in the field of tourism, especially when it focuses on a specific territorial destination. There is a body of literature that focuses on estimating the CF of the tourism industry (Sun 2014; Cai 2016; Lenzen et al. 2018; Kitamura et al. 2020; Sun and Drakeman 2020) with different calculation methods, but there are few studies using ISO 14064-1:2018 standards in tourism as a guide for GHG reporting. This is the main reason to develop a methodological and replicable framework to be adapted to the tourism phenomena in a micro destination of a Mediterranean site located in the Apulia region. Hence, this framework and the assessment of the carbon footprint could allow the identified micro destination to reach territorial and economic sustainable development through the adoption of the ISO 14064-1:2018 standards. We choose to assess the CF of this micro destination as preliminary research because this paper is part of a key output of the European Project Cross-border Cooperation Program 2014–2020 Interreg V-A Italy – Croatia, named "TAKE IT SLOW – Smart and Slow Tourism Supporting Adriatic Heritage for Tomorrow," which aims to develop sustainable tourism in a micro destination in the Apulia region (European Union 2019).

59.2 Methodology

The framework methodology was based on ISO 14064-1:2018 standards, "specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals" (Wintergreen and Delaney 2009; ISO 14064-1:2018), and it has been adapted to the tourism sector. According to the ISO 14064-1:2018 standards and to a recent study by Choudhary et al. (2018), a five-step methodology for GHG quantification and reporting has been defined, as Fig. 59.1 displays.

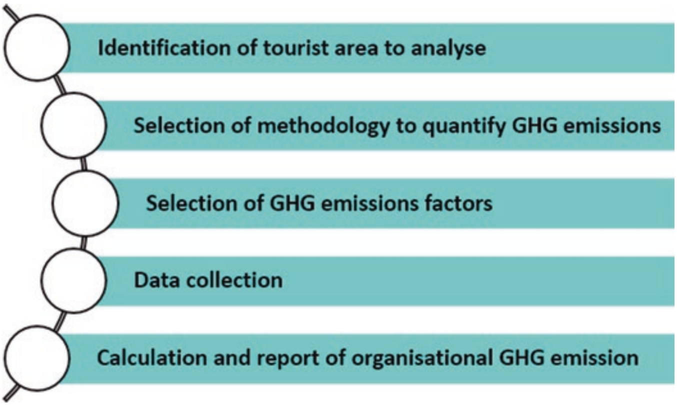

Fig. 59.1 Five-step methodology for greenhouse gas (GHG) quantification and reporting in the tourism sector. Sources: Authors' elaboration, based on Choudhary et al. (2018) research and ISO 14064-1:2018 standards

The first step concerns the identification of the tourist area and the organizations involved (such as accommodation, food and beverage, crafts, tourist agencies, rental services, etc.).

The second step involves the choice of methodology to quantify the CF, which depends on the dimension of the selected area. Among the different methods used for accounting for CF in the tourism sector, the most widely used are the top-down and bottom-up approaches. The first is based on tourism expenditure, calculated by using secondary data, such as statistical information, and is considered transparent, not economically expensive, and easy to replicate. This method is preferred for nations or large territories, and it allows CF comparison between tourism and other economic sectors. The second approach is based on tourism activity, calculated by using primary data, such as interviews or questionnaires, and is considered more detailed and accurate but also more expensive in terms of time and money costs. This method is preferred for regions or small territories. Then, the inclusion and exclusion criteria to analyze and quantify the direct and indirect GHG emissions are identified in the third step. The organization shall specify the kind of GHG emissions considered (carbon dioxide, methane, nitrous oxide, etc.) and compare the impacts generated by the different gases by converting the quantity of each type of GHG to tons of CO_2-e using a suitable global warming potential (GWP) index.

The fourth step concerns the collection of data in an identified period, following the inclusion and exclusion criteria expressed in the previous step. Finally, in the fifth step, the organizational GHG emissions are calculated through the aforementioned steps, and the results are shown in a GHG report. This preliminary study focuses on the first three steps of the proposed framework related to B&Bs and travel agencies included in the considered Apulia micro destination by applying a bottom-up approach.

59.2.1 Framework Implementation in Apulian Micro Destination

The tourist area identified in the just-mentioned European project is a Mediterranean micro destination delimited by the area between the Monopoli (BA) and Fasano (BR) municipalities in the Apulia region. According to the demographic report provided by ISTAT (2020), Monopoli has a population of 48,101 inhabitants, and Fasano has a population of 39,025. The area considered is approximately 157 km^2 for Monopoli and 131 km^2 for Fasano (ISTAT 2022). Moreover, according to the annual tourist movement report provided by Puglia Promozione – Regional Tourism Agency (2022), these areas registered, in 2021, domestic and foreign tourist arrivals of 233,407 people (46% in Monopoli and 54% in Fasano), totaling 853,023 nights (equal to 3–4 nights per tourist), of which less than 42% were spent in Monopoli and more than 58% in Fasano. These data can be compared to tourist arrivals and the presence of the Apulia region in 2021, with 3,336,729 people and 13,875,537 nights, respectively. Hence, tourist flows in Monopoli and Fasano municipalities represent approximately 7% of the total tourist flows in Apulia.

Concerning the second step, we chose the bottom-up approach for the CF assessment because it is suitable for small territories and is considered more detailed and accurate.

In addition, for the third step, the criteria chosen for the GHG emissions assessment are shown in Table 59.1.

Table 59.1 Chosen criteria for the greenhouse gas emissions assessment

Items	Evaluation methods
Technological systems (e.g., electrical, heating, air conditioning, sanitary, and water systems)	Survey
Electricity consumption referring to the year 2021	Electricity invoices
Electricity production referring to the year 2021 (if any)	Survey
GAS/LPG consumption for the year 2021	Invoices/Bills
Inventory of heat pump systems (split/fan coil)	Survey and the copy of the periodic maintenance booklet with communication to the fluorinated gases (F-gas) system
Quantification of the gas in the refrigerators (if present)	Survey
Quantification of daily commuting of employees and the identification of the means of transport used	Survey
List of the company vehicle fleet (if present) and the km travelled by employees	Survey
List of the company vehicle fleet (if present) and the km travelled by customers	Survey

59.3 Results and Discussions

The implementation of the proposed framework at the Apulian micro destination has highlighted many interesting issues. The choice of a suitable functional unit (which is the description of the reference basis of the study for the quantification of the assessment of the impact) for the tourism industry that combines all the organizations that belong to the micro destination (such as accommodations, food, and beverage, crafts, tourist agencies, etc.) is one of the main crucial items to solve. The need to avoid the identification of a tourist as a functional unit emerges, as generally displayed by the literature. Most likely, considering one tourist per km^2 of micro destination area observed could be more useful. The main problems are data collection and cooperation between the different subjects involved. To implement the ISO 14064-1:2018 standard, in order to enhance and promote the sustainable tourism growth of the organizations involved in the micro destination, the development of a network of companies is needed because a juridical body to obtain the environmental certification must be constituted. Hence, further analysis is required to complete the research with the collection of data through surveys, the calculation of GHG emissions, and the presentation of the results in a GHG report.

As this is preliminary research, its main limits concern the obstacle in acquiring data because, as small businesses, they do not have an environmental reporting system and/or a financial report, and there is often a lack of awareness of sustainability. Furthermore, it is necessary to identify the consumption of the inhabitants compared to that of tourists.

59.4 Conclusions

In this preliminary study, through ISO 14064-1:2018 standards, a framework for quantifying and reporting the CF of tourism organizations has been drawn up. This framework can be adapted to other destinations with similar characteristics with the aim of reducing their environmental pressure and enhancing and promoting their sustainable growth through the assessment, monitoring, and reduction of the CF of the organizations involved. Future research studies will provide an assessment of the GHG emissions of the tourism organizations involved in the examined area based on accurate data that will be gathered and a sustainability report. The results will be benchmarked with others from different calculation methods, as well as the development of a standardized structured report.

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Chapter 60
Life Cycle Assessment of a Spanish Pilgrimage Route: A New Style of Tourism for Promoting Sustainable Tourism and Curbing Climate Change

Cristina Campos Herrero, Jara Laso, Pere Fullana-i-Palmer, Alba Bala Gala, Jaume Albertí, Margalida Fullana, María Margallo, and Rubén Aldaco

Abstract From an economic point of view, the tourism sector is one of the most important in the world, with religious tourism, such as pilgrimages, being a growth area. However, tourism activities also make a significant contribution to CO_2 emissions (roughly 8% of the world's carbon emissions). In this framework, the main objective of this research is to develop an integrated sustainable model by assessing the impact of pilgrimages on Camino Lebaniego in the Cantabrian region, which is one of the most popular routes in northern Spain. To do this, it is necessary to quantify the environmental impacts of this activity realized in 3 days by a pilgrim by using the life cycle assessment (LCA) methodology, in which four environmental impact categories are considered. Simapro 9.3 software and the Ecoinvent and Agribalyse databases were used to assess the environmental impacts. The results showed that the electricity consumption of the hostels and the food eaten by the pilgrims at the evening meals were the hotspots of the system under study.

Keywords Environmental impact · Religious tourism · Camino Lebaniego · Hostel · Restaurant · Tourism activity

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C. C. Herrero (✉) · J. Laso · M. Margallo · R. Aldaco
Department of Chemical and Biomolecular Engineering, University of Cantabria, Santander, Spain
e-mail: cristina.campos@esci.upf.edu; jara.laso@unican.es; maria.margallo@unican.es; ruben.aldaco@unican.es

P. Fullana-i-Palmer · A. Bala Gala · J. Albertí · M. Fullana
UNESCO Chair in Life Cycle and Climate Change ESCI-UPF, Barcelona, Spain
e-mail: pere.fullana@esci.upf.edu; alba.bala@esci.upf.edu; jaume.alberti@esci.upf.edu; margalidafullanapuig@gmail.com

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_60

60.1 Introduction

Tourism is a social and cultural phenomenon (UNWTO 2022) that is continuously growing, becoming an important foundation in the economy, society, and environment. In 2019, according to the World Travel and Tourism Council (World Travel and Tourism Council 2019), tourism activities accounted for 10.4% of global gross domestic product (GDP) and generated one out of every 10 jobs (319 million) worldwide. As a result of this growth, in 2018, Europe accounted for 51% of the world's international arrivals, representing 710 million tourists and almost 40% of international tourism receipts (USD 570 million) (UNWTO 2019). Italy and France contained 35.7% of the total bed places in the European Union (EU), followed by Spain and Germany with 3.6 million bed places each. In fact, Spain was the preferred destination for international tourists, accounting for 22.0% of the EU total and spending 299 million nights in the country (Eurostat 2021a). The country received 83 million visitors in 2019 (UNWTO 2019), mainly concentrated in the Canarias (Canary Islands), Illes Balears (Balearic Islands), and Cataluña (Catalonia) (Eurostat 2021b). Tourism is a critical pillar of the Spanish economy, serving as one of the main engines of growth and recovery. However, tourism is responsible for approximately 8% of global greenhouse gas (GHG) emissions, so the need to turn to more sustainable tourism remains essential for the sector to reach international climate action targets (Lenzen et al. 2018).

In Spain, the negative effects of mass tourism influenced the emergence of new types of tourism, which are also closely linked to people's desire to reconnect with their origins, enjoy natural environments, and become more environmentally conscious. It has been observed that religious pilgrimage tourism increased due to the pandemic, as rural destinations emerged as the most attractive option after the outbreak of COVID-19 (March 2020) (Ranjbari et al. 2021). Rural areas were a great alternative for tourists who wanted to travel while socially distancing themselves. In short, people have turned from mass tourism to safer rural and pilgrimage tourism, suggesting a positive outlook for religious tourism in 2022.

This paper differs from other studies because it focuses on the environmental analysis of a hostel, while the rest of the published literature looks at other types of accommodations (including El Hanandeh 2013, who studied the pilgrimage route to Mecca but considered hotel accommodations). In addition, it analyzes different possible menus for improving the diet of pilgrims, a factor not considered in other studies, as well as tourism activity, waste management, and transport. Hence, the main objective of this paper is to assess the environmental impacts of a religious pilgrimage route in Cantabria (northern Spain) through an analysis of accommodation (hostel), transport, tourism activity, food and beverage consumption, and end-of-life treatments by applying life cycle thinking considering the product environmental footprint method.

This paper therefore fills a "gap" in the religious tourism segment and the environmental assessment of this market. Therefore, our analysis of this pilgrimage route has enabled us to identify the hotspots within the system, providing a useful contribution and a step forward in the development of tools for evaluating and improving the sustainability of tourism in an area, thereby supporting destination managers, pilgrims, and policymakers.

60.2 Materials and Methods

To analyze the environmental impact and critical points of the tourism sector, it is necessary to use rigorous environmental tools. The methodology followed in this study was based on life cycle thinking, so the guidelines established in the UNE EN-ISO 14040 standard (ISO 2021), related to the principles and framework of LCA, were considered. This procedure is divided into four steps: (1) goal and scope definition, (2) life cycle inventory, (3) life cycle impact assessment, and (4) interpretation.

60.2.1 Goal and Scope Definition

The goal of this study is to assess the environmental impact involved in walking the Camino Lebaniego in 3 days, determine the main hotspots, and allow us to propose sustainable practices for the pilgrimage. The route is approximately 73 km long and divided into three stages (from San Vicente de la Barquera to Cades, from Cades to Cabañes, and from Cabañes to Santo Toribio) (Fig. 60.1).

The main objective of this study is to assess and analyze the main environmental impacts generated by pilgrims completing the Camino Lebaniego, a religious pilgrimage route located in northern Spain (Cantabria). For this purpose, an LCA will be developed to try to identify the hotspots of the system by analyzing the

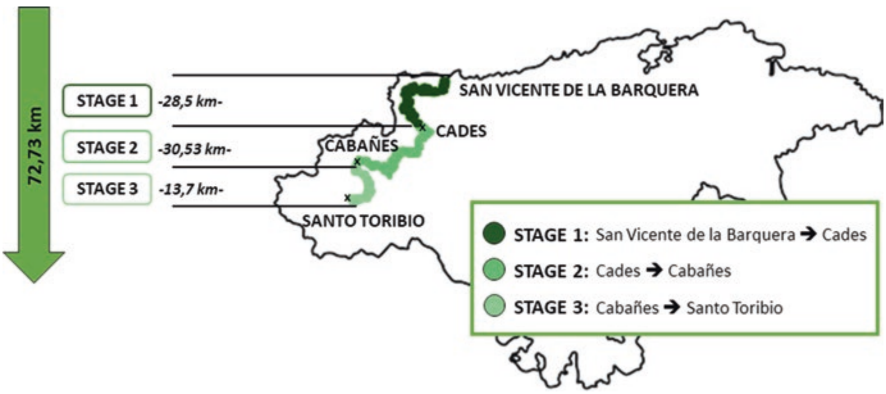

Fig. 60.1 Route map for Camino Lebaniego with 3 stages

consumption data collected from different hostels, meals, tourist activities, transport, and waste management along the route of this religious route.

According to ISO 14040, the LCA is structured according to a functional unit (FU) defined in terms of the subject under study. An FU is a unit of reference for measuring, quantifying, and relating system inputs and outputs so that LCA results are comparable (ISO 2021). Therefore, it must be consistent with the objective and scope of the study previously defined. In this study, the FU defined to relate the inputs and outputs of the system is “a pilgrim who completes the Camino Lebaniego in 3 days.” Therefore, all the data and the results obtained must be expressed in terms of this FU, which is in line with the function of the pilgrim, that is, to complete this pilgrimage route.

The system boundaries represent the interface between the product system and the environment, and their definition determines which unit processes should be included within the assessment. In this study, different subsystems are considered for the 3 days, considering that each day was a stage of the Camino Lebaniego.

- *The first day* considers the Cades hostel (with breakfast and dinner included), the food during the route, and the final management of the waste generated in the accommodation.
- *The second day* includes the same stages as the first, modifying the hostel where pilgrims stay (Cabañes hostel).
- *The third day* includes an additional activity to the pilgrimage since it does not exceed 14 km of travel: the Briz hostel with breakfast including lunch during the route, a tourist activity (canyoning), dinner at the restaurant, and waste management associated with that day.

60.2.2 Life Cycle Inventory

Life cycle inventory involves the compilation and quantification of inputs and outputs of the system throughout its life cycle. On the one hand, primary information, that is, foreground data, was obtained from the owners of the establishments (hostels and restaurants) in northern Cantabria. The three hostels and the restaurant under study reported data by means of a questionnaire comprising information on cleaning product consumption, water and energy source consumption, and food and beverage consumption in 2019. A total of five questionnaires were collected (three for each hostel, one for the restaurant, and another for the tourist activity). In the first 2 days, breakfast and dinner were included in the hostel. On the last day, dinner was provided at the restaurant. Questionnaires were also given to pilgrims who had walked the Camino Lebaniego to discover their preferences in terms of food. In this sense, as 78% of the pilgrims consumed a sandwich, a piece of fruit, and a bottle of water while walking the route, this was the reference menu chosen for lunch.

Second, secondary data, that is, background processes, were compiled from the Ecoinvent v3.7.1 and Agribalyse 3.0 databases.

60.2.3 Life Cycle Impact Assessment

This section corresponds to the life cycle impact assessment. In this case study, the EF. 3.0 (Environmental Footprint) method is used with Simapro software, which consists of a procedure for analyzing the impact of the ecological footprint using an environmental footprint analysis procedure using various impact categories. To analyze the environmental impacts of the realization of Camino Lebaniego, five impact categories were selected:

- Climate Change (CC) [kg CO_2 eq].
- Acidification (AP) [mol H+ eq.]
- Eutrophication (EP) [kg P eq.]
- Resource depletion: fossil fuels (FRD) [MJ].

60.3 Results and Discussions

This section contains the results for the four impact categories listed earlier in the report. Afterward, possible improvement measures will be proposed with the aim of reducing the negative environmental impacts studied on the route.

60.3.1 Environmental Impacts of the Camino Lebaniego

Results for the four categories of environmental impact for each of the days on which the pilgrim of environmental impact for each of the days on which the pilgrims make the pilgrimage route of the Camino Lebaniego. All the results have been shown by FU, for example, see Fig. 60.2. In general, as shown in Fig. 60.2, the scenario with the lowest contribution to the impact categories is day 1, with low values for acidification and eutrophication (less than 30% in each). On the other hand, Fig. 60.2 shows that the stage with the highest environmental impact contribution values in most of the impact categories is day 2, with percentages of 34%, 36%, and 36% for acidification, eutrophication, and fossil fuel depletion, respectively.

60.3.2 Environmental Impact Analysis by Stage

It is necessary to analyze the stages considered in the 3 days to identify the least sustainable stage on the route and to propose improvement measures. As shown in Fig. 60.3, the stages with the highest contribution in most of the environmental

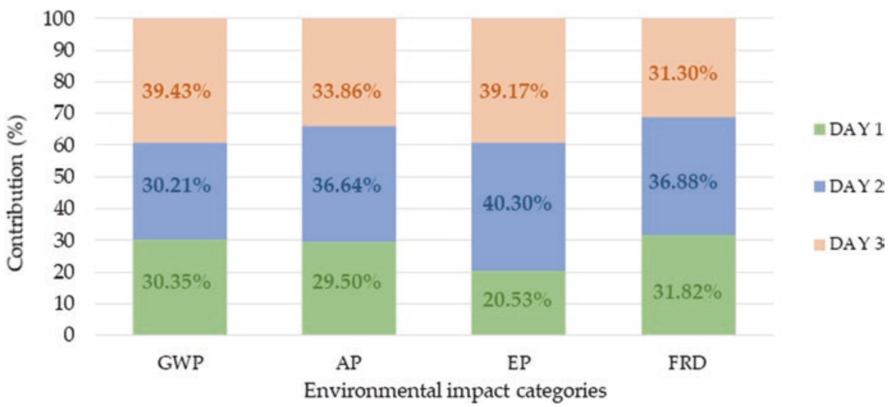

Fig. 60.2 Environmental impact of the four impact categories for the three different days

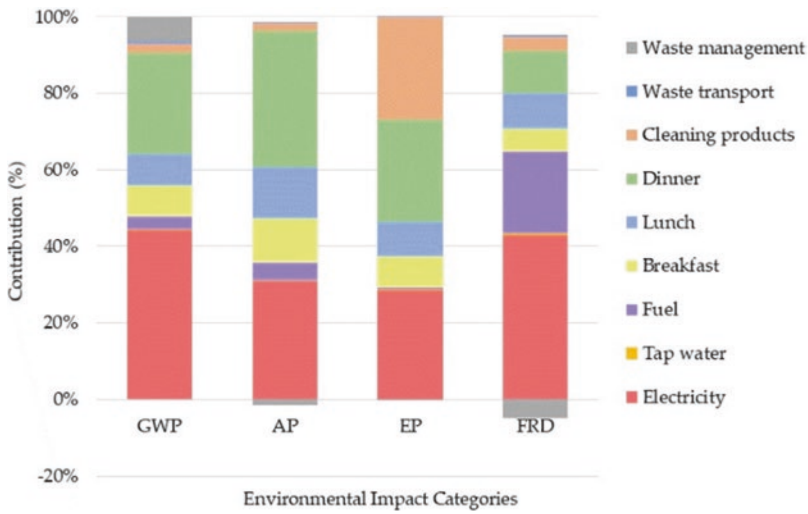

Fig. 60.3 Environmental impact of the four impact categories for the three different days

impact categories are electricity consumption and dinner, which are the hotspots of the system.

Electricity consumption contributes more than 50% of the total environmental impact, highlighting global warming and the depletion of fossil fuels as a consequence of combustion processes. Some of the improvement measures proposed to reduce its impact are the use of renewable sources (installation of solar panels in hostels and restaurant) and the application of the "3Rs Rule," based on reducing, reusing, and recycling food waste in accommodation and restaurants, and promoting the circular economy on the pilgrimage route.

In terms of evening meals, the food products that have the greatest impact are different types of meat (turkey and red meat) due to the processing involved and spaghetti Bolognese, which requires a very high degree of processing, making it an unsustainable meal. To reduce this impact, an analysis of new food proposals was considered: chicken, hake, eggs, and peas. The last three alternatives are more sustainable than the foods proposed in the evening meal menus.

60.3.3 Analysis of the Transport Subsector in Camino Lebaniego

It is necessary to analyze the environmental impact generated by the transport of pilgrims from their origin to the start of the Camino Lebaniego route. In the case of the study, the impact associated with transport was considered to be negligible because a large percentage of pilgrims (35%) came from the place where the route takes place (Cantabria). The main places of origin of pilgrims, both nationally and internationally, are Cantabria, Castilla y León, Basque Country, Madrid, Valencia, Andalusia, France, Italy, and Germany. It can be observed that the journeys causing the greatest environmental impact in terms of global warming and fossil fuel depletion are air travel from Italy and Germany, as there is a greater distance to the Lebaniego route (1350 and 1394 km). On the other hand, car travel shows clearly higher values in the eutrophication category, as shown for travel from Madrid, Basque, Country and Castile and Leon. Therefore, it was found that to travel the same distance, it was more advisable to use the car instead of the plane.

60.4 Conclusions and Future Perspectives

This work applies the LCA methodology to find the hotspots of a pilgrimage route and propose measures to reduce their impact. Electricity consumption and the food eaten by pilgrims during meals were the major contributors. As alternatives, the installation of solar panels and the substitution of meat and prepared dishes at dinners have been proposed. Finally, it has been proven that cars have a lower impact on global warming than airplanes. Further work is recommended, which could focus on the following:

- Refining this study, specifically through the inclusion of other establishments that could be chosen along the route.
- Performing an uncertainty analysis, not only for the food stage but also for the transport data collection stages.

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Chapter 61
Circular Economy Perspectives in the Italian Hotel Industry

Maria Pia Spinelli, Rossana Strippoli, Giovanni Lagioia, and Vera Amicarelli

Abstract The spread of tourism has generated benefits, both economic and employment related. However, the tourism phenomenon also generates negative impacts, mainly due to the configuration of the tourist offer that follows the linear economic model of production and consumption. For this reason, tourism needs to be well planned and monitored. The circular economy (CE) is considered a possible solution for reducing environmental, social, and economic costs and aims at an increase in benefits with a view to more sustainable tourism. This topic has recently become the object of study in the scientific literature, with contributions to evaluating the implementation of CE principles in the tourism sector. Through semi-structured interviews with sector operators, the aim of this exploratory study is to identify and evaluate the circular practices along the business processes of the hotel industry. The main results show that to meet sustainability requirements, CE practices need to be assessed through quantitative measurement tools since closing the loop does not necessarily lead to mitigation of the impacts.

Keywords Circular economy · Sustainable tourism · Hotel industry · Interviews

61.1 Introduction

The spread of tourism generated benefits, both economic and in terms of employment, making it one of the economic sectors with the most rapid growth in the world (Ren et al. 2019). However, this growth also generates negative impacts, mainly due to a configuration of the tourist offer that follows the linear economic model of production and consumption (Cornejo-Ortega and Chavez Dagostino 2020).

M. P. Spinelli · R. Strippoli · G. Lagioia (✉) · V. Amicarelli
Department of Economics, Management and Business Law,
University of Bari Aldo Moro, Bari, Italy
e-mail: maria.spinelli@uniba.it; rossana.strippoli@uniba.it; giovanni.lagioia@uniba.it; vera.amicarelli@uniba.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_61

Indeed, it represents approximately 8% of global greenhouse gas emissions (Koçak et al. 2020). The future of this sector, according to the World Tourism Organization (n.d.), will depend on the effort to transform tourism, reducing its general emissions by 50% by 2030 and fully eliminating them by 2050. In this context, the hotel industry contributes to negative externalities due to, for example, inefficient waste management and the high consumption of water and energy (Leyva and Parra 2021).

The circular economy (CE) is considered a possible solution for reducing environmental, social, and economic costs, with a view to more sustainable tourism. Although interest in this topic is growing, there is still a shortage of CE practice implementation in the tourism sector (Cornejo-Ortega and Chavez Dagostino 2020). Current academic literature suggests that CE principles applied in the hotel industry are basic and mainly refer to the reduction in consumption and reuse of energy and water, as well as the recycling of materials (Rodríguez-Antón and Alonso-Almeida 2019). In addition, circularity indicators commonly cover only the recycling rate and waste management-related impacts (Arzoumanidis et al. 2021). Therefore, there is still little concern about assessing and analyzing circular practices. Based on these brief considerations, this exploratory study aims to identify and evaluate some common practices attributable to CE principles in the hotel industry.

61.2 Methodology

A qualitative methodology was chosen to better fit the aim of this exploratory study. A semi-structured interview was selected because a well-planned research interview can be considered one of the most common and easy methods to collect qualitative data (Gill et al. 2008; Qu and Dumay 2011). Interviews are suitable when little is known about the topic or when detailed information is required (Gill et al. 2008). Among the three main kinds of interviews (structured, semi-structured, and unstructured), the semi-structured, based on an interview within a predetermined framework, is the preferred one due to its versatility and flexibility (Gill et al. 2008; Qu and Dumay 2011; Kallio et al. 2016). The investigation was conducted from May 26 to June 17, 2022, with sector operators performing management positions (front office, sales and marketing, and hotel manager) because "they are positioned at the intersection point of the vertical and horizontal flows of information and knowledge" (Darvishmotevali et al. 2020). The Italian accommodations were mainly located in Southern Italy, namely, a Luxury B&B, no. 3 Four Stars Hotel, no. 2 Five Stars Hotel, and a hotel group with no. 6 Four/Five Stars Hotel facilities throughout Italy. The main features of the seven accommodations included in the present research are recorded in Table 61.1.

Eight main business processes were considered to build the in-depth interview; therefore, questions were asked on the application of the CE principles considering (1) *booking/check-in*, (2) *procurement/purchases*, (3) *food service*, (4) *overnight stay/use of rooms*, (5) *cleaning of rooms and common areas*, (6) *laundry washing*, (7) *installation and maintenance of systems and equipment*, and (8) *induced traffic*.

Table 61.1 Features of the hotels and B&Bs interviewed

Accommodation	Type of accommodation	Stars	Rooms	Location	Geographical position	Employees
1	Luxury B&B	–	15	Downtown	Southern Italy	8
2	Hotel	4	140	Downtown	Southern Italy	40
3	Hotel	4	75	Downtown	Southern Italy	20
4	Hotel	5	115	Downtown	Southern Italy	25–30
5	Hotel/residence	4	70 + 13 apartments	Inshore	Southern Italy	20–180
6	Resort hotel	5	180	Inshore	Southern Italy	100–700
7	Hotel group	4–5	700	Inshore/in the countryside/in the mountains	South/center/north of Italy	+500

Data collected have been analyzed according to content analysis (Erlingsson and Brysiewicz 2017), which is applied in several research areas, including tourism and hospitality (Amicarelli et al. 2021). Therefore, the answers given during the interviews were classified according to the *10R concept*, namely, *Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycling,* and *Recover* (Zorpas 2020). The analysis excluded *Recycling* and *Recover* from the suitable circular practices since the waste-to-energy process is the prerogative of the companies in charge, while the separate collection is borne by the municipality and primarily depends on the correct transfer of collected waste to the sorting and recycling centers. In addition, the separate collection is a very widespread practice and in many municipalities, it is even mandatory; therefore, this would not allow a distinction in terms of worthy environmental management.

61.3 Results and Discussion

This exploratory research shows a predominance of the application of practices attributable to the principles of the CE in the processes of *booking/check-in*, *food service,* and *overnight stay/use of rooms*. The main results are shown in Fig. 61.1 and detailed below.

The most implemented actions referred to the use of recycled paper and paperless/digital operations related to the front office and back office activities; refurbishing and repairing of the workstations; seasonal menu and homemade production; absence of disposable tableware and table linen, or utilization of biodegradable and compostable alternatives when needed; incentivization for the reuse of linen; automation and/or centralization for air conditioning and lighting system; preference for

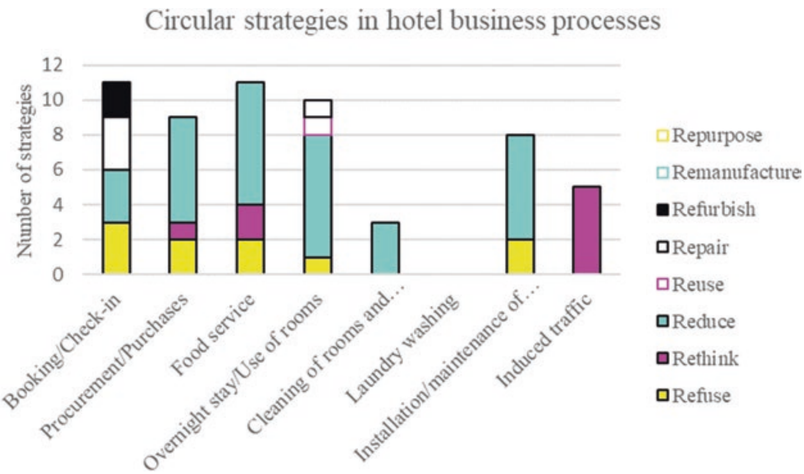

Fig. 61.1 Application of the circular economy principles in tourism business processes

non-disposable products such as dispensers for body cleansers; and furniture reparation at the end of the season. Other actions concern the choice of the local producers, purchase of products with green certifications, preference for non-disposable and biodegradable products and/or without plastic packaging (e.g., vanity kits), together with the provision of water refill stations and the replacement of low-energy efficiency appliances. In *room cleaning* and *laundry washing* processes, the implementation of circular practices proves difficult since they are often outsourced, while the installation of systems for sustainable energy supply is among the most complex practices since it requires important structural changes; indeed, only Accommodation no. 4 claimed to own thermal solar panels for heating. Regarding *induced traffic*, the only common practice is bike rental, even for free. However, it is necessary to stress that sometimes the accommodations are far from the city center and reachable only by private transport. In this case, it can be defined as a service designed to implement the offer rather than reduce the environmental impact. At the same time, other circular practices are often chosen to contain costs (e.g., automated systems, reuse of towels, refusal of single use, etc.).

The results of interviews suggest that in hotel management, it is common to identify circular practices that allow cost reduction. Even though such practices concern the principles of the CE, it is not easy to state that the environmental impact is reduced; hence, the support of quantitative impact measurement tools (e.g., Life Cycle Assessment) is needed.

In addition, from the interviews, it emerged that the more luxurious hotels are, the more difficult it is to adopt circular and sustainable practices because what truly matters is customer satisfaction. From here, the need to sensitize customers towards sustainability issues becomes evident, including for all the stakeholders in the tourist supply, including sector operators performing managerial positions who lack training in sustainability issues.

As this is exploratory research, its main limitations concern (1) the paucity of interviews, and a much higher number of interviews would be recommended to reach useful conclusions; (2) the issue of collecting suitable information due to the lack of knowledge on this topic; and (3) the availability of sector operators to be interviewed.

61.4 Conclusions

This explorative research highlights that the actions most implemented by hotel operators are not sufficient for sustainable business management. Although most practices can be classified in the so-called *short loop* (*Refuse*, *Rethink,* and *Reduce*), they are not part of green management-oriented business planning but rather aimed at achieving an economic advantage. Substantial changes are needed so that circular practices can meet the principles of sustainability, and measurement tools are required to determine environmental convenience. The reduction of negative externalities must not only concern the saving of water and energy resources but also the reduction of waste volumes. Since the offer changes according to demand, it is necessary to sensitize the customers, who if interested in the mitigation of their environmental impact will change their behavior and understanding of company choices.

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Chapter 62
Mountain Tourism: Environmental Management for Fostering Tourism Destinations: From Context Analysis to Tourism Products

Riccardo Beltramo, Stefano Duglio, and Giulia Mascadri

Abstract A tourism destination is defined as a geographical region, an administrative jurisdiction, or a relevant attraction that offers the visitor a range of tourist experiences that are memorable through one or more tourism products, a combination of tangible and intangible elements around the core of the tourism destination. In mountain contexts, a tourism destination cannot be separated from the quality of the natural environment, often representing its main attractor. For this reason, the scientific community started paying attention to defining models for assessing the sustainability of mountain tourism destinations. The present contribution reports the activities carried out in the territory of Alagna Valsesia, Monte Rosa Massif (Piedmont), as part of the Alagna Walser Green Paradise (AWGP) project, within a scientific collaboration with the Piedmont Region and the Municipality of Alagna Valsesia. Through the definition of context analysis, a new tourism product has been defined. The "way of the waters" is a walking route that will link all the municipal fountains, valorizing a natural resource through multiple viewpoints (cultural and historical), and thanks to high technology, the information will be accessible to all.

Keywords Mountain tourism · Environmental management · Tourism destination · Tourism product

R. Beltramo · S. Duglio (✉)
Department of Management, University of Torino, Torino, Italy

NatRisk – Interdepartmental Research Centre on Natural Risks in Mountain and Hilly Environments, University of Torino, Torino, Italy
e-mail: riccardo.beltramo@unito.it; stefano.duglio@unito.it

G. Mascadri
Department of Management, University of Torino, Torino, Italy
e-mail: giulia.mascadri@unito.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_62

62.1 Introduction

According to the United Nations World Tourism Organization (UNWTO), a tourism destination is a "physical space with or without administrative and/or analytical boundaries in which a visitor can spend an overnight. It is the cluster (colocation) of products and services, and of activities and experiences along the tourism value chain and a basic unit of analysis of tourism" (UNWTO 2022). These offered experiences, the so-called tourism products, can be a combination of tangible and intangible elements, supposed to be memorable for all the visitors' targets involved (Romeo et al. 2021). According to the UNWTO, sustainable tourism is "tourism that takes full account of its current and future economic, social, cultural, and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities" (UNWTO 2022). To make this goal possible, however, the identification of suitable tools plays a fundamental role. This contribution presents the activities that were carried out within the Alagna Walser Green Paradise (AWGP) project, Monte Rosa Massif (northwest of the Italian Alps), in collaboration with the Municipality of Alagna Valsesia and the Piedmont Region. The AWGP's final aim is to define an index for the quality of life for mountain destinations from an integrated perspective that considers the pillars of smart tourism: cultural heritage and creativity, environmental sustainability, accessibility, and digitalization. For environmental sustainability, the implementation of the context analysis in accordance with international standardization standards (ISO 14001 and EMAS) provided all the elements and evidence for proposing a new tourism product for this area, the "way of the waters."

62.2 Literature Review

62.2.1 Tourism Destination and Tourism Product

A tourism destination is "a basic unit of analysis of tourism" (UNWTO 2019). Initially intended as a simple geographical space, there are currently various definitions of tourism destinations that include the importance of allowing visitors to enjoy travel experiences (Goeldner and Ritchie 2003) and offering a tourism product, which means "a broad wave of facilities in transport, accommodation, food, and at least one outstanding activity or experience" (Framke 2001). Either based on cultural or intangible characteristics (Seaton and Bennett 1997), a destination incorporates various stakeholders and can network to form larger destinations (Żemła 2016). It is also intangible with its image and identity, which may influence its market competitiveness. As defined by the UNWTO, a tourism product is a combination of several components (natural and cultural resources, attractions, services, etc.) When considering mountain contexts, the natural environment plays a critical role in characterizing tourism destinations (Duglio and Letey 2019).

62.2.2 Environmental Management for Territorial Development

In considering the complex relationship between territorial management and the environment, local authorities have shown an interest in environmental management in accordance with international standards in the past decade (Ridolfi et al. 2008; Beltramo et al. 2011). As is widely known, the most adopted tools for implementing structured environmental management are environmental management systems based on two main models: ISO 14001:2015 and European EMAS Regulation EC N. 1505/2017. Even if they were born for the manufacturing sector, these tools have been adopted by any kind or organization, such as municipalities (Marazza et al. 2010; Beltramo et al. 2014), national parks (Bocca et al. 2009), and hospitality sector (Rodríguez-Antòn et al. 2012). In particular, the last revision for the two standards introduced some important innovations and, more in detail, the concepts of life-cycle perspective, risk assessment, and context analysis (Assolombarda 2015). In the new general structure of the EMS, the organization is asked to consider the environmental implications of its processes (direct and indirect environmental aspects) and the risks derived by them, both on the environment and on the same organization, in terms, for instance, business continuity and reputation. (Beltramo et al. 2016). Thus, risk has to be assessed under two different viewpoints – environmental risks and organizational risks – and to make the process effective, it is necessary to provide a context analysis of the organization. Even if there is not a specific methodology for carrying out the process, the context analysis is normally divided into subchapters aimed at first presenting the processes that are conducted by the organization and their environmental aspects and impacts. Furthermore, the impacts need to be quantified to set objectives and targets. When considering this process for territorial development, context analysis can become an ideal tool for strengthening strategies based on core evidence supported by environmental data, and if the region is tourism-oriented, it can help boost new tourism products.

62.3 Materials and Methods

62.3.1 Area of Investigation

The area of investigation is Alagna Valsesia at the foot of the Monte Rosa massif (Piedmont Region, Northwest of the Italian Alps). It is a mountain municipality (1191 m asl) within the area of the High Valsesia Nature Park with the high mountains of Monte Rosa to surround the valley. Valsesia Valley, thanks to its proximity to the imposing Monte Rosa massif and to the elongated shape and richness of different landscapes, attracts thousands of tourists every year intrigued by the beauty of this territory and the various opportunities and attractions among which tourism

Fig. 62.1 Alagna Valsesia. (Source: Internal elaboration)

connected to winter skiing emerges. The territory has become a UNESCO World Heritage Site thanks to the Valsesia Geopark, established for the conservation and protection of the fauna and flora species present in this area. Furthermore, the local ecosystem is under the protection of Alta Valsesia Nature Park, a protected area that extends between 900 and 4559 m high, making it the highest in Europe. To further enrich the context, it is worth mentioning the typical Walser architecture, the result of the northern populations that have been established in the territory of upper Valsesia since the twelfth century (Fig. 62.1).

62.3.2 Methodology

As mentioned above, the methodological tool that has been adopted is context analysis in accordance with the ISO14001 and EMAS standards to provide an updated state of the art of this area. For performing this activity, several stakeholders were involved in the process, starting with the Municipality of Alagna Valsesia, to the tourism operators, local associations, organizations, and companies that provide environmental services (energy and water distribution, waste collection, and disposal). At the same time, the research was carried out through data collection and analysis from official sources (Piedmont Region, Municipality of Alagna Valsesia, local Tourist Center, Ispra and Arpa Piemonte). Between February and June 2021, the researchers carried out four interviews with stakeholders that directly deal with the most important environmental aspects at the territorial level to obtain a better understanding of their activities and collect data. In particular, CO.R.D.A.R. Valsesia S.p. A on water distribution, Alpiq S.r.l. on energy production, C.O.Ve.Va.R. for waste management, and Enel S.p.A. for energy distribution. Then, in July 2021, nine semi-structured interviews with local associations and local groups of interest were carried out, enriching the research with the perception of local actors. Moreover, in August and September 2021, during the weeks of high tourist turnout of summer visitors, a total of 346 questionnaires were collected from tourists. A section was devoted to investigating tourists' perceptions of Alagna's environment. This multilevel on-the-ground analysis made it possible to collect evidence on the state of the art of the area and on both the strong and critical environmental aspects under several perspectives, which was useful for proposing the implementation of a tourism product.

62.4 Results and Discussion

The proposals and targeted ideas put forward by the researchers have matured on the basis of all the activities carried out thus far. The integrated data on the environmental situation included the evaluation of the emissions to air, the quality of water, the level of (green) energy, waste management and the management of green areas and paths, electromagnetic pollution, public transport, urban mobility, and noise pollution. The evaluation of these aspects led to Alagna Valsesia being considered a tourist resort with some great strengths: air quality, in fact, is at levels well above the regional average, and the production of energy derived from the natural resources of the territory is able to satisfy all the demands of the territory and to even produce more renewable energy than how much it consumes. The researchers also stressed the important work done by the municipality in raising awareness among the community of Alagna Valsesia about separate collections. On the other hand, whether it is high or low season, from the point of view of noise pollution, quietness is the normal condition of this area. The same positive assessment was also made by the researchers with regard to electromagnetic pollution, which was detected to such an extent that it could not pose a threat to human health. Finally, the data collected by water quality surveys confirm that there is no substantial difference in characteristics (organoleptic) between a bottle of water on sale and the water running in Alagna's taps. By integrating the preexisting experiences and valorizing the environmentally positive aspect of Alagna Valsesia, with the fundamental elements of accessibility, environmental sustainability, digitalization, cultural heritage, creativity, and life enhancement, the core analysis of the project, a new tourism product, has been proposed. The "Way of the Waters" is a walking path that follows the network of municipal fountains while explaining and valorizing, thanks to the latest technology such as QR codes, 3D videos, and augmented reality, the water resource from different points of view: From the supply of drinking water, its organoleptic characteristics, the use for agricultural and tourism purposes (such as snowmaking), the consumption of the territory, its scarcity, etc., in a cultural and historical framework explained during the tourism experience accessible to all of the visitors. One of the goals of this contribution was to demonstrate how the different pillars are essential to have a meaningful target and product framework and to show how the enhancement of environmental resource management can help reinforce the value of tourism products. The "Way of Waters," an intangible tourism product, can hold all these elements together, being a fundamental component of the natural mountain heritage enhanced with a social and cultural value ready to be proposed by local tour operators.

62.5 Conclusions and Future Perspectives

This contribution presented and discussed the application of standardized environmental management as a core element for proposing tourism products based on the natural heritage of a mountain tourism destination. The "Way of the waters" for Alagna Valsesia has a tourist value throughout the year, also through digital systems, which allows tourists to gain awareness on the effects of climate change and the importance of water as a resource, and, together with promoting the area, will play a training role for increasing consciousness on this topic. As with all research activities, even this proposal has some limitations. It is the authors' opinion that the main limitation of this action must be seen in the fact that it has not yet been implemented by the Municipality of Alagna Valsesia. Consequently, this contribution is not able to give positive or negative feedback on the impact of the proposal (number of tourists involved, degree of satisfaction, etc.). In the meantime, the aforementioned limitations represent future actions that should be taken to understand the robustness of the proposal as well as possible implementations.

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Part X
Tourism: Quality

Chapter 63
Tourism Participative Management in Protected Areas: Case Study in the Protected Area of Parco Naturale Regionale Sirente Velino

Federica Murmura and Guido Capanna Piscè

Abstract Community engagement and adaptive management are generally considered excellent techniques for the long-term success of environmental policies; nevertheless, several challenges emerge when faced with practice. In this research study, we analyze the joint governance design introduced in the protected area of Parco Naturale Regionale Sirente Velino (Abruzzo, Italy) through the European Charter for Sustainable Tourism (ECST). The ECST is a tool that can be likened to process certification, which allows better management of protected areas for the development of sustainable tourism in coherence with the spatial planning tools of the parks. The central element of the ECST is collaboration among all stakeholders to develop a common strategy and an action plan for tourism development based on an in-depth analysis of the local situation and the creation of a permanent forum. The objective is the protection of natural and cultural heritage and the continuous improvement of tourism management in the protected area for the benefit of the environment, the local population, businesses, and visitors. The research, combining in-depth interviews carried out with the main territorial actors with a survey carried out with the tourism actors, shows how the partnership created with ECST has contributed to the emergence of a process of improvement in tourism management in the protected area, encouraging cooperation between the territorial public institutions and private actors.

Keywords Sustainable tourism · Community participation · Tourism management · Protected areas · ECST (European Charter for Sustainable Tourism)

F. Murmura · G. Capanna Piscè (✉)
Department of Economics, Society, Politics, University of Urbino Carlo Bo, Urbino, Italy
e-mail: federica.murmura@uniurb.it; guido.capannapisce@uniurb.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_63

63.1 Introduction

Protected areas (PAs) refer to the world's most appropriate method to conserve nature and a key representative market for tourists interested in nature (Surendran and Sekhar 2011); they provide a suitable environment to develop ecotourism. The United Nations World Tourism Organization (UNWTO) defines sustainable tourism as "tourism that takes charge of its future and current social, economic, and environmental effects, considering visitors' needs, surroundings, investment, and local communities" (UNWTO and UNEP 2005, p. 12). Within this broad concept, ecotourism is defined as a type of sustainable tourism aimed at improving natural resource conservation and increasing environmental education (Engels and Job-Hoben 2005). The ecotourism industry worldwide was estimated at 181.1 billion US dollars in 2019. The sector was forecast to reach 333.8 billion US.dollars in 2027, registering a compound annual growth rate of 14.3% (www.statista.com, November 22, 2021).

The United Nations (1992) views ecotourism as having the necessary prospect of raising the formation of employment opportunities and income while at the same time "encouraging both local (domestic) and indigenous (international) societies in host nations and tourists related to preserving and respecting cultural and natural pride" (UNWTO 2013; Das and Chatterjee 2015, p. 2). Therefore, an appropriate ecotourism plan enables stakeholders' participation, such as administrators, communities, policymakers, and tourists (Warner 1997).

In 1995, the EUROPARC Federation – an association that supports the management of European Protected Areas – established the European Charter for Sustainable Tourism (ECST) in PAs. This initiative would appear to offer an effective management tool to combine competitiveness, well-being, and sustainability through a set of general principles and actions using a triple bottom-line approach. To achieve this ambition, the Charter necessitates a strategic as well as a participatory approach within it (EUROPARK 2021; Federparchi 2021).

According to Sharpley (2006, p. 8), the increased demand for "environmentally appropriate tourism experiences" has been part of the constituents contributing to ecotourism market growth, where tourists represent the ecotourism market demand side, while the representatives of the supply side are PAs, which are ideal sites due to their enterprise mission (Wood 2002). PAs are described worldwide as "well-designated geographical areas dedicated, recognized, and maintained, using a lawful or other appropriate method, to obtain nature conservation in the long run linked to cultural values and ecosystem services" (Day et al. 2012, p. 9; Eagles et al. 2002).

The participation and approval of local stakeholders have been recognized as crucial for the future success of PA management (IUCN 1994; Morandi et al. 2013; Kati et al. 2015, p. 2). Tomićević et al. (2010) described idealizing the participatory method of promoting the sustainable utilization of natural resources, while Reed (2008) identified facts that stakeholder engagement can "enhance environmental decisions' quality."

ECST adoption was an ideal move due to its certification tools and methodology to effectively manage PAs, ascertaining that tourism results in equilibrium in the societal, economic, and environmental development of Europe's reserved regions.

The outlined process in the Charter contains three factors enabling local businesses, companies, and tour operators to utilize shared objectives and vision. Part I, Sustainable Destinations, is to manage the PA body covering a given region application of the Charter, sometimes wider compared to the legally defined PA; Part II, Sustainable Partners, addresses the local companies operating in sustainable tourism activities within the Charter area; Part III, Sustainable Tour Operators, is particular to tour guides and travel agencies bringing tourists to safeguarded regions and willing to take part in the sustainable growth of the Charter region.

Italy is recognized as an excellent tourist destination where the tourism market is significant for the nation, although the institutional actors in this sector are numerous and largely disunited. Italy is among the nations that incorporate ECST as a guideline tool for administering reserved sites by regions, parks, and the Ministry of the Environment. Today, the Italian network has 36 certified areas.

Stakeholder collaboration in developing a sustainable and common action plan and strategy informed by the local situation through analysis becomes a critical element of the Charter (Getz and Timur 2012; Waligo et al. 2015).

The research aims to investigate how the network between territorial authorities and private operators that may be established with ECST can contribute to the emergence of a positive process to help enhance the management of tourism in the PA through real cooperation.

63.2 Materials and Methods

Sirente Velino Park is the westernmost PA in the Italian region of Abruzzo, in the province of L'Aquila, on the border with the Lazio region. With an extension of approximately 47,500 hectares, the PA covers 22 municipalities divided into three zones. Marsica Settentrionale is characterized by a gradual development and benefits from the positive influence of the Piana del Fucino (outside the park), which hosts one of the most important agricultural and industrial realities of the region; Altopiano delle Rocche represents the most developed area of the park thanks to its summer and winter tourist aptness; Valle dell'Aterno and Valle Subequana are areas with less infrastructure, which have some of the criticalities and potentialities typical of Italian mountain areas.

On January 1, 2021, a resident population of 32,953 (16,483 males and 16,470 females) was reported. The analyzed area faced a drastic population decline from post-World War II to the 1970s. Over the last decade, the population has started to decrease again because of a general reduction in the birth rate, which has become increasingly important in recent years and has affected the entire national territory. Obviously, it is having a more evident impact on those communities in the inland Apennines already marked by an advanced average age.

The tourism sector in Sirente Velino Park shows a very heterogeneous situation. The Altopiano delle Rocche area welcomes a good number of tourists every year, basing its attractiveness on the area's natural resources that provide the opportunity to practice various sports activities either in the winter or summer season, from skiing to hiking. The Northern Marsica and especially the Media Valle dell'Aterno and Valle Subequana register smaller numbers; thus, the network of accommodation and services related to tourism appears less developed. In addition to the sports component and the part linked to environmental tourism, the Park area also offers interesting insights into rural and food and wine tourism with a series of renowned products that characterize the territory. In the last 5 years, leaving aside the data for 2020 deeply marked by the COVID-19 pandemic, which led to a loss of approximately 30% of tourist movement, a slightly positive medium-term trend can be noted, both in terms of arrivals (44,810) and presences (115,032).

Starting in the summer of 2021, the new management of Sirente Velino Regional Natural Park embarked on the path of obtaining the ECST in PAs, which ended in February 2022. The candidature for the ECST certifies the commitment of the Park Authority and of all the stakeholders involved in the protection of the natural and cultural heritage.

The methodology for constructing the ECST strategy of the Sirente Velino Regional Natural Park was characterized by an inductive approach. Two cycles of meetings on the territory (for a total of 20 meetings) were constructed with the aim of defining a common strategy to develop more sustainable tourism within the ECST area. Four strategic axes emerge from a critical and shared rereading of the territory's strengths and weaknesses and a common vision activity identified during the participatory process (Waligo et al. 2013). The categories of actors involved included local administrations, associations, accommodation operators, facilities managers, guides, and businesses. The involvement of these actors was continuous, attempting to attract interest in participation even from subjects who had not joined the initiative during the initial phase (Roxas et al. 2020). Together with the Park Authority, 88 local actors took part in at least one of the meetings for the definition of the 2022–2026 Strategy and Action Plan, representing 69 organizations operating in the territory, including two PAs, 17 local public authorities, one university, 14 associations, and 36 private tourism operators. In addition to the described methodologies, this research included in-depth interviews conducted with the territorial actors encountered throughout the described pathway (for a total of 26 in-depth interviews). The survey questionnaires used to complete the strategy document were completed by all participants in the action plan.

63.3 Results and Discussions

During the participatory process, four strategic axes were identified through a common visioning activity.

The following strategic objectives were prioritized by the stakeholders of the Altopiano delle Rocche: (1) the development of active tourism to complete the skiing offer with quality services throughout the year, focusing on communication that diversifies itineraries and proposals in the context of a single touristic destination; (2) the enhancement of the identity and integrity of a single territory (the Park among the parks), also by recovering and reviving the fortresses and towers, cultural spaces, and museums. The discovery of local testimonials, bridges of dialogues between locals and visitors to tell stories and revive traditions, as well as on new frontiers of telematic networks (roles of schools, local authorities, and community facilities).

For the Area of Subequana: (1) the growth of sustainable mobility, connexion, and communication among the different villages and sights both in the valley floor and in the ridges ("stazzi and pagliari" animal pens and barns): roads, means of transportation (the little train in the valley floor, TPL, shared mobility) and accessible trails or paths dedicated to specific targets (bike paths, horse trails) and to different ages and abilities; (2) promotions of events, excursions, and meetings during different seasons to encourage a community network beyond the municipalities for discovering and knowing the still authentic territory. Relaunching a new agricultural, artisan, and commercial entrepreneurship to support the quality of the tourist business by capitalizing on the flavors and knowledge of the farm culture.

Regarding the 48 proposed actions, a total of 10 will be implemented directly by the Sirente Velino Regional Natural Park Authority, while the remaining 38 actions will be the responsibility of the 36 other subjects in the area who have committed themselves by signing at least one action sheet. These subjects range from other PAs (two actions), public administrations (10 actions), universities (one action), associations (seven actions), and other private operators (18 actions). The value of the commitments envisaged by the submitted actions is €3,965,020.

The "Sirente Velino" work analysis in the Natural Regional Parc showed the duties of participatory and strategic methods for ecotourism development effectiveness and how the methods can be operational.

The assessment theoretically ascertained the key role of participatory and strategic methods in improving the appropriateness of the process of ecotourism development within PAs (Hardy and Pearson 2018). The assessment also showed those elements that are influenced by these methods.

63.4 Conclusion and Future Perspectives

Ecotourism can be ideal when it is guided by a safeguarding-oriented authority such as a PA and led by a participatory method such as the one advocated by the ECST.

The initial crucial elements are planning, coordination, and the real chance of the Charter's strategy completion and action strategy in 5 years. It is hard to engage public authorities constantly and repeatedly in the Forum, despite the evidence that they are crucial for unity policies in the region. The other weakness is the top-down pressure that leads to the parks establishing the ECST process or interest in creating European recognition, failing to follow the method and concept. Additionally, the change in presidents and directors of certified parks is an important issue. In some cases, the new administration of the PAs fails to understand or overlook the significance of the ECST route, which they have not "anticipated happening."

The cooperation between the Park Authority and the private sector will become more important in the future with the implementation of Phase II of the ECST. Federparchi-Europarc Italia has powered the national network, which strengthens the Italian system, and this requires maintenance via the development of joint projects. It will be important for Italian-reserved regions to enhance their commitment to the European network based on information exchange, participation, presence, and engagement.

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Chapter 64
"Alagna Walser Green Paradise" Research: Quality of Life as a Topic to Enhance a Mountain Tourist Destination

Riccardo Beltramo, Giacomo Pasino, and Giovanni Peira

Abstract This contribution focuses on the construction of a model of the quality of life within the research project "Alagna Walser Green Paradise" (AWGP), developed with the Municipality of Alagna Valsesia and the Piedmont Region. Quality of life was measured through gross domestic product (GDP) for decades, but over time, other perspectives have been considered, such as health, education, employment, leisure, social relations, security, environment, landscape, and cultural heritage. Well-being measurement frameworks are applied at international and national levels but unlikely at rural levels. AWGP research activities define an experimental method to identify, together with local stakeholders, a set of indicators to measure rural quality of life. The suggested set considers the following context: Alagna Valsesia is a mountain rural tourist destination. The purpose is to collect useful information that allows local stakeholders to carry out activities of monitoring and improvement. Positive results at the end of this model test would allow reiteration of the same set of indicators in other rural areas.

Keywords Alagna Valsesia · Quality of life · Rural quality of life · Stakeholder

64.1 Introduction

Alagna Valsesia is a mountain rural tourist destination located in Piemonte (Italy) on the slopes of Monte Rosa, with winter and summer flows and the aim of developing sustainable tourism growth.

Quality of life can be generally defined as people's satisfaction with their life and personal well-being. It is widely verified that measures such as gross domestic product (GDP) or per capita GDP, used for decades, are insufficient to study quality

R. Beltramo · G. Pasino · G. Peira (✉)
Department of Management "Valter Cantino", University of Torino, Torino, Italy
e-mail: riccardo.beltramo@unito.it; giacomo.pasino@unito.it; giovanni.peira@unito.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_64

of life. Even strictly objective variables such as life expectancy, literacy rate, or death rate are not sufficient (Casini et al. 2019; Nissi and Sarra 2016). Quality of life is a multidimensional concept, and for this reason, it is necessary to consider both quantitative and qualitative dimensions (Viccaro et al. 2021; Greyling and Tregenna 2020; Musikanski et al. 2017), such as leisure, social relations, environment, landscape, cultural heritage, available services, and innovation. Governmental (and non-governmental) entities have developed frameworks and indicators to study citizens' well-being, to gather information in support of public policies, and in relation to sustainable development goals (Istat 2020a, b; Nissi and Sarra 2016; Casini et al. 2021; European Union 2017). Despite a wide debate, it is not available that a single method or framework is generally recognized as better than others (Casini et al. 2021; Greyling and Tregenna 2020; Al-Qawasmi et al. 2021). One question, among other difficulties, is that useful dimensions vary because of the specific context of analysis. Quality of life is a matter not only at national levels but also at rural levels (Viccaro et al. 2021; Al-Qawasmi et al. 2021); in this second case, well-being is a topic that influences the community's sustainable development in a crucial way (Casini et al. 2021, 2019; Viccaro et al. 2021).[1] The research project "Alagna Walser Green Paradise" (AWGP) is part of the studies about rural quality of life. It has been developed with reference to the municipality of Alagna Valsesia.[2] The aim of the research is to gather useful information, together with local stakeholders, to define sustainable development and responsible tourism projects. Quality of life and well-being cross the other four research pillars: cultural heritage and creativity, environmental sustainability, digitalization, and accessibility.

Indicators, indexes, and frameworks about quality of life are available at national levels, sometimes at regional levels, and rarely in relation to provinces or metropolises. It is difficult to find studies and frameworks that examine well-being in rural areas, even with reference to single dimensions such as sustainability and related elements (Sehnem et al. 2020; Battis-Schinker et al. 2020; Casini et al. 2021; Viccaro et al. 2021; Nissi and Sarra 2016).

64.2 Methodology

As it is said, it is not available in literacy one framework about rural quality of life (with or without tourism integration) is recognized as a best practice.[3] Since then, the need to identify a reliable set of indicators with reference to a rural mountain

[1] It is useful to consider that unsatisfaction quality of life in rural areas involves/accelerates phenomenon like depopulation (Casini et al. 2021).

[2] AWGP has started thanks to the collaboration with the municipality and the Management Department of Università degli Studi di Torino, with recognition of Regione Piemonte.

[3] Some examples of studies about this topic are available here: Battis-Schinker et al. (2020), Greyling and Tegenna (2020), Sehnem et al. (2020), Viccaro et al. (2021), Nissi and Sarra (2016), Al-Qawasmi et al. (2021). Starting points have been international and national frameworks in different cases.

tourism destination, such as Alagna Valsesia, has led the research team to carry out these steps[4]:

- identification and analysis of international and national frameworks about quality of life (in general or about specific dimensions) on the one hand and tourism industry and sustainable tourism on the other hand;
- evaluation of rural information availability in relation to quality-of-life dimensions for a tourism destination;
- proposition of a potential set of indicators, relevant and measurable, that can supply local stakeholders with useful information for their decisional processes and implementation of improvement activities.

A total of 17 frameworks have been analyzed, with more than 1700 indicators/variables.[5] The useful dimensions identified to measure even rural quality of life are as follows, with positive confirmations in the examined literacy (Al-Qawasmi et al. 2021; Casini et al. 2019, 2021; Greyling and Tregenna 2020; Viccaro et al. 2021; Nissi and Sarra 2016): employment and economic well-being; health and physical security; education and knowledge; subjective well-being,[6] leisure, and social relations; government and politics; landscape and cultural heritage; environment; and service industry. To obtain a preparatory selection of 62 potential indicators related to the dimensions mentioned above, the team has resorted to the Italian National Institute of Statics (Istat) "BES" and "BES of the provinces" (Istat 2020a, b)[7] and UNWTO "Indicators of Sustainable Development for Tourism Destinations: A Guidebook" (2004). This preliminary selection is compliant with the other frameworks considered.

64.3 Results and Discussions

A discussion among local stakeholders and the research team results in the need to modify and/or integrate some indicators of preparatory selection for the following reasons: better adherence to the particular context of Alagna Valsesia, which is a mountain rural tourism destination with winter and summer flows and the aim of developing sustainable tourism growth; and the measurement and relevance of the collected information for local stakeholders and decision-makers (Casini et al. 2019; Sehnem et al. 2020; Greyling and Tregenna 2020; Viccaro et al. 2021; Nissi and Sarra 2016; UNWTO 2004).

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[4] The activities conducted in the research project AWGP are in line with the main steps recommended by UNWTO (2004). A similar approach was carried out by Sehnem et al. (2020) and Al-Qawasmi et al. (2021).

[5] According to information available in each framework.

[6] Satisfaction with one's life in general.

[7] The framework is mentioned by Nissi and Sarra (2016), Casini et al. (2021), Battis-Schinker et al. (2020), European Union (2017), Viccaro et al. (2021).

The team then identified a proposal of 70 indicators. The topics of investigation are various, in line with the multidimensionality of well-being and quality of life (as discussed before) and the necessity to consider tourism matters. Moreover, the suggested set of indicators includes objective and subjective measures, as appropriate and stated before. Among the topics related to quality of life are accessibility (with a focus on people with special needs), waste management, energy management, water management, pollution, employment, quality of life (in general and in relation to specific matters), income, housing expenses, traffic and congestion, local public transport, volunteer activities, young people and/or women involved in the administration of the municipality, green areas, internet services, availability and accessibility to services related to primary needs, and cultural asset use. Among specific topics about tourism are enhancement of typical products, tourist flows, tourist offer, perceived quality of life (in general and in relation to specific matters), the relationship between the local community and tourism, visitors' satisfaction, and spread of agritourism. The proposed set of 70 indicators covers each of the eight dimensions and five pillars of the research (Figs. 64.1 and 64.2).[8]

The design of questionnaires has been a relevant step to let the team collect specific information and analyze specific topics. These have been developed for public and private stakeholders (such as tourist operators, associations, and entities) and residents, who play a crucial role in quality-of-life-related studies and surveys about the relationship between the local community and tourism (Greyling and

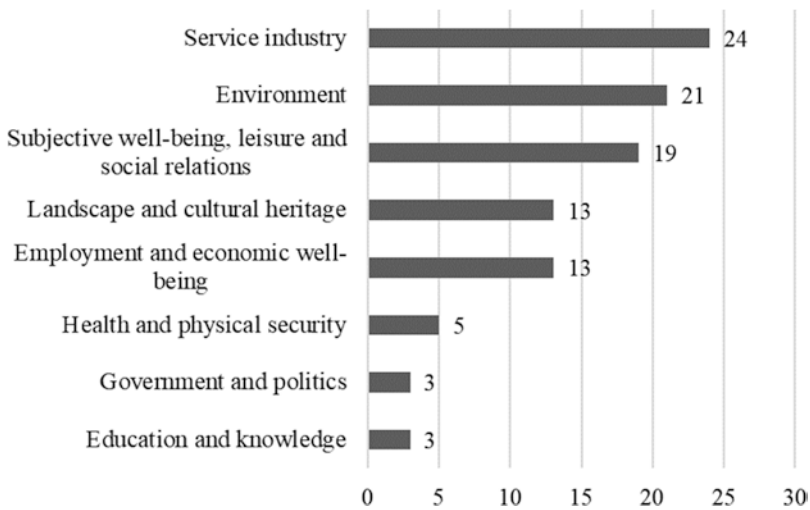

Fig. 64.1 Number of indicators for each dimension

[8] Some indicators are related to more than one dimension/pillar.

Fig. 64.2 Number of indicators for each pillar of the Alagna Walser Green Paradise research

Tregenna 2020; UNWTO 2004; Musikanski et al. 2017), tourists – to examine the perceived quality of life, which is considered in this case as an attractive element for the tourist destination itself.

64.4 Conclusion, Limits, and Outlooks

The suggested set of indicators aims to measure the quality of life in rural areas, with reference to a mountain tourist destination such as Alagna Valsesia. It derives from the analysis of 17 frameworks, indexes, and documents arranged by institutions and entities of international and national relevance. They guarantee a rigorous methodology of analysis and/or a rigorous methodology in the selection of indicators. Moreover, the indexes analyzed are up to date by the referral entity (according to the frequency of each index). In addition, free information about most of the frameworks analyzed is available on the internet, which allows the team to deeply explore them in terms of dimensions, variables, and indicators. Although both composite indexes and subjective approaches are criticized (Casini et al. 2019, 2021), the team believes that it is impossible to exclude these international and national frameworks for the reasons briefly stated before.

The proposed experimental method is formed by 70 indicators, useful to gather both quantitative and qualitative information of interest for local stakeholders. The set of indicators covers all the dimensions generally adopted in quality-of-life studies. Since the measurement at a local scale of the indicators, thanks to the involvement of numerous subjects (public and private stakeholders, entities, residents, visitors), it is possible to obtain a comprehensive state of the art that is useful for local decision-makers to evaluate performances over time, identify and monitor criticalities, and decide how to intervene to improve quality of life and enhance the destination. Positive results at the end of this model test at Alagna Valsesia would allow replaying the same set of indicators in other rural contexts. In addition, future research programs could propose a standardization of indicators to obtain a unique composite index that would be compared among different rural areas in an easier way.

The proposed set of indicators has been packaged with reference to the results of AWGP research. However, the aim is to achieve a framework that could be applied and reliable in similar rural areas to evaluate quality of life. A program of gradual involvement of other mountain municipalities and tourist destinations in different environmental, economic, and social contexts has been stated to evaluate the strength, flexibility, and validity of the model.

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Chapter 65
The Alagna Walser Green Paradise Project as a Tool for Enhancing the Cultural Heritage and Creativity Pillar

Riccardo Beltramo, Enrica Vesce, Greta Buoso, and Alessandro Bonadonna

Abstract This contribution describes the activities carried out in the territory of Alagna Valsesia on the slopes of Monte Rosa (north-east of Piedmont) as part of the Alagna Walser Green Paradise (AWGP) project, developed through scientific collaboration with the Piedmont Region and the Municipality of Alagna Valsesia. The project is structured into four research pillars: cultural heritage and creativity, environmental sustainability, digitalization, and accessibility. With reference to the cultural heritage and creativity pillar, the concept of authenticity has been identified as an essential element in the tourism sector since it encourages the link between tourists and destinations. Alagna Valsesia is analyzed as an "authentic" tourist destination through the analysis of three specific areas, that is, food and wine, artifact and products, and landscape. Therefore, the AWGP research group was involved in developing an integrative tourism proposal based on the evaluation of the existing offer. The results show that Alagna Valsesia embodies its authenticity with the tradition of the territorial culture, and they help to highlight some improvement proposals related to (1) the creation of a visual communication system, (2) the enhancement and measurement of the attractions and the tourist offer on the territory with the use of dissemination tools in the various sites of interest, and (3) the introduction of new itineraries (i.e., De.Co.).

Keywords Alagna Valsesia · AWGP · Cultural heritage · Creativity · Walser · Sport and leisure

R. Beltramo · E. Vesce · G. Buoso · A. Bonadonna (✉)
Department of Management "Valter Cantino", University of Torino, Torino, Italy
e-mail: riccardo.beltramo@unito.it; enrica.vesce@unito.it; greta.buoso@unito.it; alessandro.bonadonna@unito.it

G. Lagioia et al. (eds.), *Innovation, Quality and Sustainability for a Resilient Circular Economy*, Circular Economy and Sustainability,
https://doi.org/10.1007/978-3-031-28292-8_65

65.1 Introduction

The Alagna Walser Green Paradise (AWGP) project was designed to improve some areas of interest, such as accessibility, sustainability-quality of life, and cultural heritage. Specifically, the cultural heritage area of interest has been divided into three core areas (or pillars) present in the destination, that is, enogastronomy, manufactured, and landscape. Each area was defined through the analysis of cultural ecosystem services, which can be identified in the territory of Alagna Valsesia.

The three pillars are united conceptually by the term authenticity. As is well known, consumers tend to seek experiential tourism connoted by uniqueness and authenticity elements. The territory of Alagna Valsesia synthesizes its authenticity with the encounter between Walser tradition (e.g., in architecture and territorial culture) and the typicality of the opportunities it offers in terms of sports and leisure activities (e.g., skiing and mountaineering activities). These characteristics make the Alagna Valsesia destination a place where authenticity is an expression of the maintenance of ancient mountain traditions and the evolution of activities over time. In the literature, the concept of authenticity in tourism is constantly analyzed (Tazim and Hill 2004; Buonincontri et al. 2017; Wang et al. 2015), as it fosters the bond between tourists and destinations and makes for unforgettable experiences.

For the AWGP/cultural heritage project, the destination Alagna Valsesia is analyzed as a tourism destination by highlighting the elements of authenticity dedicated to the three pillars, that is, food and wine, artifact and products, and landscape. Each pillar was analyzed through specific indicators and defined by scientific literature to verify the state of the art of Alagna Valsesia's tourism service offerings and then evaluate the opportunity for improvement where the need arose, based on the highlighted criticalities.

65.2 Review of the Literature

65.2.1 Authenticity

Authenticity is one of the key elements in making a destination distinctive. The tourism literature is full of debates about the meaning and validity of authenticity; in fact, Taylor argues that there are as many definitions of authenticity as people are writing about it (Taylor 2001).

Studies that theorize authenticity as an "objective" concept are criticized as being based on a static understanding of place and culture (Boorstin 1964). Other research states that authenticity should be viewed as a social construct since cultures change and there are no longer pure societies on which concepts of authenticity can be based (Meethan 2003; Hughes 1995).

Jackson (1999), instead of talking about "authenticity," suggests focusing on the term "authentication," which is the process by which people make claims of authenticity and obtain veracity assurance.

Recent developments have extended the discussion to different meanings. According to Wang (1999), objective and constructivist studies of authenticity are limited by the nature of attractions visited by tourists. Objective understanding thus depends on whether something can be "proven" to be authentic using specific external criteria ("scientific" criteria), while constructivist conceptions focus on how particular attractions are "staged" by tour operators (MacCannell 2013). Therefore, Wang addresses the "existential" understanding of authenticity not to the objects or attractions themselves but to the response that a particular tourism experience generates in the tourist. Existential authenticity, then, describes how tourists, by participating in tourist activities, can construct identity to experience a more authentic sense of self (Wang 1999). The concept of existential authenticity related to identify formation is important to the provision of tourism products and services, including food and beverages, because tourists try to develop an authentic sense of self through the purchase of particular products (Sims 2009).

Therefore, authenticity is a key value to feel by the tourist so that a place attachment, that is, a sense of connection between the tourist and the place, can be created.

65.2.2 Cultural Ecosystem Services (CES)

In 2005, the Millennium Ecosystem Assessment (Reid 2005) classified ecosystem services into four functional groups:

- Supply services, that is, products obtained from ecosystems, for example, food, pure water, fiber, fuel, medicine.
- Regulatory services, in those benefits, are obtained from the regulation of ecosystem processes, for example, concerning climate, water regime, pathogen action.
- Cultural services are understood as the set of nonmaterial benefits obtained from ecosystems such as spiritual, ethical, recreational, and/or aesthetic sense and social relations.
- Supporting services include services necessary for the production of all other ecosystem services, such as soil formation, nutrient cycling, and primary biomass production.

Cultural ecosystem services (CES) refer to the nonmaterial benefits that people obtain from the ecosystem and directly affect the quality of life (Plieninger et al. 2013). "Valuation" refers to the process of assessing the value of something.

CES, based on the classification and definitions provided by the Millennium Ecosystem Assessment, are listed as follows: cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation, and ecotourism.

In particular, several studies (Cheng et al. 2009; Daniel et al. 2012; Plieninger et al. 2015; Schirpke et al. 2020) note that CES are essential tools, should one wish to assess the trends of a given tourist destination and/or a given place characterized by a distinct cultural connotation. They allow qualitative and/or quantitative assessments to be made through the analysis of the indicators that characterize each CES.

65.3 Materials and Methods

To define the cultural heritage of the Alagna Valsesia destination, the study investigated and evaluated the existing offerings. The first step of this activity was oriented to a statistical analysis of the (1) tourist data of Alagna Valsesia, (2) tourist itineraries and services already offered, and (3) local literature review and documents dedicated to the explanation and the storytelling of the territory.

The second step was oriented to identify the local authenticity of the destination and the CES (see also Sect. 65.2). Additionally, in this case, the literature review was used to focus on the main elements of the Alagna Valsesia destination. Each CES identified was investigated with a multiapproach method, that is, analysis of Google and TripAdvisor reviews, survey dedicated to tourists through socials, materials, and documents (only for artifact and products and landscape), UNWTO indicators analysis (only for artifact and products and landscape), tools (De.CO.; Walser Museum; Protected areas), survey dedicated to local operators (only food and wine) (see Fig. 65.1). The two-step method was used to define three different solutions to improve the Alagna Valsesia offer as a tourist destination.

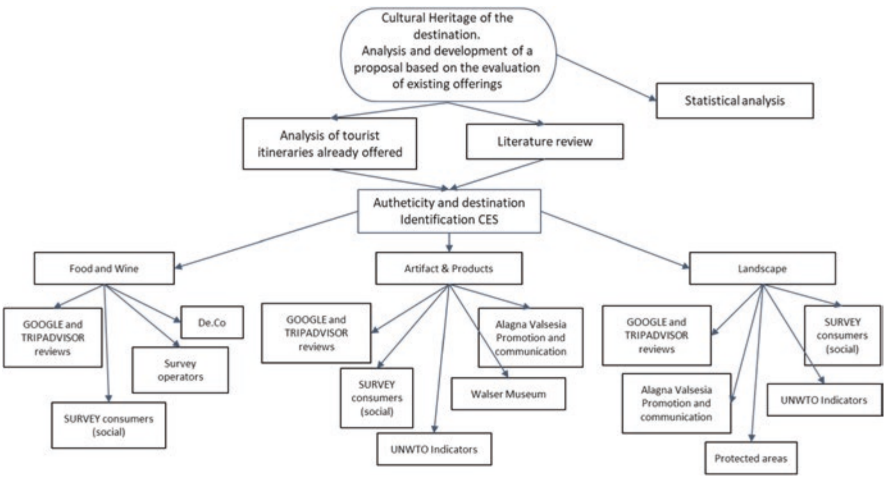

Fig. 65.1 Flowchart of the method used; *CES* cultural ecosystem services

65.4 Results and Conclusions

Based on the analysis of materials dedicated to the territorial literature and local documents provided, Alagna Valsesia is a tourist destination with a cultural vocation, specifically expressed by the presence of a Walser colony.

Moreover, the analysis of the activities and attractions present in the destination and related bibliography allows the identification of three different key areas (see Fig. 65.1), that is, food and wine, artifact and products, and landscape, in line with other studies (Sidali et al. 2015; Lee et al. 2016; Beltramo et al. 2020, 2021; Bonadonna et al. 2020).

Overall, the study suggests the creation of a system of evaluation and visual identification of the contents of the proposed tourist routes in the territory of Alagna Valsesia. In addition, the analysis carried out will lead to the identification of some route proposals that are not currently implemented in light of the changes that have occurred in the last period (e.g., the establishment of the De.CO. Alagna Valsesia). Furthermore, the final objective is oriented to the implementation of an evaluation system of the services of the Alagna Valsesia territory regarding the three magnitudes (food and wine, artifact and products, and landscape), allowing easy identification in conjunction with tourist routes through iconized visual communication.

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Appendix

List of the 29 Commodity Science congresses that were held from 1962 to 2020; the 30th was held in March 2022 whose proceedings are contained in this Springer volume.

1962	"Convegno sul tema: Progresso tecnologico e miglioramento della qualità", Bari, 12–13 settembre 1962. Atti in: Quaderni di Merceologia (Bari), 1, 1, Bari, Editore Cressati
1963	"Secondo convegno nazionale sulla Qualità", Roma, 27–28 maggio 1963. A cura del prof. Elvio Cianetti. Riassunti delle relazioni e comunicazioni in: Rassegna Chimica, 15, (3), 127132 (maggio.-giugno 1963)
1964	"III Convegno sulla Qualità, Perugia, 25–27 maggio 1964". "Atti del III Convegno sulla qualità", Istituto di Merceologia, Università di Perugia, 1964
1965	"Convegno nazionale della Qualità, Trieste 11–12 settembre 1965". "Atti del I convegno regionale dell'alimentazione e del IV Convegno Nazionale della Qualità", Regione Autonoma Friuli-Venezia Giulia, Assessorato dell'Igiene e della Sanità, Trieste, 1965
1966	"V Convegno della qualità, Messina, 10–12 settembre 1966", Atti in: "Annali della Facoltà di Economia e commercio di Messina, IV, (2), 1966
1967	"VI Congresso della Qualità, Genova, 11–13 settembre 1967. Atti del VI Convegno della Qualità, Istituto di Merceologia Università degli Studi, Genova
1971	VII Convegno internazionale della Qualità, "Difesa dei beni naturali e valorizzazione della produzione", Cagliari-Sassari 17–22 maggio 1971, "Atti del VII Convegno Internazionale della Qualità", Istituto di Merceologia, Università di Cagliari, 1971
1976	VIII Convegno sulla qualità Perugia, 11–13 ottobre 1976. Atti in: "Annali della Facoltà di Economia e Commercio dell'Università degli studi di Perugia", N.S., n. 3, Anno Accademico 1975–76, Perugia

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1977 IX Congresso di Merceologia sul tema: "I contributi della Merceologia alla risoluzione dei problemi tecnici, economici e sociali", Bologna, 30 settembre – 1ottobre 1977. Atti in: Quaderni di Merceologia (Bologna), 16, (III), settembre dicembre 1977, Clueb, Bologna

1982 X Congresso Nazionale di Merceologia sul tema: "Classificazione e caratterizzazione delle merci", Palermo, 14–17 ottobre 1982. Atti in: Atti del X Congresso Nazionale di Merceologia, Università degli Studi di Palermo, 1982

1984 XI Congresso Nazionale di Merceologia sul tema: "Ruolo della merceologia nell'ambito dello sviluppo tecnologico", Napoli, 2–5 ottobre 1984, Miccoli Editore, Napoli, 1984

1986 XII Congresso Nazionale di Merceologia sul tema: "Contributo delle Scienze Merceologiche allo sviluppo delle regioni", Torino, 22–25 settembre 1986, Atti del XII Congresso Nazionale di Merceologia, Istituto di Merceologia e Università di Torino, 1986

1988 XIII Congresso Nazionale di Merceologia sul tema: "Le merci.: produzione, distribuzione, consumo ed impatto ambientale", Messina – Taormina, 10 – 13 ottobre 1988, Istituto di Merceologia – Facoltà di Economia e Commercio, Università di Messina

1990 XIV Congresso Nazionale di merceologia sul tema: "Qualità e sicurezza degli alimenti nell'Europa degli anni '90", Pescara, 27 – 30 settembre 1990

1992 XV Congresso di Merceologia (in collaborazione con S.I.M. e I.G.W.T.) sul tema: "Libera circolazione e qualità dei prodotti nel mercato unico Europeo", Roma 24 – 26 settembre 1992, Università degli Studi "La Sapienza", Istituto di Merceologia, Ed: KAPPA, Roma 1994

1994 XVI Congresso Nazionale di Merceologia sul tema: "Innovazioni tecnologiche, qualità e ambiente", Pavia, 1 – 3 settembre 1994, Atti del XVI Congresso Nazionale di Merceologia, Università degli Studi di Pavia e Società Italiana di Merceologia, Pragma, Pavia, 1994

1996 XVII Congresso Nazionale di Merceologia sul tema: "Merci e cicli produttivi nel settore agroindustriale alle soglie del 21° secolo", Atti del XVII Congresso Nazionale di merceologia. Lecce 3 – 5 ottobre 1996, Adriatica Salentina, Lecce, 1996

1998 XVIII Congresso Nazionale di Merceologia sul tema "Qualità verso il 2000. Contributi dalla Scienza Merceologica", Verona, 1–3 ottobre 1998, Atti del XVIII Congresso nazionale di Merceologia, Università degli Studi di Verona – SIM, Verona 1998

2000 XIX Congresso Nazionale di Merceologia sul tema "La sfida per il terzo millennio: tecnologia, innovazione, qualità e ambiente" Sassari-Alghero, 27–29 settembre 2000

2002 XX Congresso Nazionale di Merceologia, Euroconference on University and Enterprise" - Università "La Sapienza" di Roma, 26 - 28 settembre 2002

2004 XXI Congresso Nazionale di Merceologia sul tema "Risorse naturali e sviluppo economico sociale. Contributi delle scienze merceologiche", Foggia, 22–24 settembre 2004

2006 XXII Congresso Nazionale delle Scienze Merceologiche: “La qualità dei prodotti per la competitività delle imprese e la tutela dei consumatori”, Roma, Università Roma Tre, 2–4 marzo 2006

2007 XXIII Congresso Nazionale delle Scienze Merceologiche sul tema: “Qualità, ambiente e valorizzazione delle risorse territoriali”, Atti del Convegno, Fossanova – Terracina – Fondi, 26–28 settembre 2007

2009 XXIV Congresso Nazionale delle Scienze Merceologiche sul tema: “Ambiente, Internazionalizzazione, Sistemi, Merci, Energia”, Torino–Alba, 23–25 giugno 2009

2011 XXV Congresso nazionale di Scienze Merceologiche sul tema “Contributo delle scienze Merceologiche per un mondo sostenibile”. Trieste-Udine, 26–28 settembre 2011

2014 XXVI Congresso Nazionale di Scienze Merceologiche sul tema “Innovazione, Sostenibilità e Tutela dei Consumatori: L’Evoluzione delle Scienze Merceologiche per la Creazione di Valore e Competitività, 13–15 febbraio 2014

2016 XXVII Congresso Nazionale di Scienze Merceologiche “Qualità & Innovazione per una Economia Circolare ed un Futuro Sostenibile”. Viterbo 2–4 marzo 2016

2018 XXVIII Congresso Nazionale di Scienze Merceologiche Firenze 21–23 febbraio

2020 XXIX Congresso Nazionale di Scienze Merceologiche- Le scienze merceologiche nell’era 4.0 Salerno 13–14 febbraio