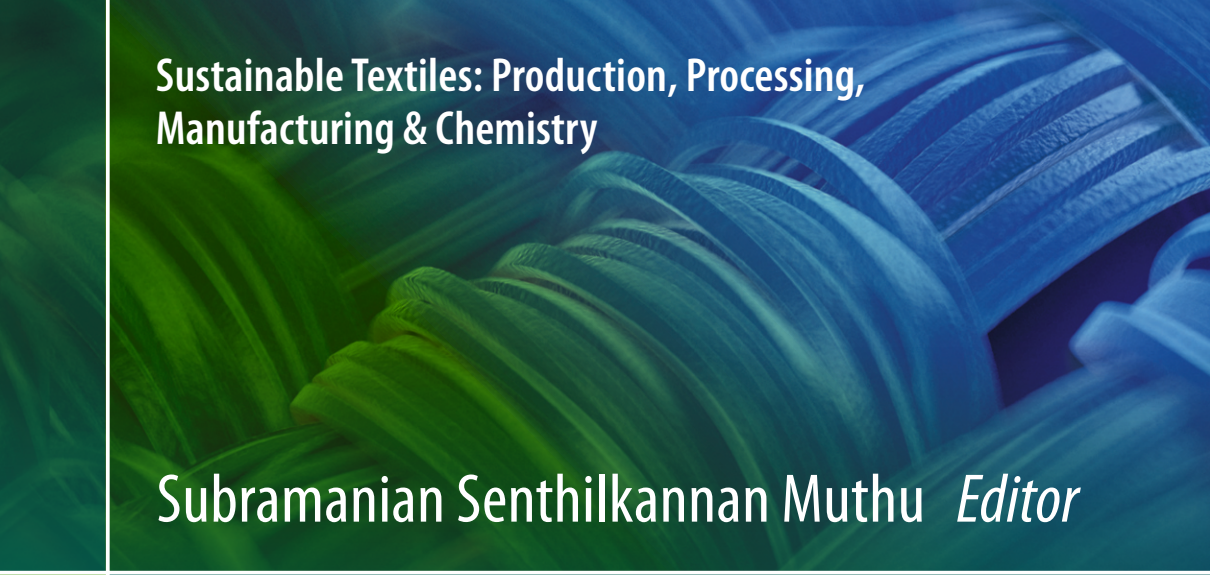

Sustainable Textiles: Production, Processing, Manufacturing & Chemistry

Subramanian Senthilkannan Muthu *Editor*

Consumer Awareness and Textile Sustainability

Springer

Sustainable Textiles: Production, Processing, Manufacturing & Chemistry

Series Editor
Subramanian Senthilkannan Muthu, Chief Sustainability Officer,
Green Story Inc., Canada

This series aims to address all issues related to sustainability through the lifecycles of textiles from manufacturing to consumer behavior through sustainable disposal. Potential topics include but are not limited to: Environmental Footprints of Textile manufacturing; Environmental Life Cycle Assessment of Textile production; Environmental impact models of Textiles and Clothing Supply Chain; Clothing Supply Chain Sustainability; Carbon, energy and water footprints of textile products and in the clothing manufacturing chain; Functional life and reusability of textile products; Biodegradable textile products and the assessment of biodegradability; Waste management in textile industry; Pollution abatement in textile sector; Recycled textile materials and the evaluation of recycling; Consumer behavior in Sustainable Textiles; Eco-design in Clothing & Apparels; Sustainable polymers & fibers in Textiles; Sustainable waste water treatments in Textile manufacturing; Sustainable Textile Chemicals in Textile manufacturing. Innovative fibres, processes, methods and technologies for Sustainable textiles; Development of sustainable, eco-friendly textile products and processes; Environmental standards for textile industry; Modelling of environmental impacts of textile products; Green Chemistry, clean technology and their applications to textiles and clothing sector; Eco-production of Apparels, Energy and Water Efficient textiles. Sustainable Smart textiles & polymers, Sustainable Nano fibers and Textiles; Sustainable Innovations in Textile Chemistry & Manufacturing; Circular Economy, Advances in Sustainable Textiles Manufacturing; Sustainable Luxury & Craftsmanship; Zero Waste Textiles.

Subramanian Senthilkannan Muthu
Editor

Consumer Awareness and Textile Sustainability

Springer

Editor
Subramanian Senthilkannan Muthu
Chief Sustainability Officer
Green Story Inc.
Kowloon, Hong Kong

ISSN 2662-7108 ISSN 2662-7116 (electronic)
Sustainable Textiles: Production, Processing, Manufacturing & Chemistry
ISBN 978-3-031-43878-3 ISBN 978-3-031-43879-0 (eBook)
https://doi.org/10.1007/978-3-031-43879-0

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

This book is dedicated to:
The lotus feet of my beloved Lord Pazhaniandavar

My beloved late Father
My beloved Mother
My beloved Wife Karpagam and Daughters – Anu and Karthika
My beloved Brother

Last but not least
To all well-informed textile consumers who help to make textile sector sustainable

Preface

This book is intended to revolve around an important topic, i.e., consumer awareness, in the textile sustainability domain. It goes without saying that consumers play an important role in making any sector sustainable including textiles and clothing. Depending on the type of product, consumer's role in deciphering the life cycle environmental impacts of a textile product will vary in the consumer phase of a textile product, which is use and disposal phases. Making consumers aware of sustainability in terms of choices of purchases, use and disposal behavior, and so on is the key to make the product as well as the entire sector sustainable. This book deals around consumer awareness and textile sustainability, and it disseminates a lot of important information on this important topic with the aid of six chapters written by qualified practitioners. I am blessed to get the wonderful authors to contribute these carefully selected six chapters to talk about this very timely topic in the textile sustainability space.

I take this opportunity to thank all the contributors for their earnest efforts to bring out this book successfully. I am sure readers of this book will find it very useful.

With best wishes,

Kowloon, Hong Kong — Subramanian Senthilkannan Muthu

Contents

Measuring Textile (Un)sustainability to Raise Purchasing Choices Awareness: Theoretical Background

Maria Pia Spinelli, Giovanni Lagioia, Christian Bux, and Vera Amicarelli

Abstract The textile industry is ranked amongst the top four sectors, which impact to the environment the most, and the European Union has enacted several strategies to strengthen competitiveness, sustainability, and resilience of the sector by promoting circular economy. On the global scale, the textile sector generates over 1,715 million tons of waste. In Europe, the clothing consumption has been estimated at 26 kg per person, and their environmental impacts have been evaluated at 650 kg of CO_2eq per consumer. Considering the importance of measuring macro-level material flows to assess the sustainability of a consumption model and raise awareness on consumers' purchasing choices, the present chapter deals with the unsustainable production and consumption of textiles in the European Union highlighting the lack of effective schemes aimed at recording material flows in the textile and clothing market to assess their potential effect on the environment. Under the managerial perspective, the chapter highlights the main challenges to improve the sustainability and the circularity of the textile sector, discussing the adoption of measuring and assessment tools for more sustainable production processes and the enhancement of circular economy actions in Europe. Under the theoretical perspective, common European recommendations must tackle the linear economy paradigm and the fast fashion by encouraging and providing schemes and tools for the tracking and traceability of the textile supply chains.

Keywords Textile industry · Circular economy · Material flow analysis · Life cycle assessment · Environmental sustainability

M. P. Spinelli · G. Lagioia · C. Bux · V. Amicarelli (✉)
Department of Economics, Management and Business Law, University of Bari Aldo Moro – Largo Abbazia Santa Scolastica, Bari, Italy
e-mail: maria.spinelli@uniba.it; giovanni.lagioia@uniba.it; christian.bux@uniba.it; vera.amicarelli@uniba.it

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0_1

1 Introduction

The textile and clothing industry has a complex value chain and covers a wide range of products. The main processes occurring are fibre production, spinning, weaving, or knitting, coloration, finishing, and manufacturing of made-up articles such as cloths (e.g. underwear, outerwear), furnishing and home textiles (e.g. curtains, carpets, bed linen), and industrial and technical textiles (e.g. ropes and nettings, parachutes, medical textiles, synthetic grass, sunblind, smart textiles) (EURATEX, 2022). Textile fibres can be distinguished into natural and man-made fibres and classified according to their chemical nature. As regards natural fibres, they refer to vegetable, animal, and mineral fibres. Vegetable fibres include bast, leaf, and seeds fibres, which are worth mentioning flax, jute, hemp, and cotton; animal fibres comprehend silk, wool, and other hair fibres like cashmere; whilst mineral fibres refer to asbestos (Mather & Wardman, 2015). Concerning man-made fibres, they relate to natural polymer, synthetic, and inorganic fibres. Natural polymers are cellulose rayon (e.g. viscose and modal), cellulose esters, and others like PLA (polylactic acid); synthetic fibres are many and include polyester, polyvinyl derivates, Teflon, nylon, polyolefin, and elastane; lastly, inorganic fibres are glass, carbon, and metal fibres (Mather & Wardman, 2015). On the global scale, polyester is the most produced fibre in 2019 (60 Mt. per year), followed by cotton (25 Mt.), whereas wool (1 Mt.) and silk (0.16 Mt.) are less consumed. Other synthetic fibres and polyamide record approx. 6.4 Mt. and 5.6 Mt. (Textile Exchange, 2020).

Several supply chain stages must be considered from the production of fibres to the consumption of finished products. When talking about spinning, it can be referred to polymer extrusion (melt spinning, wet spinning, and dry spinning), or to the conversion of staple fibres and filaments into yarns (twisting) (Lawrence, 2010). Based on the required performance, textile fabrics can mostly be manufactured through weaving and knitting or be nonwoven. Woven fabrics are characterised by two-dimensional or three-dimensional perpendicular interlacements of yarns, whereas in knitted fabrics, yarns are interloped in the horizontal (weft knitting) or vertical (warp knitting) way. On the contrary, nonwoven fabrics do not use yarns but are formed by bonding fibres through mechanical, chemical, thermal, or solvent processes. Woven and nonwoven fabrics have numerous applications and are produced for high-performance industrial and technical textiles, as well as for apparel and household products, whereas knitting fabrics are stretchable and ideal for garment production (Gong, 2018). Other subsequent processes are aimed at giving physical and aesthetic properties to the fabric by mechanical and chemical treatments (e.g. bleaching, mercerising, dyeing and/or printing, sanforising) and make it suitable for its end use (Bullon et al., 2017).

Resources and substances used during these value chain stages raise concerns about the negative influence on the environment and people well-being. Indeed, the textile industry represents the fourth most impacting business after food, housing, and transportation at the global level (European Environmental Agency, 2019). Under the environmental perspective, it is estimated that the clothing sector, which

represents 65% of textiles production, consumes more than 80 billion m^3 of water and generates over 1,715 Mt. of CO_2eq worldwide, whereas the amount of its waste has been assessed at 90 Mt. each year (Uddin, 2019; European Parliament, 2020). Considering a business-as-usual scenario, the quantity of textile waste is presumed to increase by 46%, reaching more than 134 Mt. by 2030 (European Parliament, 2019). In Europe, the latest statistics (European Parliament, 2020) illustrate that a single consumer purchase approx. 26 kg of textiles each year, which correspond to 654 kg of CO_2eq emissions for each person. In the field of textile waste management, it is roughly calculated that over 37% of textiles are separate collected, but still 35% are incinerated with energy recovery and 28% landfilled (Watson et al., 2018, 2020). Specifically, out of the European countries, Germany shows the highest separate collection rate (75%), whilst the Netherlands and Denmark go behind (45% and 43%, respectively) (Watson et al., 2020).

In published literature, several authors (Amicarelli et al., 2022) examined the environmental impacts related to fibres, yarns, and fabric production by the life cycle assessment (LCA), which represents a standardised method (ISO 14040:2006) to evaluate the environmental impacts associated with the product life cycle and which at current is intended as one of the most promising tools to prioritise improvements towards increasing the environmental sustainability of textiles (Muralikrishna & Manickam, 2017). The application of the LCA methodology in the textile industry helps both tackling the production-consumption-disposal model and supporting circular economy strategies by highlighting the main hotspots under the environmental perspective (Wiedemann et al., 2021; Liu et al., 2020; Zhang et al., 2015). From these studies, it emerges that the textile industry is still more oriented towards the linear economy than to the circular one. Indeed, in recent years, public authorities have developed and promoted different strategies to pursue sustainability in the textile industry worldwide. Even in the 17 Sustainable Development Goals (SDGs), the United Nations promote sustainable production and consumption to achieve the zero waste in the textile sector (United Nations, 2019; Li et al., 2021).

Considering the premises above, the present chapter deals with the environmental sustainability of the textile sector in Europe. In particular, the chapter intends to highlight the main challenges to measure and improve the sustainability of the textile sector, discussing the lack of useful schemes for recording the material flows linked to the textile and clothing market and raising awareness towards the adoption of circular economy strategies and better purchasing choices.

2 Key Facts About the Textile Sector

2.1 Textiles and Clothing Market

In the global economy, the textile and clothing sector plays a leading role, being intrinsically linked to the needs of an ever-growing global population. Recent events severely hit the economies of the world countries, but despite the widespread

fragmentation of supply chains, the markets reacted differently. Apparently, during the Covid-19 emergency, there was a decrease in market size due to disruptions in global supply chains, including those of textile and clothing products (Statista, 2021). Nevertheless, in 2020, textile and clothing items represented the world's seventh most traded product with a total value of 779 billion USD (OEC, 2023), maybe due to personal protective equipment demand (WTO, 2022). Textiles maintained high values and reached a relatively low growth (+7%) during the years of the post-pandemic recovery, while clothes saw an increase of more than 20% in exports (WTO, 2022). Today, roughly half of the textile and clothing market value refers to the clothing (outerwear, underwear, workwear, and accessories) production and trade, followed in the order by fabrics, industrial and technical textiles, home textiles, and yarns (EURATEX, 2020).

The clothing industry has approx. 95,000 companies operating in the European Union (EU) during 2021, showing a decrease compared to previous years (Statista, 2023a). Although the textile and clothing sector plays a relevant role in the European economy, it is predominantly based on small businesses (European Union, 1995–2023a). Many companies outsource production to cheaper locations, with 60% of clothing value produced elsewhere (European Commission, 2020a; Statista, 2023b). This involves a decrease in domestic production and a significant increase in imports from the producing countries. According to the latest statistics, the bigger exporter of textile and clothing items is China, whilst the larger importer are the United States, confirming the trends from previous years (WTO, 2022; EURATEX, 2022). During the pandemic, China experienced growth thanks to the PPE (personal protective equipment) textile trade, but a slight decrease after the emergency was over, leaving India marking a new trend with an increase in its exports by almost 50% (WTO, 2022). So that, developing countries like China, India, Bangladesh, Vietnam, and Turkey are gaining market shares to the detriment of developed countries (USA and Europe) which in recent decades were leaders in exports.

This leads to reflections of an economic, environmental, and social nature, since the growing market demand of developed countries determines an increase of the negative impacts in developing countries, where the production is mainly localised. In the period from 2000 to 2015, the production of clothes doubled to 100 billion units, whilst their utilization rate (indicating how many times a garment is used during its life cycle) dropped by 36%, meaning that more than a half of produced clothes do not last even a year. Moreover, it has been estimated that less than 1% of material is reused in new production processes corresponding to an associated value loss equal to 500 billion USD in the same observed period (Ellen MacArthur Foundation, 2017). The so-called fast fashion market has a size valued at 12,000 million USD in 2021, which will be increasingly linked to the demand for affordable clothing by youth population but also developing countries (Verified Market Research, 2022). Therefore, these growing trade flows of low-quality textiles and clothes cause alarming rates of resource consumption, emissions, and waste production, which need to be addressed urgently.

2.2 Textiles and Clothing Legislative Framework

Textiles and clothing fall into the scope of many legislations (European Union, 1995–2023b). Specific EU regulations related to textiles detail the rules concerning names, composition, and labelling (European Union, 1998–2023). As far as environmental aspects are concerned, EU Ecolabel standards and Green Public Procurement criteria for textile items are established (European Commission, 2014; European Union, 2017).

To date, the only binding measures on the topic 'textiles and sustainability' are essentially related to (i) the separate collection, launched with the Waste Framework Directive of 30th May 2018, and which must be ensured by the Member States by 2025; and (ii) the new legal norm to comply with targets regarding over 20 pollutants responsible for emissions to air and water, together with a chemical management strategy for the substitution of hazardous and harmful chemicals, both adopted under the Industrial Emissions Directive of 20th December 2022 (European Union, 1995–2023c). However, coherently with the recent Circular Economy Action Plan (European Commission, 2020a), the European Green Deal (European Commission, 2019), the Chemicals Strategy for Sustainability (European Commission, 2020b), and the Industrial Strategy (European Commission, 2020c), the EU is going to move towards greater sustainability in the textile sector. To this end, the sector is included amongst the 14 industrial ecosystems to be monitored through an annual analysis of the state of the market (European Commission, 2020c). Further, on 30th March 2022, the European Commission published a Strategy for Sustainable and Circular Textiles (European Commission, 2022a). Specifically, an action plan was stated with the aim to guide organisations in switching to more sustainable pathways. By 2030, the new policy is intended to pursue a production that allows to put on the European market safe, high-quality, durable, recycled, and recyclable textiles.

The key measures to achieve such goals basically concern the application of a new product framework and the implementation of regulations to provide incentives and support to the industry. As stated in the document, the EU has planned to (i) launch mandatory eco-design requirements, (ii) stop destroying the textiles not sold or returned, (iii) tackle the pollution caused by microplastics, (iv) introduce information requirements and a digital passport for products, (v) ensure green claims for the textiles that are truthfully sustainable, and (vi) institute extended producer responsibility and boost reuse and recycling of textile waste. Moreover, to accomplish that, the European Commission declares that enabling conditions must be created through (i) launching a transition pathway; (ii) implementing measures to reverse the overproduction and overconsumption; (iii) guarantee fair competition and accordance to guidelines for a well-operating internal market; (iv) promote innovation, research, and investments; and (v) spread the skills required by the green and digital transitions. The main limitation of this document is that it is configured more as a vision than a strategy. Whereas the principles, values, and aspirations that will guide the actions of the EU are illustrated, no measures aimed at setting up and coordinating these actions are mentioned. In addition, the EU

strategy for textile guidance is focused on the implementation of circular business models applied to production, consumption, and waste management, completely ignoring all those aspects related to measuring and evaluating the sustainability of products, processes, and supply chains through the application of recognised assessment tools like the Material Flow Analysis (MFA) and the LCA. The only references to the development of science-based assessment tools for eco-design can be found in the regulation proposal of 30th March 2022 which establish a framework for the eco-design requisites (European Commission, 2022b) and in the Green Claim Initiative which will require companies to make claims reliable, comparable, and verifiable by using standard methods for quantifying their footprint (European Union, 1995–2023d).

3 Circular Economy and Sustainability

Circular business models could mitigate the environmental impacts. Contrary to the linear economic model, linked to the paradigm 'take-make-use-dispose', the circular one decouples revenues from virgin resource use, because materials keep flowing in a closed system economy, also preventing pollution and waste generation (Ellen MacArthur Foundation, 2021). The conventional circular economy concept, also referred to the 3R framework, which stands for 'reduce', 'reuse', and 'recycle', has gained growing attention. So that, more 'R' concepts have been introduced (Ang et al., 2021), giving shape to a hierarchy of strategies regarding smarter product use and manufacturing, extended lifespan, and functional use of materials, as follow: 'refuse', 'rethink', 'reduce', 'reuse', 'repair', 'refurbish', 'remanufacture', 'repurpose', 'recycle', and 'recover' (Kirchherr et al., 2017).

Looking at the textile industry, they result in four business models that should guide the transition of this sector towards more sustainable pathways: repair, remaking, rental, and resale (Ellen MacArthur Foundation, 2021). *Repair* allows bringing back to a good condition broken items instead of buying new also by brand programs; *remaking* at different levels can transform products or single components to adapt for the same use or for a different purpose; *rental* is intended both by private owners and platforms or brands; and *resale* mainly refers to selling and purchase of second-hand products in stores, marketplaces or through take-back programs (Ellen MacArthur Foundation, 2021). Apart from the potential of these circular strategies, it must be highlighted that there is no unequivocal relationship between circular design and reduction of environmental burdens. A product inspired by the circular economy principles should impact less to the environment compared to its conventional competitor; however, more users per product or recovering secondary raw materials may not generate benefits for the environment. There are critical issues related to handling and transformation of materials, as well as to the functionality and durability of the redesigned products and the effectiveness of new consumption models. For example, textile recycling and remanufacturing can prove challenging for items made with mixed fibres, which are difficult to classify and separate, as

well as for those made from cotton fibres, which cannot be used without adding virgin cotton for new textile production and may result in products of lower quality and durability (Jia et al., 2020; Johnson et al., 2020). Likewise, collaborative consumption (i.e. rental, lease) can have rebound effects resulting in an extra consumption of clothes, which also implies additional transportation and care practices (Iran & Schrader, 2017).

It results that the circular economy strategies will never be effective if the enabling conditions are not created, such as designing high-quality products made to be repaired, disassembled, and recycled, creating supply networks to circulate the materials, and rethinking consumer experience (Ellen MacArthur Foundation, 2021). To then be sure that the strategies implemented are successful, it is essential to use measurement and assessment tools (i.e. MFA, LCA) that allow the identification of a net benefit for the environment. These tools are important not only at the micro-level and meso-level to support product redesign but also at the macro-level when considering the need to track and trace the products and materials circulating in a broader system with the aim to foster the sustainability of processes. First, detailed information about the amount of material entering, being stored, and leaving a system during a defined period of time and within a defined space is the basis to assess or improve the circularity through recycling and reuse practices (Corona et al., 2019), considering the quantity and losses related to renewable, virgin, and recycled materials (Elia et al., 2017). Secondly, to prioritise sustainable solutions based on evidence, evaluations from a life cycle perspective are needed, since implementing CE practices doesn't necessarily generate a benefit for the environment. Indeed, according to Sandin and Peters (2018), reuse and recycling are preferable to landfilling or incineration, but the benefits can be deleted if replacement rates are low. In this context, the quantity of materials stored in the system is an essential parameter to consider, as to determine the long-lasting of textiles.

4 Measuring and Monitoring Sustainability

4.1 Material Flow Analysis (MFA) and Life Cycle Assessment (LCA) Methodologies

Under the empirical perspective, amongst the challenges to address climate change, minimise waste generation, and extend the life cycle of products is data collection and analysis. Monitoring the levels of waste and emission generation within a system through the application of different tools is essential. Latest technical specifications, such as the UNI/TS 11820:2022 (UNI, 2022; Amicarelli & Bux, 2023), refer to inventory methodologies (i.e. MFA) and environmental impact assessment methodologies (i.e. LCA), highlighting their essential role in helping to lower the amount of waste and emissions and to adopt sustainable valorisation pathways amongst consumers.

In the field of the inventory methodologies, as outlined by Brunner and Rechberger (2017), the MFA represents a 'systematic assessment of the state and change of material flow and stock in space and time' and is currently considered as an essential tool, both in resource and waste management. The MFA is based on the principle of conservation of mass, and its goals are related to (i) the analysis of the conditional features of a metabolic system in space and time through the selection of the pertinent processes, the main material flows, and the indicative stocks; (ii) the analysis of the quantitative features of flows, processes, and stocks within a system; (iii) the analysis of the metabolic system over time, exploring past trends and predicting future opportunities related to resource consumption and waste generation.

As regards the environmental impact assessment methodologies, the LCA is one of the most used tools to assess the environmental impacts associated with products and processes. Different from the MFA, which has never been standardised but it is considered as an essential basis for conducting circularity or sustainability assessments (e.g. ISO 14051:2011, UNI/TS 11820: 2022), the LCA has been introduced as a standardised method by the ISO 14040:2006. Specifically, the ISO 14040:2004 defines the principles and the framework for conducting the life cycle assessment, including the description of the goal and scope, the life cycle inventory (LCI), the life cycle impact assessment (LCIA), and the interpretation of results. According to its definition, which states that the LCA 'is a compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle', such a method represents an appropriate tool to look into the environmental hotspots, as well as the environmental opportunities, at scientific and corporate level (Sala et al., 2016). In practice, there are limitations to the use of this tool, especially related to modeling choices; however, it has a strong potential towards circular and sustainable design, even in the face of the development of a pragmatic framework called Life Cycle Sustainability Assessment (LCSA) that allows to investigate all the three pillars of sustainability, incorporating also life cycle costing (LCC), and social life cycle assessment (S-LCA) (Valdivia et al., 2021).

4.2 Macro-Level Flow Estimation

As already stated, to enhance material and product circularisation, it is essential to have prior knowledge about the quantity, quality, and timing of materials and products within a given system (Franco, 2017). In this context, Information and Communication Technologies (ICT) can be useful (i.e. common identifiers combined with sensors and supported by Internet of Things) (Jia et al., 2020) at both micro-level and macro-level for product redesign and to evaluate the environmental sustainability from a system perspective. Indeed, to raise awareness on the environmental effects of consumption models and develop improvement strategies,

environmental assessments should analyse the impacts of products and processes from a system perspective and not through isolated evaluations (Onat et al., 2017). However, in the literature, there is a paucity of studies regarding macro-level measurements to support policymakers' decisions (Guarnieri et al., 2023), and to date, no scheme is aimed at this purpose (Jia et al., 2020). Also, the latest technical standard UNI/TS 11820:2022 on 'Measurement of Circularity—Methods and Indicators for Measuring Circular Processes in Organizations' introduces a set of 71 indicators to be calculated both at micro- and meso-level, without providing an original and novel support for the macro-level, which still represents a challenge (Amicarelli & Bux, 2023).

In an attempt to evaluate the natural resource consumption, the waste generation and the environmental impacts at the macro-level, national statistics on production and trade can be used, as already reported in several studies on the accounting of textile flows by the European Commission Joint Research Centre (JRC) (Beton et al., 2014; Köhler et al., 2021). The community scheme ProdCom details national production and trade data information on an annual basis at EU level, considering both commodities and services. These statistics are compiled through a community survey based on ProdCom list, which reports product codes and descriptions. The products in the ProdCom list refer to an 8-digit code, where the first four digits designate the statistical classification of economic activities in the European community (NACE classification), whilst digits 5 and 6 are taken from the statistical classification of products by activity (CPA classification). Most codes refer to the combined nomenclature (CN) which connects the harmonised system (HS) at the international level, allowing a full comparability with data from foreign trade. Enterprises of the member states have to transmit true and complete information to Eurostat under the European Business Statistics (EBS) regulation, though some data can be confidential and therefore are processed according to the Statistical Law (European Union, 2022). This means that they shall be used for calculating the EU totals only, with EU aggregates rounded. In addition, some data might be missing or have low reliability. Data is freely accessible online through Eurostat's website, within the database 'statistics on the production of manufactured goods (prom)'.[1] Specifically, a drop-down menu allows access to ProdCom data sets, which provide data on total production, sold production, exports, and imports, and Comext data sets, which combine access to international trade and ProdCom data. The national production data comprises the total production and the sold production, the former referred to both the production sold, and the production reused as input to other manufacturing processes. From this data are excluded the productions done outside the national territory from enterprises with plants abroad. As regards trade data, only that relating to sold production is included in ProdCom data sets, whereas detailed statistics are available in Comext (European Union, 2022).

[1] http://ec.europa.eu/eurostat/web/prodcom/data/database

One of the main limits related to the ProdCom and the Comext data sets is that production data may not be aligned with trade data; thus, this heterogeneity can make data integration difficult for flow estimation purposes. In addition, aggregation codes utilised to record production and trade data do not allow to characterise the flows within multi-material products. For a more complete analysis, waste statistics data referring to waste generation, waste treatment, recovery, and disposal facilities collected under the Waste Statistics Regulation (European Union, 1995–2023e) could be integrated; however, in practice, only aggregate data relating to NACE classification codes on the manufacture of textiles, wearing apparel, leather, and related products is available.

5 Conclusions

The present chapter discussed the main challenges to improve sustainability and circularity in the textile sector in Europe highlighting the importance of measuring macro-level material flows to assess the sustainability of consumption models and raise awareness on consumers' purchasing choices. The growing trade flows of low-quality textiles and clothes cause alarming rates of resource consumption, emissions, and waste production, which need to be addressed urgently. The implementation of circular business models is considered a solution and therefore incentivised. However, there is no unequivocal relationship between circular design and reduction of environmental impact. The EU strategy for sustainable and circular textiles incentivises a production that allows to put on the European market products inspired by the circular economy principles but does not provide science-based assessment schemes to measuring and evaluating the sustainability of textile production and consumption at macro-level. Indeed, the use of measuring tools and standardised methodologies at macro-level is an essential requirement to foster the sustainability of products and processes. It is crucial to have detailed information about the amount of material flowing within a defined space and during a defined period to assess the related environmental effect and prioritise sustainable solutions based on evidence. MFA and LCA are suitable tools to address this need, but data collection of textile flows at macro-level is hindered by the lack of useful schemes and tools aimed at this purpose, leading to the use of methodological expedients that have many limits. National statistics on production and trade can be used to evaluate resource consumption, waste generation, and the related environmental impacts at macro-level by means of the community scheme ProdCom and Eurostat data sets. However, the aggregated and heterogeneous data available make the estimation of flows unreliable and thus not very effective for the purpose of estimating the environmental impacts of consumption models. Therefore, consumer choices can only be based on micro-level estimates, which can be misleading since they do not reflect the impacts along the entire life cycle of the product but stop at the production stage.

References

Amicarelli, V., & Bux, C. (2023). Users' perception of the circular economy monitoring indicators as proposed by the UNI/TS 11820:2022: Evidence from an exploratory survey. *Environments, 10*(4), 65.

Amicarelli, V., Bux, C., Spinelli, M. P., & Lagioia, G. (2022). Life cycle assessment to tackle the take-make-waste paradigm in the textiles production. *Waste Management, 151*, 10–27. https://doi.org/10.1016/j.wasman.2022.07.032

Ang, K. L., Saw, E. T., He, W., Dong, X., & Ramakrishna, S. (2021). Sustainability framework for pharmaceutical manufacturing (PM): A review of research landscape and implementation barriers for circular economy transition. *Journal of Cleaner Production, 280*, 124264.

Brunner, P. H., & Rechberger, H. (2017). *Handbook of material flow analysis. For environmental, resource and waste engineers* (2nd ed.). CRC Press.

Bullon, J., González Arrieta, M. A., Hernández Encinas, A., & Queiruga Dios, M. A. (2017). Manufacturing processes in the textile industry: Expert Systems for fabrics production. *Advances in Distributed Computing and Artificial Intelligence Journal, 6*(4), 15.

Beton, A., Dias, D., Farrant, L., Gibon, T., Le Guern, Y., Desaxce, M., et al. (2014). Environmental improvement potential of textiles (IMPRO-textiles). European Commission, 20.

Corona, B., Shen, L., Reike, D., Carreón, J. R., & Worrell, E. (2019). Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. *Resources, Conservation and Recycling, 151*, 104498. https://doi.org/10.1016/j.resconrec.2019.104498

Elia, V., Gnoni, M. G., & Tornese, F. (2017). Measuring circular economy strategies through index methods: A critical analysis. *Journal of Cleaner Production, 142*, 2741–2751. https://doi.org/10.1016/j.jclepro.2016.10.196

Ellen MacArthur Foundation. (2017). *A New textiles economy: Redesigning fashion's future*. Retrieved from https://ellenmacarthurfoundation.org/a-new-textiles-economy. Accessed 11 Apr 2023.

Ellen MacArthur Foundation. (2021). *Circular business models: Redefining growth for a thriving fashion industry*. Retrieved from https://emf.thirdlight.com/file/24/Om5sTEKOmmfEeVOm7xNOmq6S2k/Circular%20business%20models.pdf. Accessed 11 Apr 2023.

EURATEX. (2020). FACTS & KEY FIGURES OF THE EUROPEAN TEXTILE AND CLOTHING INDUSTRY. Retrieved from https://euratex.eu/wp-content/uploads/EURATEX-Facts-Key-Figures-2020-LQ.pdf. Accessed 11 Apr 2023.

EURATEX. (2022). FACTS & KEY FIGURES 2022 OF THE EUROPEAN TEXTILE AND CLOTHING INDUSTRY. Retrieved from https://euratex.eu/wp-content/uploads/EURATEX_FactsKey_Figures_2022rev-1.pdf. Accessed 23 Oct 2023

European Commission. (2014). Consolidated text: Commission Decision of 5 June 2014 establishing the ecological criteria for the award of the EU Ecolabel for textile products (notified under document C(2014) 3677) (Text with EEA relevance) (2014/350/EU) Text with EEA relevance. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02014D0350-20170727. Accessed 11 Apr 2023.

European Commission. (2019). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. The European Green Deal. COM/2019/640 final. Retreived from https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX:52019DC0640. Accessed 11 Apr 2023.

European Commission (2020a). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A new Circular Economy Action Plan For a cleaner and more competitive Europe. COM/2020/98 final. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN. Accessed 11 Apr 2023.

European Commission (2020b). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Chemicals Strategy for Sustainability Towards a Toxic-Free Environment. COM/2020/667 final. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A667%3AFIN. Accessed 11 Apr 2023.

European Commission (2020c). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. A New Industrial Strategy for Europe. COM/2020/102 final. Retrieved from https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX:52020DC0102. Accessed 11 Apr 2023.

European Commission. (2022a). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. EU Strategy for Sustainable and Circular Textiles. COM(2022) 141 final. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0141. Accessed 11 Apr 2023.

European Commission. (2022b). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. COM/2022/142 final. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022PC0142. Accessed 11 Apr 2023.

European Environmental Agency. (2019). *Textiles in Europe's circular economy*. https://www.eea.europa.eu/publications/textiles-in-europes-circular-economy. Accessed 8 Nov 2022.

European Parliament. (2019). *Environmental impact of the textile and clothing industry*. What consumers need to know. European Union, 1–10. https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2019)633143. Accesed 8 Nov 2022.

European Parliament. (2020). *The impact of textile production and waste on the environment (infographic)*. https://www.europarl.europa.eu/news/en/headlines/society/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographic. Accessed 8 Nov 2022.

European Union. (2017). *Revision of the EU Green Public Procurement (GPP) criteria for textile products and services: Technical report with final criteria*. Retrieved from https://ec.europa.eu/environment/gpp/pdf/criteria/textiles_gpp_technical_report.pdf. Accessed 11 Apr 2023.

European Union. (2022). European business statistics methodological manual for PRODCOM — 2021 edition. Retrieved from https://ec.europa.eu/eurostat/documents/3859598/14358654/KS-GQ-21-024-EN-N.pdf/f6533c1cd95a-4e65-6c43-9aad5f72187d?t=1645786507249 (accessed 11/04/2023)

European Union. (1995–2023a). *Textiles and clothing in the EU*. Retrieved from https://single-market-economy.ec.europa.eu/sectors/fashion/textiles-and-clothing-industries/textiles-and-clothing-eu_en. Accessed 11 Apr 2023.

European Union. (1995–2023b). *Other legislation related to textiles and clothing*. Retrieved from https://single-market-economy.ec.europa.eu/sectors/fashion/textiles-and-clothing-industries/legislation/other-legislation-related-textiles-and-clothing_en. Accessed 11 Apr 2023.

European Union. (1995-2023c). *New EU environmental norms to make chemical and textile industry plants greener*. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news/new-eu-environmental-norms-make-chemical-and-textile-industry-plants-greener-2023-01-13_en. Accessed 11 Apr 2023.

European Union. (1995–2023d). *Green claims*. Retrieved from https://environment.ec.europa.eu/topics/circular-economy/green-claims_en. Accessed 11 Apr 2023.

European Union. (1995–2023e). *DATABASE*. Retrieved from https://ec.europa.eu/eurostat/web/waste/data/database. Accessed 11 Apr 2023.

European Union. (1998–2023). *Textile products: Textile fibre names and labelling*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:32011R1007&qid=1621402779084. Accessed 11 Apr 2023.

Franco, M. A. (2017). Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *Journal of Cleaner Production, 168*, 833–845.

Gong, H. (2018). Fabric structures: Woven, knitted, or nonwoven. In *Engineering of high-performance textiles* (pp. 107–131). Woodhead Publishing. doi:https://doi.org/10.1016/B978-0-08-101273-4.00007-X.

Guarnieri, P., Haleem, F., Bianchini, A., Rossi, J., Wæhrens, B. V., Farooq, S., et al. (2023). How can we measure the prioritization of strategies for transitioning to a circular economy at macro level? A New Approach. *Sustainability, 15*(1), 680.

Iran, S., & Schrader, U. (2017). Collaborative fashion consumption and its environmental effects. *Journal of Fashion Marketing and Management: An International Journal, 21*(4), 468–482.

Jia, F., Yin, S., Chen, L., & Chen, X. (2020). The circular economy in the textile and apparel industry: A systematic literature review. *Journal of Cleaner Production, 259*, 120728.

Johnson, S., Echeverria, D., Venditti, R., Jameel, H., & Yao, Y. (2020). Supply chain of waste cotton recycling and reuse: A review. *AATCC Journal of Research, 7*(1_suppl), 19–31.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221–232.

Köhler, A., Watson, D., Trzepacz, S., Löw, C., Liu, R., Danneck, J., Konstantas, A., Donatello, S. & Faraca, G. (2021). Circular economy perspectives in the EU textile sector, EUR 30734 EN, publications Office of the European Union, Luxembourg, https://doi.org/10.2760/858144, JRC125110.

Lawrence, C. A. (Ed.). (2010). *Advances in yarn spinning technology*. Elsevier.

Li, X., Wang, L., & Ding, X. (2021). Textile supply chain waste management in China. *Journal of Cleaner Production, 289*, 125147. https://doi.org/10.1016/j.jclepro.2020.125147

Liu, H., Huang, H., Zhu, L., Zhang, C., Ren, F., & Liu, Z. (2020). Could the recycled yarns substitute for the virgin cotton yarn: A comparative LCA. *The International Journal of Life Cycle Assessment, 25*, 2050–2062. https://doi.org/10.1007/s11367-020-01815-8

Mather, R. R., & Wardman, R. H. (2015). *The chemistry of textile fibres*. Royal Society of Chemistry.

Muralikrishna, I. V., & Manickam, V. (2017). *Environmental management*. Butterworth-Heinemann, Elsevier, Science and Engineering for Industry.

OEC. (2023). *Textiles*. Retrieved from https://oec.world/en/profile/hs92/textiles?disaggregationButton=hs4Button. Accessed 11 Apr 2023.)

Onat, N. C., Kucukvar, M., Halog, A., & Cloutier, S. (2017). Systems thinking for life cycle sustainability assessment: A review of recent developments, applications, and future perspectives. *Sustainability, 9*(5), 706.

Sala, S., Reale, F., Cristobal-Garcia, J., Marelli, L., & Pant, R. (2016). Life cycle assessment for the impact assessment of policies. In *Life thinking and assessment in the European policies for evaluating policy options*. EUR 28380 EN, https://doi.org/10.2788/318544.

Sandin, G., & Peters, G. M. (2018). Environmental impact of textile reuse and recycling—A review. *Journal of Cleaner Production, 184*, 353–365. https://doi.org/10.1016/j.jclepro.2018.02.266

Statista. (2021). *Coronavirus: Impact on apparel and textiles in Europe*. Retrieved from https://www.statista.com/study/75595/coronavirus-impact-on-apparel-and-textile-industry-in-europe/. Accessed 11 Apr 2023.

Statista. (2023a). *Number of textile and clothing manufacturing companies in the European Union (EU28) from 2009 to 2021, by industry segment*. Retrieved from https://www.statista.com/statistics/417766/eu-european-union-textile-clothing-manufacturing-companies-by-segment. Accessed 11 Apr 2023.

Statista. (2023b). *Apparel and clothing market Europe—Statistics and facts*. Retrieved from https://www.statista.com/topics/3423/clothing-and-apparel-market-in-europe/#topicOverview. Accessed 11 Apr 2023.

Textile Exchange. (2020). *Preferred fiber & materials. Market Report* 2020. https://textileexchange.org/wp-content/uploads/2020/06/Textile-Exchange_Preferred-Fiber-Material-Market-Report_2020.pdf. Accessed 8 Nov 2022.

Uddin, F. (2019). Introductory chapter: Textile manufacturing processes. In *Textile manufacturing processes*. IntechOpen. doi:https://doi.org/10.5772/intechopen.87968.

UNI. (2022). UNI/TS 11820. Misurazione Della Circolarità—Metodi ed Indicatori per la Misurazione dei Processi Circolari Nelle Organizzazioni. Ministero dell'Ambiente e della Sicurezza Energetica: Rome, Italy, 2022.

United Nations. (2019). *ActNow for Zero-Waste Fashion*. https://www.un.org/sustainabledevelopment/blog/2019/08/actnow-for-zero-waste-fashion/. Accessed 8 Nov 2022.

Valdivia, S., Backes, J. G., Traverso, M., Sonnemann, G., Cucurachi, S., Guinée, J. B., et al. (2021). Principles for the application of life cycle sustainability assessment. *The International Journal of Life Cycle Assessment, 26*(9), 1900–1905.

Verified Market Research. (2022). *Fast fashion market size and forecast*. Retrieved from https://www.verifiedmarketresearch.com/product/fast-fashion-market/. Accessed 11 Apr 2023.

Watson, D., Trzepacz, S., & Pedersen, O. G. (2018). *Mapping of textile flows in Denmark*. Danish Environmental Protection Agency.

Watson, D., Trzepacz, S., Svendsen, N. L., Skottfelt, S. W., Kiørboe, N., Elander, M., & Nordin, H. L. (2020). *Towards 2025: Separate collection and treatment of textiles in six EU countries*. Danish Environmental Protection Agency.

Wiedemann, S. G., Biggs, L., Nguyen, Q. V., Clarke, S. J., Laitala, K., & Klepp, I. G. (2021). Reducing environmental impacts from garments through best practice garment use and care, using the example of a Merino wool sweater. *The International Journal of Life Cycle Assessment, 26*, 1188–1197. https://doi.org/10.1007/s11367-021-01909-x

WTO. (2022). *World trade statistical review.* Retrieved from https://www.wto.org/english/res_e/booksp_e/wtsr_2022_e.pdf. Accessed 11 Apr 2023.

Zhang, Y., Liu, X., Xiao, R., & Yuan, Z. (2015). Life cycle assessment of cotton T-shirts in China. *The International Journal of Life Cycle Assessment, 20*(7), 994–1004. https://doi.org/10.1007/s11367-015-0889-4

Consumers' Sustainable Clothing Consumption Practices: Adopting the Principles of Voluntary Simplicity

M. A. Olwoch, N. C. Sonnenberg, T. L. Reis, and H. Taljaard-Swart

Abstract Consumers' engagement in sustainable clothing consumption practices is a global imperative. Although various stakeholders have invested substantial effort in addressing environmental and social concerns in the clothing and textile supply chain, consumers have an equally important role to fulfil through their acquisition, use, and disposal of garments. Overconsumption of, driven by amongst others, fast fashion trends has drawn severe critique in fashion circles and has prompted pushback from several environmental and social activist groups. Increasingly, consumers are now also realising that change is needed in the way they consume fashion. Along with mounting consumer awareness, ideologies such as voluntary simplicity have grown in popularity and could in turn manifest in sustainable clothing consumption behaviour such as purchasing eco-friendly clothing, adopting ethical consumption behaviours, favouring handcrafted garments, reusing and buying second-hand clothing, reducing overall consumption, making purchases based on necessity, repurposing garments, and prioritising clothing longevity. This chapter provides a deeper understanding of these specific types of sustainable clothing consumption practices and how consumers' adoption of such practices may ultimately contribute to the broader pursuit of circularity in the fashion domain.

Keywords Sustainable practices · Clothing consumption · Voluntary simplicity · Slow fashion · Fashion circularity · Ethical buying · Handcrafted apparel · Clothing longevity

M. A. Olwoch · N. C. Sonnenberg (✉) · T. L. Reis · H. Taljaard-Swart
Department of Consumer and Food Sciences, University of Pretoria, Pretoria, South Africa
e-mail: olwochma@tut.ac.za; nadine.sonnenberg@up.ac.za; tracey.reis@up.ac.za; hanri.taljaard@up.ac.za

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0_2

1 Introduction

Excessive consumption is seen as a major culprit for the continual deterioration of the world's natural resources and increased greenhouse gas emissions. Various industry sectors are thus focused on reducing emissions and conserving natural resources, including the apparel and textile industry. However, matters are worsened by forecasts that the sector will continue to expand due to changing consumer trends (McKinsey & Company, 2021). Increased demand for inexpensive 'fast fashion' apparel has resulted in many adverse environmental and societal effects along each step of the supply chain, including the impact it has on human health and human rights (Bick et al., 2018). Fortunately, social justice and human rights concerns are getting a stronger voice in the debate over the fashion industry's urgent need to become more sustainable (McKinsey & Company, 2021).

The Covid-19 pandemic has expedited not just the pre-existing criticism of consumerism but also amplified public recognition of social injustice in the supply chain and the necessity of sustainable buying decisions (McKinsey & Company, 2021). Clothing consumption in particular has been impacted (Liu et al., 2021). Not only were consumers prompted to consume less in response to confinement but also to rethink their choices with greater attention devoted to the ecological impact of raw materials, precisely favouring those brands most sensitive to environmental and social issues (Degli Esposti et al., 2021).

Consumers are important stakeholders in the pursuit of sustainability as it is within their capacity to enact socially conscious and informed product choices (Rudell, 2006). Reduced consumption brought about by lifestyle changes is a powerful lever and the most direct method to mitigate the negative consequences of human activity (Osikominu & Bocken, 2020). Adopting sustainable ways of living is deeply entrenched in voluntary simplicity, which is described as living in a way that is outwardly simple and inwardly rich, embracing consumption frugality and a strong sense of environmental urgency (Elgin & Mitchell, 1977). A voluntary simplistic lifestyle involves, amongst others, choosing local, handcrafted, and ethical clothing alternatives and reducing clothing consumption (Taljaard & Sonnenberg, 2019). The Covid-19 pandemic might have amplified such consumption practices, which is vital in transitioning to a more sustainable society (Cinar, 2020).

With the above in mind, this chapter provides a brief review of consumers' sustainable clothing consumption practices based on the principles of voluntary simplicity. The chapter will commence with a discussion of overconsumption and the growth of fast fashion along with the associated need for circularity in the clothing and textile sector. Thereafter, the conversation will delve into various sustainable clothing consumption practices that underscore the principles of voluntary simplicity, including purchasing eco-friendly clothing, adopting ethical consumption behaviours, favouring handcrafted garments, reusing and buying second-hand clothing, reducing overall consumption, making purchases based on necessity, repurposing garments, and prioritising clothing longevity. The chapter is concluded with recommendations for future research surrounding sustainable clothing consumption practices.

2 Consequences Related to Overconsumption and Fast Fashion

Fast fashion is an extensively acknowledged concept within the clothing and textile industry, encompassing the rapid production and consumption of affordably priced yet fashionable items (Gazzola et al., 2020). It relies on cost-effective materials, cheap labour, short production cycles, and high volumes (Fletcher, 2010; Ozdamar Ertekin & Atik, 2015). However, the current fast fashion model has faced extensive criticism for encouraging overconsumption and generating excessive waste (Niinimäki et al., 2020). This approach has allowed people from all socioeconomic backgrounds to partake in the pleasures of fashion, irrespective of their class, wealth, or background (Niinimäki et al., 2020). Furthermore, clothing sales have surged in developing and emerging economies as poverty eradication efforts propel individuals into the middle-class bracket (Koszewska, 2018), paving the way for increased consumption levels. Even amidst the COVID-19 pandemic, which initially limited in-store shopping, the rise of e-commerce has sustained the industry's growth, particularly on social media platforms, which have become leading avenues for online shopping (Gao et al., 2018). In fact, sales through these platforms are projected to triple by 2025 (Keenan, 2022a, b).

Consequently, clothing and textile wastes have also witnessed a significant surge. Developing and emerging economies face particular challenges with post-consumer textile waste. As an illustration, approximately 500,000 tons of clothing, which would otherwise be destined for US landfills, is exported to lower- and middle-income countries, frequently entering the secondary market (Bick et al., 2018). However, a considerable portion of this exported clothing cannot be resold due to poor quality, leading to landfill accumulation and exacerbating environmental issues. Apart from waste, fast fashion's supply chain has drawn attention to its adverse environmental implications, spanning from raw material production to disposal. Moreover, the act of engaging in fast fashion consumption not only causes harm to the environment but also contributes to social issues such as labour exploitation, consumerism, and excessive spending (Ozdamar-Ertekin, 2016; Gwozdz et al., 2017).

In recent times, the fashion industry has encountered substantial accusations of wage theft, infringements on labour rights, and the employment of child labour (Cavusoglu & Dakhli, 2016). These exploitative practices have drawn sharp criticism from critics, who express profound outrage (Arnold & Hartman, 2006). Reports on unfavourable working conditions in the clothing manufacturing sector have intensified scrutiny of labour practices (Ellen MacArthur Foundation, 2023). 'Working conditions' generally encompass various aspects of employment, such as pay, work organisation, training, health and safety, employee well-being, and work-life balance (Arnold & Hartman, 2006). However, the shift of clothing production to low- and middle-income countries has resulted in insufficient enforcement of decent working conditions and occupational safety standards due to weak political infrastructure and organisational management (Hiba et al., 2021). The unfortunate collapse of the Rana Plaza factory in Bangladesh highlighted the precarious

working conditions and insufficient enforcement of labour rights within the garment industry (Bick et al., 2018).

Fortunately, consumers have exhibited a growing awareness of and interest in the conditions under which workers are employed in the textile and clothing manufacturing sector (Gardetti & Torres, 2013). Social media has developed as a significant facilitator in enhancing consciousness and empowering independent activists (Doesmagan, 2016). It has furnished users with a platform to amplify their voices and leverage their impact for causes that extend beyond their personal sphere (Wood, 2022). Notable platforms like the Clean Clothes Campaign and Fashion Revolution have mobilised consumers and promoted transparency within the supply chain. For instance, the Fashion Revolution's #insideout campaign, initiated in 2014, encouraged users to take selfies in their clothes and tag the brands they purchased, shedding light on unethical labour practices (Hepburn, 2015). Similar campaigns have generated significant attention and led to calls for boycotts against companies engaged in exploitative practices (Wazir, 2001, Nissen & Krampe, 2021). Although some stakeholders still promote cheap and indiscriminate clothing acquired through global sourcing channels (Henry & Mitchell, 2019), efforts to combat worker exploitation are expected to continue in response to consumer demands (McKinsey & Company, 2021). Consumers not only demand products of superior quality but also prioritise companies that demonstrate a commitment to social and environmental concerns (Moisander, 2007).

As a result, the fashion industry, including brands, designers, manufacturers, marketers, models, influencers, and consumers, is being called upon to collaborate and drive real change (Langenheim, 2023). The COVID-19 pandemic, specifically, has intensified consumer consciousness regarding social concerns and the ecological consequences associated with the apparel sector (Bilinska-Reformat & Dewalska-Opitek, 2021). Therefore, businesses must exert significant effort to enhance their reputation in these areas and transition from a linear model, where raw materials end up in landfills, to a circular model that enables continuous recycling or upcycling of materials for creating new products.

3 The Pursuit of Circularity in the Clothing and Textile Industry

The Ellen MacArthur Foundation (2023) detailed the notion of a circular economy presenting a meticulously defined methodology for tackling critical global concerns, which encompass climate change, the decline of biodiversity, the generation of waste, and the occurrence of pollution. Its primary goal is to create a regenerative system by utilising organic or renewable materials and encouraging companies to prioritise resource management (Gazzola et al., 2020). Product life cycle analysis, systems thinking, resource efficiency, and cradle-to-cradle design all form essential elements of a circular economy business model (Diddi & Yan, 2019). By embracing

this model, the fashion industry can optimise the value of clothing, textiles, and fibres throughout their life cycle and reintegrate them into the economy instead of generating waste (Ellen MacArthur Foundation, 2023). Recent years have witnessed considerable progress in the fashion industry to enhance sustainability across the entire production process and transition towards a circular fashion model in line with circular economy principles (Jacometti, 2019).

One key focus area for promoting circularity in fashion consumption is the acquisition, use, and disposal of clothing (Vladimirova et al., 2022). Consumers wield significant influence in determining the quantity, frequency, and type of clothing they purchase, as well as how they use, maintain, and ultimately discard these items when they are no longer desired or worn out (Gwozdz et al., 2017). At each stage, consumers could adopt environmentally conscious and ethical consumption habits that align with the principles of the circular economy. Social media technologies have attracted considerable attention due to their capacity to magnify environmental concerns and promote sustainable behaviours, thereby facilitating the pursuit of circularity (Sogari et al., 2017).

Sustainable fashion also referred to as 'green fashion', 'eco-fashion', 'slow fashion', and 'ethical fashion' has gained significant popularity (Khandual & Pradhan, 2019). These concepts are often used interchangeably, indicating a shared understanding of their fundamental principles and objectives (Moisander, 2007; Newholm & Shaw, 2007). Whilst there may be slight variations in emphasis or specific nuances associated with each term, they ultimately converge on the overarching goal of creating a fashion industry that operates in harmony with the planet and respects the rights and well-being of all individuals involved. In a comprehensive sense, sustainable apparel can be characterised as clothing deliberately engineered to exhibit prolonged resilience, integrating eco-certified or upcycled materials, and crafted in an ethically sound manner, potentially within regional settings, whilst upholding fair trade tenets and ensuring labour conditions free from exploitative practices. This approach aims to minimise harm to the environment and ensure fair treatment of workers (Fletcher, 2008). From a consumer perspective, reduction of overall consumption levels is paramount, but should the opportunity present itself to acquire clothing, then selecting more sustainable alternatives, with the aforementioned attributes in mind, is crucial in realising the goal of a circular fashion industry.

4 Sustainable Clothing Consumption and Associated Ideology of Voluntary Simplicity

Sustainable clothing consumption is broadly described as any effort towards relegating the detrimental consequences of apparel consumption including the acquisition of quality, durable, and longer-lasting items, showing preference in purchasing decisions for garments that are produced in an ethically and/or environmentally sound manner, acquiring less or second-hand clothing, repairing and/or finding

other means of extending the lifespan of an apparel item (Diddi et al., 2019). In their systematic review of 58 studies, Vesterinen and Syrjälä (2022) identify two dimensions linked to sustainable clothing consumption, namely, (1) sustainable acquisition (which involves buying sustainable options with pro-environmental and/or social attributes) and (2) sustainable anti-consumption (that is focused on lowering personal consumption) through the adoption of various ideologies and strategies. Of the ideologies identified in Vesterinen and Syrjälä's (2022) review, slow fashion and voluntary simplicity are the only approaches that incorporate both sustainable acquisition and anti-consumption strategies. The conceptualisation of slow fashion and voluntary simplicity is in fact closely related, in that both ideologies include aspects such as concern for local communities, appreciation for craftsmanship, as well as strategies that extend product lifespans and reduce consumption (Vesterinen & Syrjälä, 2022). However, whilst the concept of slow fashion is mainly focused on clothing consumption and finds its origins in the contribution of scholars such as Fletcher (2008, 2010) as well as Jung and Jin (2014), voluntary simplicity entails a broader lifestyle approach that extends beyond clothing consumption and has a history that dates further back to the early 1900s (Reis, 2019).

The notion of voluntary simplicity in fact initially emerged in 1936 through the work of Richard Gregg, who advocated lifestyles characterised by reduced material consumption (Rich et al., 2017), i.e. living simply without clutter (Ballantine & Creery, 2010). The notion gained further exposure in the 1970s when awareness emerged of the detrimental effects of overpopulation and the over-exploitation of natural resources, which was substantiated by prominent stakeholders including scientific scholars and United Nations representatives (Leonard-Barton, 1981). Leonard-Barton (1981) was one of the first scholars to establish voluntary simplicity as a lifestyle index based on behavioural traits that include mindful consumption (e.g. crafting by hand, repairing broken items, and buying quality goods purely based on need), supporting a 'back to basics' approach (e.g. constructing your own garments), adopting sustainable practices (e.g. reselling and/or recycling), and actively supporting pro-environmental initiatives (e.g. being mindful of natural resources and using them wisely). Overall, the goal of reducing consumption based on voluntary simplistic principles is to acquire greater satisfaction with life by excluding materialism (Huneke, 2005) and is governed by personal choice (Etzioni, 1999; Wu et al., 2013). In contrast, unintentional voluntary simplicity is not embraced through personal choice but rather forced upon an individual as a result of economic pressures, increasing debt, and/ or resource scarcity, especially during times of economic instability and recessions (Wu et al., 2013). Those who voluntarily embrace simplicity may, in fact, have the means to consume but deliberately choose not to acquire goods based on material worth and, instead, strive towards fulfilment without overconsuming (Alexander & Ussher, 2012).

In sum, voluntary simplicity can be described as living in an externally simple yet inwardly rich manner (Elgin & Mitchell, 1977). It is achieved by reducing spending on consumer goods and services and devoting more time and attention to non-materialistic sources of pleasure and meaning (Osikominu & Bocken, 2020). In addition, consumers may choose non-polluting, durable, repairable, recyclable, or renewable

goods in practically adopting the principles of a voluntary simplistic lifestyle (Elgin & Mitchell, 1977). Through their research, Elgin and Mitchell (1977) identified five overarching dimensions that underlie a voluntary simplistic lifestyle, namely, human scale, material simplicity, ecological awareness, self-determination, and personal growth. As Reis (2019) explains, material simplicity involves a conscious decision to embrace minimalism and limit all unnecessary consumption, whereas self-determination further advances the idea of being in control of your own future and not driven by excessive financial lifestyles. Ecological awareness taps into people's understanding of their environmental impact and their simultaneous reliance on natural resources for survival, whereas the human-scale dimension relates to consumers' support of smaller-scale institutions and innovations (Leonard-Barton, 1981). This dimension may also refer to people's concern for better working conditions in manufacturing sectors and supporting smaller entrepreneurial entities rather than large-scale industrial set-ups or sweatshops. The fifth dimension, namely, personal growth, relates to an individual's pursuit of life purpose whilst remaining modest, owning less, and rather focusing on personal growth. It should, however, be noted that this dimension has attitudinal connections, whereas the other dimensions manifest in behaviour. Elgin and Mitchell (1977), and later on Leonard-Barton (1981), developed measures for behaviour in accordance with these dimensions to predict, amongst other, energy conservation. Because voluntary simplicity encompasses a broader lifestyle approach, it may span over several consumption spheres and could therefore very well find meaning in a person's sustainable clothing consumption practices.

5 Sustainable Clothing Consumption Practices Underscored by Voluntary Simplistic Principles

Inspired by earlier seminal works of Elgin and Mitchell (1977) and Leonard-Barton (1981), Reis (2019) developed and validated a scale to measure consumers' engagement in sustainable clothing consumption practices that underscore the principles of voluntary simplicity. Her findings revealed three prominent factors that revolved around the support for local and ethical brands, an appreciation for unique product features (such as those included in handcrafted items), and striving to reduce consumption. These factors partially resembled the original dimensions outlined by Elgin and Mitchell (1977). Taljaard and Sonnenberg's (2019) study further expanded on Reis' (2019) findings surrounding consumers' voluntary simplistic inclinations towards sustainable clothing consumption. Their study revealed additional dimensions that could be added to the scope of sustainable clothing consumption behaviour. The following section will delve into various sustainable clothing consumption practices that emerged from these studies, including purchasing eco-friendly clothing, adopting ethical consumption behaviours, favouring handcrafted garments, reusing and buying second-hand clothing, reducing overall consumption, making purchases based on necessity, repurposing garments, and prioritising clothing longevity.

5.1 Buying Eco-Friendly Clothing

Understanding consumers' acquisition of eco-friendly clothing is a significant topic in sustainable fashion research. Eco-friendly products, commonly referred to as 'green' products, exhibit minimal detrimental effects on the environment (Sobuj et al., 2021) and are thus well aligned with the principles of voluntary simplicity and sustainable clothing consumption. Eco-friendly clothing is produced with the aim of reducing environmental impact by employing various practices and materials that prioritise eco-friendliness. These measures include the use of recycling, biodegradable materials, organic fibres cultivated without chemicals, and natural dyes and the adoption of environmentally conscious technologies (Chang & Watchravesringkan, 2018). Despite persistent concerns about the affordability of eco-friendly clothing, there has been a notable rise in consumer inclination to purchase such garments, driven by a heightened awareness of the detrimental environmental consequences associated with the apparel industry (Chen & Tung, 2014).

Throughout time, numerous renowned fashion labels have taken initiative to endorse and offer clothing options that are environmentally conscious. Patagonia stands out as a prominent illustration, asserting that a significant portion, specifically 64%, of its product range is crafted from recycled materials such as nylon, polyester, cotton, and cashmere (Abbas & Shipin, 2022). Since 1985, Patagonia has made a commitment to dedicate 1% of its sales towards nature conservation (Patagonia, 2023). Levi's is another brand that exemplifies this trend. Levi's has recently introduced a fresh addition to their collection, the Levi's 501 jeans, which exemplify their commitment to sustainability. These jeans are meticulously crafted from a combination of certified organic cotton, responsibly sourced wood pulp, and a remarkable material known as Circulose (Levi's 2021). By incorporating these environmentally conscious materials, Levi's aims to reduce their ecological footprint and contribute to the pursuit of sustainable fashion. Prada is also amongst the first luxury fashion brands to incorporate recycled nylon thread in its collections (Langenheim, 2023).

However, despite an increasing number of fashion brands promoting eco-friendly product ranges, these products still have insufficient representation in the market (Kim & Lee, 2023). This leaves further scope for promoting sustainable clothing consumption behaviour and tapping into consumers' ecological awareness.

5.2 Ethical Clothing Consumption

Ethical consumption entails making purposeful and mindful decisions rooted in personal moral convictions and values (Oh & Yoon, 2014). Consumers may opt to purchase products that align with specific moral concerns such as human rights, fair labour conditions exempt from exploitation, fair trade, sustainable and local production, and animal welfare, all of which address important voluntary simplistic

principles (Reis 2019; Taljaard & Sonnenberg 2019). Similarly, consumers may choose to boycott brands that do not meet their moral standards. Ethical consumption plays a crucial role in fostering a sustainable fashion industry (Shen et al., 2012). Ethically produced fashion encompasses the principles of manufacturing within secure working environments and guaranteeing equitable remuneration for workers (Humphery & Jordan, 2018). In recent years, major international brands have faced significant backlash for their involvement in unethical labour practices in offshore sweatshops during production (Ellis & Higgins, 2006; Shaw et al., 2006).

Social media movements such as #WhoMadeMyClothes have made substantial efforts to promote transparency and keep consumers informed about labour conditions in the clothing manufacturing sector (Fashion Revolution, 2023). Additionally, brands like Patagonia, for instance, emphasise that 82% of their product lines are sewn in Fair Trade Certified factories, ensuring fair wages for workers (Abbas & Shipin, 2022). Likewise, Levi's has implemented a Worker Well-Being program that collaborates with suppliers and local organisations to ensure financial empowerment, health, family well-being, equality, and acceptance (Abbas & Shipin, 2022).

5.3 Preference for Handcrafted Clothing

Handcrafted garments include clothing items that are meticulously fashioned through manual craftsmanship, employing either exclusive manual labour or the utilisation of hand tools. In certain instances, mechanical methods may be employed as long as the producer manually contributes to the vital aspects of the final product (Gaikwad Sunita & Shiware, 2013). Traditional handcrafted designs typically embody simple aesthetic styles and often incorporate environmentally friendly materials (Xue et al., 2022). This concept aligns with the 'DIY' ethos of voluntary simplicity and is promoted to consumers as unique items created with a conscious effort to showcase specialised craftsmanship (Taljaard & Sonnenberg, 2019). Handcrafted products possess unique characteristics that distinguish them from mass-produced items, making them highly sought after in local markets (Reis, 2019). According to Fan and Feng (2019), despite the attractiveness associated with the traditional handcraft industry, it faces persistent obstacles when it comes to competing against modern mass producers. Research conducted by Sehnem et al. (2020) suggest that this inequality can be attributed to several key factors, such as the elevated cost associated with handcrafted goods and the general absence of competitive and sustainable management approaches. These challenges present opportunities for the handcraft industry to explore innovative solutions that can enhance their market position and ensure the long-term viability of their craft. Nevertheless, there has been a recent upward trend in consumer preferences for unique handmade garments as an alternative to standardised mass-produced clothing (van der Westhuizen & Kuhn, 2023). This revival in the demand for handmade products can be attributed to consumers becoming more critical of the prevailing 'mass-produced, mass-consumption culture' (van der Westhuizen & Kuhn, 2023)

and rather embracing the human-scale dimension of voluntary simplicity. Yet, as will be pointed out in the conclusion of this chapter, further research is necessary to explore this topic more thoroughly as current insight is predominantly derived from the craft producers rather than the consumers thereof.

5.4 Reusing and Buying Second-Hand

Textile reuse encompasses a range of methods aimed at extending the lifespan of textile products as they pass from one owner to another (Muthu, 2015). These strategies encompass renting, exchanging, swapping, borrowing, or procuring pre-owned garments from diverse outlets such as brick-and-mortar stores, flea markets, garage sales, and digital platforms (Sadin & Peters, 2018). Reusing clothing is widely regarded as a highly beneficial option for reducing environmental impact since it decreases the production of new materials and delays or prevents garments from ending up in landfills (Muthu, 2015). Machado et al.'s (2019) study supported the effectiveness of textile reuse and the consumption of second-hand clothing as strategies for reducing textile waste and pollution. Some research indicates that consumers' inclination to purchase pre-owned clothing may be influenced by their environmental consciousness (Xu et al., 2022).

In conjunction with environmental advantages, the reuse of second-hand clothing also brings economic benefits by reducing costs associated with new materials, water consumption, production, and landfill space required for producing new garments (Persson & Hinton, 2023). Furthermore, the affordability of used apparel serves as an incentive for consumers to opt for second-hand items, leading to increased supply and demand (Armstrong & Park, 2020). Pre-owned luxury items have gained popularity amongst aspirational consumers who desire luxury brands but have limited financial means (du Plessis & Abdoolla, 2022). As a result, the resale industry is projected to experience significantly faster growth compared to the overall global apparel market (thredUp, 2023b), with estimations indicating a remarkable market valuation of $218 billion by 2026 (Keenan, 2022a, b).

The second-hand clothing market's momentum is partly credited to the prevalence of sustainable fashion models and their significant role in the move towards a circular economy (Xu et al., 2022). However, the growth of the second-hand clothing industry is also attributed to technological progress and the proliferation of online marketplaces, including social media platforms, with 70% of consumers stating that second-hand shopping has become more accessible than ever before (Keenan, 2022a, b). The COVID-19 pandemic further amplified the success of platforms like thredUp (Hughes, 2021). ThredUp is amongst the largest online platforms for second-hand women's and children's apparel (thredUp, 2023a, b). Other brands, such as Patagonia, have launched initiatives like their Worn Wear program, which encourages customers to buy and sell used items instead of purchasing new ones (Keenan, 2022a, b).

5.5 Reduced Clothing Consumption

Sustainability in consumption cannot be achieved solely through technological advancements, efficiency improvements, and actions driven by producers. It is essential to also reduce overall consumption levels (Blatt et al., 2020). Anti-consumption is a concept closely related to the reduction of clothing consumption. Embracing an anti-consumption ideology can be as simple as practicing abstinence, which means buying fewer clothes or less frequently (Diddi et al., 2019; Joanes, 2019). The industry is witnessing a surge in popularity for the 'less is more' approach, as indicated by Bilinska-Reformat and Dewalska-Opitek (2021). Reduced or need-based clothing consumption involves purchasing clothing based on necessity rather than desire (Taljaard & Sonnenberg, 2019). Need-based consumption became particularly applicable during the pandemic. Consumers shifted their spending primarily to essential items like groceries and household supplies whilst reducing discretionary spending on clothing (Arora, 2020). Nevertheless, well before the arrival of the pandemic, scholarly inquiry has examined individual choices to curtail consumption through practices such as buying less or refraining from purchases (Capstick et al., 2014; García-de-Frutos et al., 2018). Exploring several reasons behind consumer rejection or avoidance of consumption, including reduced or need-based clothing consumption, is crucial as it holds the potential for meaningful declines in greenhouse gas emissions (Capstick et al., 2014).

5.6 Clothing Longevity and Repurposed Clothing Consumption

Research findings indicate that prolonging the lifespan of clothing is a crucial aspect of sustainable consumption (Klepp et al., 2020; Muthu, 2015; Vesterinen & SyrJala, 2022). Repurposed clothing consumption refers to consumers' efforts to repurpose, alter, or repair old clothing instead of discarding it prematurely (Taljaard & Sonnenberg, 2019). Whilst clothing longevity and repurposed clothing consumption are separate dimensions, they are closely interconnected (Taljaard & Sonnenberg 2019). Longevity involves maximising the use of products and extending their lifespan (Taljaard & Sonnenberg, 2019; Cinar, 2020). Following care instructions for proper cleaning and laundering can help preserve garments and extend their life (Koszewska, 2021). Careful maintenance is crucial for prolonging the use phase of clothing items (McQueen et al., 2022). Additionally, reducing the frequency of laundering can extend garment lifespan and conserve resources, as many textiles are sensitive to wet cleaning methods (McQueen et al., 2017). For instance, a campaign launched by Levi's known as 'Buy Better, Wear Longer' emphasises clothing longevity as a key aspect of sustainable consumption, reflecting the brand's commitment to sustainability and extending product lifespan (Levi's, 2021).

Repairing or mending clothing is another way to prolong its lifespan (McQueen et al., 2022), along with upcycling through creative repurposing and reshaping (Kamleitner et al., 2019). However, consumers often hesitate to repair clothes due to time constraints, lack of expertise, and the perceived low cost of replacement (Gibson et al., 2011). It is important to remind consumers that their actions can have significant environmental benefits, encouraging a repair mindset and emphasising the value of longer-lasting styles and materials (Farrant et al., 2010; McNeill & Venter, 2019). By conveying that damaged garments can be repaired and restored for further use, consumers may develop a greater appreciation for materials, products, and clothing items (Niinimäki & Durrani, 2020).

Overall, consumers must make fundamental choices that prioritise ethical alternatives, reduce spending, and embrace sustainable clothing consumption practices (Shaw & Newholm, 2002). Whilst these decisions have been promoted for years, the COVID-19 pandemic has accelerated modifications and fostered a greater understanding that sustainable production and consumption patterns are attainable within the apparel industry (Cohen, 2020).

6 Conclusion and Future Research Recommendations

Fresh air and clean water are basic human rights. However, if these rights are to be maintained, drastic change is needed in all spheres of consumption but also more specifically in the way we consume and dispose of our clothing. Ultimately, it is more feasible to manage human behaviour than attempting to salvage an ecosystem that has been utterly destroyed by human activity. Embracing ideologies such as voluntary simplicity can do much to encourage lower consumption levels and simultaneously allow individuals to seek a quality of life beyond material consumption. Although many studies have focused on voluntary simplistic lifestyles and associated behaviour in more developed countries, it seems to remain an understudied topic in developing countries, despite the fact that consumption levels are also rising in those contexts. As pointed out earlier, the fast fashion model has allowed people from all socioeconomic contexts to engage in fashion consumption, and therefore, efforts to better understand and promote sustainable clothing consumption practices are a global imperative.

Regarding particular practices that support sustainable clothing consumption, the preference for handcrafted items can be isolated as a topic that may benefit from future investigation. Presently, the majority of studies offer insights from the perspective of crafters, with a limited focus on the consumer's viewpoint regarding handmade products, highlighting a gap in the existing literature (Campbell, 2005). The fashion industry is however constantly evolving with new trends relentlessly introduced on a seasonal basis driven by, amongst others, technological innovation and consumer preferences. For these reasons, it would be important to also consistently monitor and investigate other types of sustainable consumption practices.

Looking ahead, social media is regarded as an indispensable marketing instrument for amplifying the market presence of environmentally conscious garments (Sun & Wang, 2020). A research study revealed that millennials who regularly engage in social media for consumption-related activities and actively participate in online discussions on environmentally conscious practices exhibit a greater inclination to purchase eco-friendly products (Bedard & Tolmie, 2018). Information disseminated through social media often emphasises the severity of environmental degradation and may inspire individuals to realise their potential in driving change and protecting the environment (Sun & Wang, 2020). For these reasons, future studies should prioritise the investigation of social media usage and to what extent it serves as a platform for change in sustainable clothing consumption practices.

References

Abbas, T., & Shipin, S (2022). *31 sustainable fashion brands you can shop confidently*. https://www.glamour.com/story/sustainable-fashion-brands. Accessed 15 Mar 2023.

Alexander, S., & Ussher, S. (2012). The voluntary simplicity movement: A multi-national survey analysis in theoretical context. *Journal of Consumer Culture, 12*(1), 66–86.

Armstrong, C. M. J., & Park, H. (2020). Online clothing resale: A practice theory approach to evaluate sustainable consumption gains. *Journal of Sustainability Research, 2*(2), e200017.

Arnold, D. G., & Hartman, L. P. (2006). Worker rights and low wage industrialization: How to avoid sweatshops. *Human Rights Quarterly*, 676–700.

Arora, A. (2020). Life after COVID-19: A better normal? *Perspectives in Public Health, 140*(6), 311–312.

Ballantine, P. W., & Creery, S. (2010). The consumption and disposition behaviour of voluntary simplifiers. *Journal of Consumer Behaviour, 9*(1), 45–56.

Bedard, S. A. N., & Tolmie, C. R. (2018). Millennials' green consumption behaviour: Exploring the role of social media. *Corporate Social Responsibility and Environmental Management, 25*(6), 1388–1396.

Bick, R., Halsey, E., & Ekenga, C. (2018). The global environmental injustice of fast fashion. *Environmental Health, 17*, 92.

Bilińska-Reformat, K., & Dewalska-Opitek, A. (2021). E-commerce as the predominant business model of fast fashion retailers in the era of global COVID 19 pandemics. *Procedia Computer Science, 12*, 2479–2490.

Blatt, E. F., Giannetti, B. F., Agostinho, F., Sevegnani, F., Wang, Y., & Almeida, C. M. V. B. (2020). Evaluating producers as resource consumers and alternative consumption patterns: Outcomes from energy synthesis of the jeans supply chain. *Cleaner and Responsible Consumption, 1*, 100002.

Campbell, C. (2005). The craft consumer: Culture, craft and consumption in a postmodern society. *Journal of Consumer Culture, 5*(1), 23–42.

Capstick, S., Lorenzoni, I., Corner, A., & Whitmarsh, L. (2014). Prospects for radical emissions reduction through behavior and lifestyle change. *Carbon Management, 5*(4), 429–445.

Cavusoglu, L., & Dakhli, M. (2016). The impact of ethical concerns on fashion consumerism: A review. *Markets, Globalization & Development Review, 1*(2).

Chang, H. J., & Watchravesringkan, K. T. (2018). Who are sustainably minded apparel shoppers? An investigation to the influencing factors of sustainable apparel consumption. *International Journal of Retail & Distribution Management., 46*(2), 148–162. https://doi.org/10.1108/IJRDM-10-2016-0176

Chen, M.-F., & Tung, P. J. (2014). Developing an extended theory of planned behavior model to predict consumers' intention to visit green hotels. *International Journal of Hospitality Management, 36*, 221–230.
Cinar, D. (2020). A research on the evaluation of consumers' voluntary simplicity lifestyle tendency in the Covid-19 period. *International Journal of Social Sciences and Education Research, 7*, 25–38.
Cohen, M. J. (2020). Does the COVID-19 outbreak mark the onset of a sustainable consumption transition? *Sustainability: Science, Practice and Policy, 16*(1), 1–3.
du Plessis, A, & Abdoolla, R. (2022). *Why Worn Clothes are Thriving in Africa*. https://www.euromonitor.com/article/why-worn-clothes-are-thriving-in-africa. Accessed 25 Mar 2023.
Degli Esposti, P., Mortara, A., & Roberti, G. (2021). Sharing and sustainable consumption in the era of COVID-19. *Sustainability, 13*(4), 1903.
Diddi, S., & Yan, R. N. (2019). Consumer perceptions related to clothing repair and community mending events: A circular economy perspective. *Sustainability, 11*(19), 5306.
Diddi, S., Yan, R.-N., Bloodhart, B., Bajtelsmit, V., & McShane, K. (2019). Exploring young adult consumers' sustainable clothing consumption intention-behavior gap: A behavioral reasoning theory perspective. *Sustainable Production and Consumption, 18*, 200–209.
Dosemagen, S. (2016). *Can social media help to save the environment?* https://www.weforum.org/agenda/2016/04/can-social-media-help-to-save-the-environment. Accessed 16 Mar 2023.
Elgin, D., & Mitchell, A. (1977). Voluntary simplicity. *Planning Review, 5*(6), 13–15.
Ellen MacArthur Foundation. (2023). *Redesigning the future of fashion*. https://ellenmacarthurfoundation.org/topics/fashion/overview. Accessed 1 Apr 2023.
Ellis, N., & Higgins, M. (2006). Recatechizing codes of practice in supply chain relationships: Discourse, identity and otherness. *Journal of Strategic Marketing, 14*(4), 387–410.
Etzioni, A. (1999). Voluntary simplicity: Characterization, select psychological implications, and societal consequences. In *Essays in socio-economics* (pp. 1–26). Springer.
Fan, K.-K., & Feng, T. T. (2019). Discussion on sustainable development strategies of the traditional handicraft industry based on su-style furniture in the Ming dynasty. *Sustainability, 11*(7), 2008.
Farrant, L., Olsen, S. I., & Wangel, A. (2010). Environmental benefits from reusing clothes. *The International Journal of Life Cycle Assessment, 15*(7), 726–736.
Fashion Revolution. (2023). *About*. https://www.fashionrevolution.org/about/. Accessed 30 Mar 2023.
Fletcher, K. (2008). *Sustainable fashion and textiles design journeys*. Earthscan.
Fletcher, K. (2010). Slow fashion: An invitation for systems change. *Fashion Practice, 2*(2), 259–265.
Gaikwad, S. P., & Shiware, T. A. (2013). Trends of Indian handicraft export since 2001. *Sona Global Management Review, 7*(2), 38–45.
Gao, H., Tate, M., Zhang, H., Chen, S., & Liang, B. (2018). Social media ties strategy in international branding: An application of resource-based theory. *Journal of International Marketing, 26*. https://doi.org/10.1509/jim.17.0014
García-de-Frutos, N., Ortega-Egea, J. M., & Martínez-del-Río, J. (2018). Anti-consumption for environmental sustainability: Conceptualization, review, and multilevel research directions. *Journal of Business Ethics, 148*(2), 411–435.
Gardetti, M. A. & Torres, A. L. (2013). *Sustainability in fashion and textiles: Values, design, production and consumption.*
Gazzola, P., Pavione, E., Pezzetti, R., & Grechi, D. (2020). Trends in the fashion industry. The perception of sustainability and circular economy: A gender/generation quantitative approach. *Sustainability, 12*, 2809.
Gibson, C., Head, L., Gill, N., & Waitt, G. (2011). Climate change and household dynamics: Beyond consumption, unbounding sustainability. *Transactions of the Institute of British Geographers, 36*(1), 3–8.

Gwozdz, W., Nielsen, K., & Müller, T. (2017). An environmental perspective on clothing consumption: Consumer segments and their behavioral patterns. *Sustainability, 9*, 762.
Henry, P., & Michell, M. J. (2019). Challenging excessive fashion consumption by fostering skill-based fashion education. *Journal of International Education and Practice.*
Hepburn, S. (2015). *Fast fashion is not good for you or the planet*. [online] Available from https://www.thegoodtrade.com/features/fast-fashion/. Accessed 13 June 2023.
Hiba, J. C., Jentsch, M., & Zink, K. J. (2021). Globalization and working conditions in international supply chains. *Zeitschrift für Arbeitswissenschaft, 75*(2), 146–154.
Hughes, T. (2021). The Digital 2021 October Global Statshot Report. https://digital-leadership-associates.passle.net/post/102h94w/the-digital-2021-october-global-statshot-report. Accessed 20 Oct 2023
Humphery, K., & Jordan, T. (2018). Mobile moralities: Ethical consumption in the digital realm. *Journal of Consumer Culture, 18*(4), 520–538.
Huneke, M. E. (2005). The face of the un-consumer: An empirical examination of the practice of voluntary simplicity in the United States. *Psychology & Marketing, 22*(7), 527–550.
Jacometti, V. (2019). Circular economy and waste in the fashion industry. *Laws, 8*(4), 27.
Joanes, T. (2019). Personal norms in a globalized world: Norm-activation processes and reduced clothing consumption. *Journal of Cleaner Production, 212*, 941–949.
Jung, S., & Jin, B. (2014). A theoretical investigation of slow fashion: Sustainable future of the apparel industry. *International Journal of Consumer Studies, 38*(5), 510–519.
Kamleitner, B., Thürridl, C., & Martin, B. A. S. (2019). A Cinderella story: How past identity salience boosts demand for repurposed products. *Journal of Marketing, 83*(6), 76–92.
Keenan, M. (2022a). *Global ecommerce explained: Stats and trends to watch*. https://www.shopify.com/enterprise/global-ecommerce-statistics. Accessed 11 Apr 2023.
Keenan, M. (2022b). *The state of the ecommerce fashion industry: Statistics, trends & strategies to use in 2023*. https://www.shopify.com/za/enterprise/ecommerce-fashion-industry. Accessed 25 Mar 2023.
Khandual, A., & Pradhan, S. (2019). Fashion brands and consumers approach towards sustainable fashion. In S. S. Muthu (Ed.), *Fast fashion, fashion brands and sustainable consumption*. Singapore.
Kim, N., & Lee, K. (2023). Environmental consciousness, purchase intention, and actual purchase behavior of eco-friendly products: The moderating impact of situational context. *International Journal of Environmental Research and Public Health, 20*(7), 5312. https://doi.org/10.3390/ijerph20075312
Klepp, I. G., Laitala, K., & Wiedemann, S. (2020). Clothing lifespans: What should be measured and how. *Sustainability, 12*(15), 6219.
Koszewska, M. (2018). Circular economy – Challenges for the textile and clothing industry. *Autex Research Journal, 18*, 337–347. https://doi.org/10.1515/aut-2018-0023
Koszewska, M. (2021). Clothing labels: Why are they important for sustainable consumer behaviour? *Journal of Consumer Protection and Food Safety, 16*(1), 1–3.
Langenheim, J. (2023). *Five initiatives making fashion more sustainable*. https://www.nationalgeographic.com/environment/article/partner-content-five-initiatives-making-fashion-more-sustainable. Accessed 30 Mar 2023.
Leonard-Barton, D. (1981). Voluntary simplicity lifestyles and energy conservation. *The Journal of Consumer Research, 8*, 243–251.
Levi's. (2021). *Buy better wear longer*. https://www.levi.co.za/blog/buy-better-wear-longer/. Accessed 30 Mar 2023.
Liu, C., Xia, S., & Lang, C. (2021). Clothing consumption during the COVID-19 pandemic: Evidence from mining tweets. *Clothing and Textiles Research Journal, 39*(4), 314–330.
Machado, M. A. D., Almeida, S. O. D., Bollick, L. C., & Bragagnolo, G. (2019). Second-hand fashion market: Consumer role in circular economy. *Journal of Fashion Marketing and Management: An International Journal, 23*(3), 382–395.

McKinsey and Company. (2021). *The state of fashion 2021*. https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/state%20of%20fashion/2021/the-state-of-fashion-2021-vf.pdf. Accessed 24 Feb 2021.

McNeill, L., & Venter, B. (2019). Identity, self-concept and young women's engagement with collaborative, sustainable fashion consumption models. *International Journal of Consumer Studies, 43*(4), 368–378.

McQueen, R. H., Batcheller, J. C., Moran, L. J., Zhang, H., & Hooper, P. M. (2017). Reducing laundering frequency to prolong the life of denim jeans. *International Journal of Consumer Studies, 41*(1), 36–45.

McQueen, R. H., McNeill, L. S., Kozlowski, A., & Jain, A. (2022). Frugality, style longevity and garment repair – Environmental attitudes and consumption behaviour amongst young Canadian fashion consumers. *International Journal of Fashion Design, Technology and Education, 15*(3), 371–384.

Moisander, J. (2007). Motivational complexity of green consumerism. *International Journal of Consumer Studies, 31*(4), 404–409.

Muthu S. S. & Textile Institute (Manchester England). (2015). *Handbook of life cycle assessment (lca) of textiles and clothing*. Woodhouse Publishing is an Imprint of Elsevier. https://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1044198. Accessed 11 Mar 2023.

Newholm, T., & Shaw, D. (2007). Studying the ethical consumer: A review of research. *Journal of Consumer Behaviour, 6*, 253–270.

Niinimäki, K., & Durrani, M. (2020). *Repairing fashion cultures: From disposable to repairable*. https://doi.org/10.3390/books978-3-03897-873-2-8.

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. *Nature Reviews Earth & Environment, 1*(4), 189–200.

Nissen, A., & Krampe, C. (2021). Why he buys it and she doesn't – Exploring self-reported and neural gender differences in the perception of eCommerce websites. *Computers in Human Behavior, 121*, 106809.

Oh, J. C., & Yoon, S. J. (2014). Theory-based approach to factors affecting ethical consumption. *International Journal of Consumer Studies, 38*(3), 278–288.

Osikominu, J., & Bocken, N. (2020). A voluntary simplicity lifestyle: Values, adoption, practices and effects. *Sustainability, 12*(5), 1903.

Ozdamar Ertekin, Z., & Atik, D. (2015). Sustainable markets: Motivating factors, barriers, and remedies for mobilization of slow fashion. *Journal of Macromarketing, 35*(1), 53–69.

Ozdamar-Ertekin, Z. (2016). Conflicting perspectives on speed: Dynamics and consequences of the fast fashion system. *Markets, Globalization & Development Review, 1*(1).

Patagonia. (2023). *Home page*. https://www.patagonia.com/home/. Accessed 30 Mar 2023.

Persson, O., & Hinton, J. B. (2023). Second-hand clothing markets and a just circular economy? Exploring the role of business forms and profit. *Journal of Cleaner Production, 390*, 136139.

Reis, T. L. (2019). *Validation of a scale to measure consumers' engagement in voluntary simplistic clothing consumption behaviour in South Africa*. University of Pretoria.

Rich, S. A., Hanna, S., Wright, B. J., & Bennett, P. C. (2017). Fact or fable: Increased wellbeing in voluntary simplicity. *International Journal of Wellbeing, 7*(2).

Rudell, F. (2006). Shopping with a social conscience: Consumer attitudes toward sweatshop labor. *Clothing and Textiles Research Journal, 24*(4), 282–296.

Sandin, G., & Peters, G. M. (2018). Environmental impact of textile reuse and recycling – A review. *Journal of Cleaner Production, 184*, 353–365.

Sehnem, S., Piekas, A., Dal Magro, C. B., Fabris, J., & Leite, A. (2020). Public policies, management strategies, and the sustainable and competitive management model in handicrafts. *Journal of Cleaner Production, 266*, 121695.

Shaw, D., & Newholm, T. (2002). Voluntary simplicity and the ethics of consumption. *Psychology & Marketing, 19*(2), 167–185.

Shaw, D., Hogg, G., Wilson, E., Shiu, E., & Hassan, L. (2006). Fashion victim: The impact of fair trade concerns on clothing choice. *Journal of Strategic Marketing, 14*, 427–440.

Shen, B., Wang, Y., Lo, C. K., & Shum, M. (2012). The impact of ethical fashion on consumer purchase behavior. *Journal of Fashion Marketing and Management: An International Journal, 16*(2), 234–245.

Sobuj, M., Khan, A. M., Habib, A. M., & Islam, M. M. (2021). Factors influencing eco-friendly apparel purchase behavior of Bangladeshi young consumers: Case study. *Research Journal of Textile and Apparel, 25*(2), 139–157.

Sogari, G., Pucci, T., Aquilani, B., & Zanni, L. (2017). Millennial generation and environmental sustainability: The role of social Media in the Consumer Purchasing Behavior for wine. *Sustainability, 9*(10), 1911.

Sun, Y., & Wang, S. (2020). Understanding consumers' intentions to purchase green products in the social media marketing context. *Asia Pacific Journal of Marketing and Logistics, 32*(4), 860–878.

thredUp. (2023a). *About*. [online] Available from: https://www.thredup.com/about. Accessed 25 Mar 2023.

thredUp. (2023b). *Resale Report*. Thredup. [online] Available from: https://cf-assets-tup.thredup.com/resale_report/2023/thredUP_2023_Resale_Report_FINAL.pdf. Accessed 25 Mar 2023.

Taljaard, H., & Sonnenberg, N. (2019). Basic psychological needs and self-determined motivation as drivers of voluntary simplistic clothing consumption practices in South Africa. *Sustainability, 11*(13), 3742.

van der Westhuizen, L.-M., & Kuhn, S. W. (2023). Handmade clothing consumption as a means of self-expression. *Journal of Fashion Marketing and Management*. https://doi.org/10.1108/JFMM-07-2021-0175

Vesterinen, E., & Syrjälä, H. (2022). Sustainable anti-consumption of clothing: A systematic literature review. *Cleaner and Responsible Consumption, 5*, 100061.

Vladimirova, K., Henninger, C. E., Joyner-Martinez, C., Iran, S., Diddi, S., Durrani, M., Iyer, K., Jestratijevic, I., McCormick, H., Niinimäki, K., Thangavelu, P., Sauerwein, M., Singh, R., Simek, P., & Wallaschkowski, S. (2022). Fashion consumption during COVID-19: Comparative analysis of changing acquisition practices across nine countries and implications for sustainability. *Cleaner and Responsible Consumption, 5*, 100056.

Wazir, B. (2001). *Nike accused of tolerating sweatshops*. https://www.theguardian.com/world/2001/may/20/burhanwazir.theobserver. Accessed 25 Feb 2023.

Wood, K. (2022). *Social media activism: This is how you start a movement*. https://sproutsocial.com/insights/social-media-activism/. Accessed 25 Mar 2023.

Wu, D. E., Boyd Thomas, J., Moore, M., & Carroll, K. (2013). Voluntary simplicity: The great American apparel diet. *Journal of Fashion Marketing and Management: An International Journal, 17*(3), 294–305.

Xu, J., Zhou, Y., Jiang, L., & Shen, L. (2022). Exploring sustainable fashion consumption behavior in the post-pandemic era: Changes in the antecedents of second-hand clothing-sharing in China. *Sustainability, 14*(15), 9566.

Xue, X., Caiguo, X., Yi, L., & Chenxia, M. (2022). Consumption of traditional handicraft fashion: Motivations, intentions and behaviours of Chinese consumers. *Cleaner and Responsible Consumption, 4*, 100046.

Toward Increasing Public Awareness of Cellulose-Based Textiles with Improved Sustainability

Snežana Stanković

Abstract Modern textile product consumers are interested in clothing with good aesthetic performance, easy care, and comfort. Consumers are also becoming more aware of sustainability issues. In an attempt to meet consumers' demand, textile producers and suppliers have to put a lot of effort into promoting textile sustainability but also improving sustainability aspects of textile production. This chapter presents hemp as a more sustainable alternative to cotton. At the beginning of the twenty-first century, hemp is being recognized as a renewable source of intrinsically biodegradable raw material for various industry sectors. Thanks to the specific hygienic and protective properties of hemp fiber, hemp is expected to play an important role in the textile industry, especially in the high-quality clothing sector. In addition to a concise presentation of the potential and challenges of hemp, several sustainability aspects of hemp, starting from plant cropping to fiber and yarn production, were considered. The findings presented in this chapter, coming from the collected data, are aimed to contribute to the recognition of hemp as a promising sustainable textile fiber source.

Keywords Textiles · Sustainability · Natural fiber · Industrial hemp · Cotton · Yarn · Online survey

1 Introduction

The textile and fashion industries have numerous sustainability challenges such as air and water pollution, land degradation, loss of biodiversity, unsafe working conditions, low wages, use of child labor, etc. In response to public pressure for

S. Stanković (✉)
Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia
e-mail: stankovic@tmf.bg.ac.rs

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0_3

sustainable development, the textile and fashion sectors have to respond to the challenges. In addition, there is a global trend of increasing consumer awareness of healthy lifestyles. With the popularity of natural and healthy lifestyles, the public is moving toward using natural and sustainable textile products. Therefore, ongoing efforts are being made to improve the sustainability aspects of textile production. Environmental and sustainability issues play a role in all the stages of the natural fiber production chain including agricultural production, textile fiber processing, textile production, and utilization. Therefore, various investigations have been conducted about the potential implementation of alternative raw materials (fibers), technical improvement in manufacturing processes or development of economically and ecologically attractive technologies, reduction in the use of water and chemicals for textile finishing, and so on.

In this chapter, hemp as a more sustainable alternative to cotton will be presented. Hemp is a cosmopolitan plant found all over the world. For centuries, hemp (*Cannabis sativa* L.) has been widely grown and used for its string fibers, seeds, and oil production. From being extensively used, the cultivation of hemp experienced a decline in the middle of the twentieth century due to the intensive development of synthetic fibers and the prohibition caused by confusion about understanding industrial hemp. By explaining mistakes made due to genetic closeness to the marijuana (*Cannabis indica*), a renewed interest in hemp cultivation and use has arisen on account of its biodegradability, biocompatibility, healthy features, and eco-friendly nature. Hemp is adaptable to a wide range of agronomic and climatic conditions with low herbicide and pesticide requirements and limited or no irrigation. Hemp cultivation is of benefit to soil due to its ability to suppress weeds and some soil-borne diseases. Hemp is a fast-renewable resource for many industry sectors, such as textile, automotive, construction, energy, pharmaceutical, cosmetic, etc. In addition to the traditional usage of hemp fibers for technical textiles (ropes, packaging), there is great potential for the development of hemp-based high-added value products for specific uses. The outstanding hemp fiber properties, such as breathability, high-absorbent, hygroscopic, bacteriostatic, antistatic, and anti-allergic properties, determine hemp textile fabrics as physiologically friendly textiles with good predispositions toward achieving excellent comfort performances. However, increasing recognition of hemp as a more sustainable cellulose fiber has to be accompanied by an improvement in some comfort-related properties, easy-care aspects, and last but not least, cost-effectiveness.

2 Industrial Hemp: Potential and Challenges

Although different information can be found in the literature about the beginnings of hemp cultivation, industrial hemp (*Cannabis sativa* L.) is certainly among the earliest nonfood crops cultivated by humans for fibers and plant extracts. It is believed that hemp cultivation spread from Central Asia throughout East Asia,

South Asia, and Europe. Industrial hemp (referred to as hemp hereinafter) has been grown and used throughout history reaching its zenith in the seventeenth and eighteenth centuries. In the nineteenth century, hemp was still the world's leading fiber widely used for paper production and making products such as cordage and sailcloth. However, the hemp industry began to shrink in the early twentieth century, and hemp large-scale cultivation was significantly reduced in the mid-twentieth century for several reasons (Fugazza et al., 2022). Some technological innovations related to the invention of modern cotton machinery which greatly increased the efficiency of cotton production, and the development of motorized ships which dramatically reduced the demand for sailcloth, diminished the importance of hemp fiber as a raw material for textile products. After World War II, the intensive development and commercialization of synthetic fibers also contributed to a significant reduction in hemp usage. In the mid-twentieth century, hemp cultivation ceased in many countries due to the prohibition on the cultivation of any type of *Cannabis L.* genus plants proclaimed by the United Nations Members States in 1961 (Single Convention on Narcotic Drugs). Even though industrial hemp and drug-type hemp (marijuana) share the same plant species, hemp is classified as an industrial crop containing 0.3% or less (0.2% in Europe and 0.1% in Australia) psychoactive substance (Δ^9-tetrahydrocannabinol, THC), while marijuana can contain up to 20% THC (Sebastian et al., 2023; Adesina et al., 2020). By overcoming the misconceived relations with marijuana, the renewed interest in hemp arose in the 1990s mainly from ecological concerns, environmental safety, and growing demand for nonfood crops. Hemp is a biodegradable and fast-renewable and versatile raw material for a diverse range of products in a variety of industries such as textile, paper, automotive, agriculture, construction, energy, pharmaceutical, food, cosmetic industry, etc. (Crini et al., 2020; Zhao et al., 2022). Although the entire hemp plant – the roots, stem, flowers, fruits, and leaves – can be used for various industrial, medical, and nutritional purposes, industrial use involves mainly the stalks and seeds. Currently, about 40 countries produce raw or semi-processed industrial hemp, more of which (about 30 countries) produce hemp for fibers. In the total area cultivated for hemp seeds, Canada, France, and China are the largest suppliers in the world. At the beginning of the 1990s, the production of hemp fibers was less than 100,000 tons, while in 2019, hemp fiber production was approximately 275,000 tons. In 2019, the major producing countries (share in total hemp fiber production) were Canada, France, China, the Netherlands, Poland, Lithuania, Austria, and Italy (Fugazza et al., 2022). In addition to hemp grown as a fiber or seed-purpose crop, the monoecious hemp varieties are available today allowing a dual-purpose use which improves sustainability by using the whole plant (both fiber and seed production) (Baldini et al., 2018). The hemp versatility is reflected in the fact that the plant can be used in various forms, such as fibers, felts, powders, shives, seeds, oil, and oil cake (Sadrmanesh & Chen, 2019). More than 25,000 various hemp products currently available on the global market confirm the potential of industrial hemp (Johnson, 2018). The growing importance of industrial hemp is also confirmed by a great deal of research conducted in the last 20 years. According to the Scopus database, about

11,900 scientific articles were devoted to hemp, about 83% of which were published in the last 10 years. Half of this number of papers was related to hemp fiber research. Despite the rapid expansion of hemp-related literature, the stakeholders in the USA believe that research on the productivity and quality of hemp, as well as further work on policy issues, economics, and marketing of hemp products, should be continued (Sebastian et al., 2023).

The stem of the hemp plant is the source of two types of fibers: long outer fibers referred to as bast fibers and woody short inner (core) fibers called hurds or shives. Bast fibers can account for 20–30% of the stalk, while 70–80% of the stem consists of short fibers. The phloem layer contains the primary bast fibers (technical fibers) consisting of a bundle of fibers that extend along the entire length of the stem. In some hemp varieties, the stem (the part of the stem closer to the root of the plant) also contains secondary bast fibers arising from the cambium. These fibers are strongly lignified, stiff, and difficult to divide (degummed). Hemp fiber has a multicelled structure consisting of elementary fibers mutually glued by lignin and pectin (Manaia et al., 2019). Compared to other vegetable fibers (except cotton), hemp fibers contain more cellulose, an average amount of hemicellulose, and a lower amount of lignin and pectin (Ahmed et al., 2022), making them advantageous for further processing and use. The fiber extraction from the steam includes degumming (retting), breaking, scutching, and hackling. Water retting enables the loosening of the bonds between fibers which makes it possible to break and separate the fibers from the stem manually or mechanically (breaking and scutching), followed by hackling or straightening of fibers (Zimniewska, 2022). All types of fibers have their use in various industry sectors. Quality long fibers are used for various textile products and specialty papers, while short fibers (hurds) are used for paper and construction sectors, livestock bedding, etc. Hemp bast fibers are among the longest natural fibers having strength comparable to that of glass fibers, durability, and high resistance to water damage, weather, and ultraviolet rays. For these reasons, hemp fibers are used for cordage, upholstery, furniture, floor coverings, and packaging materials. In addition to home furnishing (carpets and rugs), traditional use of hemp fibers also includes clothing textiles, mainly working clothes and accessories (hats, bags). However, thanks to hemp fiber properties such as excellent hygienic properties (good breathability, water permeability, and thermal behavior), antistatic, hypoallergenic, antibacterial, and anti-mold properties, hemp fibers offer outstanding performance for high-quality home textiles (bed linen, towels) and protective and fashion clothing. It has been shown in the investigation conducted by Ju et al. (2016) that US consumers tend to perceive bast fibers as being "wearable," "modern," and "rich."

The specific structure of hemp fiber and the content of additional substances (lignin, pectin), which is much higher in hemp than in cotton, worsen their "spinnability" and affect the quality of the products. Being longer and thicker than cotton or wool fibers, hemp fibers require different technology for fiber processing. However, traditional bast spinning technology is labor-intensive and unproductive, and therefore, the machinery to produce hemp fibers is currently out-of-date without

significant investments in the development of more productive equipment. For the aim to introduce hemp fibers to the area of high-added value products, efforts have been made to develop new technology for hemp fiber processing. Its key point is the hemp fiber elementarization (cottonization and woollenization) or, in other words, the individualization of technical fibers to elementary fibers with simultaneous separation of noncellulose substances to achieve the fineness and flexibility necessary for textiles (Jinqiu & Jianchun, 2010). Fiber modification can be realized in several ways using mechanical, chemical, or biological (enzymatic) treatments (Kozlowski et al., 2005). By this modification, the hemp fibers become cleaner and softer with improved flexibility, resembling cotton fibers, which enables their processing on highly productive cotton or wool spinning systems. Improved spinnability of the cottonized (woollenized) hemp fibers allows for the production of pure hemp yarns or yarns blended with cotton (or cotton-like) or wool (or wool-like) fibers, with linear density ranging from 50 to 100 tex (Cierpucha et al., 2004).

Research efforts and technological advances led not only to the involvement of hemp fiber in the high-quality clothing sector but also resulted in the expansion of the product range in other sectors of hemp fiber usage. From thermal and acoustic insulation materials (Gutierrez-Moscardo et al., 2022), the hemp product range has been expanded to hemp concrete (hempcrete) and various sorts of building materials such as blocks and bricks, wallboards, roofing tiles, etc. These products are lightweight, durable, water- and fireproof, highly breathable, self-insulating, and resistant to mold and pests (Crini et al., 2020; Ingrao et al., 2015). Besides, numerous novel products for diverse applications have been developing recently, such as biosorbents (Morin-Crini et al., 2019), bioplastics (Wibowo et al., 2004), bioethanol (Das et al., 2017), geotextiles, and various composite materials. Hemp fibers are involved in a wide range of composites for automotive, building, paper, etc., as either the matrix or the reinforcement in different forms such as mats (Ahmad et al., 2023), rovings (Corbin et al., 2020), yarns (Mussig et al., 2020), and fabrics (Miller, 2018; Misnon et al., 2015). Offering renewability, eco-friendliness, and mechanical properties comparable to synthetic fibers, hemp fibers can be effectively utilized for biocomposite (green composite) materials (Ead et al., 2021). Some contemporary research offers innovative hemp uses, such as fillers for 3D printing pastes (Sabbatini et al., 2021), and components in lithium-ion batteries (Wang et al., 2022; Toprakci & Toprakci, 2021).

Despite the challenges that hemp faces, its potential presented in this text points to the bright future of the modern hemp market. Despite numerous hemp products on the market, the full potential of hemp fibers has not been realized, and there is therefore still a need for research and development of new products and promising technologies. In addition, further efforts on balancing regulations in favor of legalizing the production of industrial hemp as an agricultural commodity are to be made.

3 Sustainability Aspects of Hemp

Over the recent years, with increasing public consciousness of sustainable societal development, no one in the world can ignore anymore the apparent need for sustainable resource use, clean production, and the development of eco-friendly and healthy products. Hemp has already been recognized as a crop that fits well in the concept of sustainability (Amaducci et al., 2015). Several sustainability aspects can be considered about hemp. The fact that hemp is a multipurpose plant (all parts of the plant can be used or further transformed) makes it possible for their processing to generate zero waste. Hemp is one of the fastest-growing plants with 70–90 days' cropping period and a high yield of 25 tons of fiber matter per hectare (Ahmed et al., 2022). It can be grown worldwide in a wide range of environmental conditions in many different types of soil while offering several agricultural benefits such as good crop rotation and weed management. Hemp is very competitive against weeds due to its extensive root system and fast growth, which makes it ideal for organic farming (Ranalli & Venturi, 2004). When grown in rotation with other crops, hemp adds value to the following crop by reducing weed and insect pressure as well as increasing the next crop yield. It has been proven that hemp has a positive effect as a preceding crop of cereals and soybean (Amaducci et al., 2015). In addition, hemp has bioremediation ability or the capacity to accumulate heavy metals (mainly in the roots) from the soil with no detrimental effect on the yield and quality of the crop (Cleophas et al., 2023). Kozlowski et al. (1994) have shown in their studies that hemp can be used for the restoration of contaminated land (removal of copper, zinc, cadmium, and lead from the soil) with further use of hemp biomass in the pulp and paper industry. The contaminated biomass with an elevated content of heavy metals does not imply necessarily a negative effect on human health and the environment if it is used in biofuel, building, paper, and furniture industries. However, hemp fibers with increased content of heavy metals should not be used in the textile clothing sector due to some health risks (Angelova et al., 2004). Life cycle analysis of the environmental impacts of hemp and seven other arable crops (sunflower, rapeseed, pea, wheat, maize, potato, and sugar beet) indicated that hemp is a low-input and low-impact crop in terms of eutrophication, climate change, acidification, terrestrial ecotoxicity, energy use, and land use (van der Werf, 2004). It has been shown that hemp has minimal impact on nutrient removal and pesticide use. In addition, hemp cultivation has a medium impact on biodiversity and water consumption. The hemp plants can return to the soil about 70% of the nutrients needed for their growth (Rehman et al., 2021). As a fast-grown and high-biomass crop, hemp is one of the fastest CO_2-to-biomass converters. It can absorb more CO_2 (per hectare) from the atmosphere than any other commercial crops (including forests), improving air quality and thermal balance. It has been stated that one hectare of hemp can absorb about 22 tons of CO_2 per hectare and store it in the stem and root of the plant through bio-sequestration (Adesina et al., 2020).

Nowadays, cotton fiber is the most widely used natural fiber in the textile industry representing about 40% of the total fibers consumed in the textile industry

(Bevilacqua et al., 2014). However, the growing of cotton crop requires intensive irrigation and high levels of pesticide and fertilizer use. It has been reported that 1 ton of cotton production consumes 6 kg of pesticides, 290 kg of fertilizers, and 2300 m^3 of water (Dong et al., 2016). Although cotton is grown on only 2.5% of the world's arable land, its cultivation accounts for 25% of the world's total insecticide consumption, 45% of global greenhouse gas emissions, and 80% of total water consumption in the textile sector (Garcia et al., 2019). On the other hand, hemp was recognized as a low-maintenance crop requiring low inputs (water, agrochemicals). In the study conducted by Cherrett et al. (2005), the overall water requirement for the production of 1 kg of hemp fiber is 2123 L, in contrast to the water requirement for cotton which is about 10,000 L/kg. Schumacher et al. (2020) demonstrated in their analysis that the lowest water requirement needed per cotton's growing season was 2.5 times that of hemp's lowest water requirement. Besides, hemp productivity is much greater with a yield of up to 3 tons of dry fiber per hectare as compared to 1.35 tons of cotton lint per hectare (Cherrett et al., 2005). By calculating the crop total life cycle, which included both the direct impact of hemp production on the environment and the impacts connected with the manufacture and transport of the inputs needed for hemp cultivation, Smit-Heisters (2008) confirmed the low input and low environmental impact of hemp grown for fiber. According to the ecological footprint, which takes into consideration the demand of land area compared to the available supply on earth (the world average productive hectares), measured in global hectares (gha), hemp fiber represents a lower ecological footprint with 1.46–2.01 gha than that of cotton fiber which is 2.17 gha for organic and 3.57 gha for conventional cotton (Smit-Heisters, 2008). This can be mainly attributed to the yield of hemp fibers since it is possible to produce three times the amount of hemp fiber as cotton from the same land area. La Rosa and Grammatikos (2019) supposed in their research that the impacts involved in the production of hemp fibers would reasonably be lower than the impacts associated with organic cotton. To analyze the economic aspect of sustainability, Schumacher et al. (2020) systematically analyzed the cost associated with agricultural activities representing the first stage of the complex supply chain of hemp and cotton fibers. Agricultural activities included four main cost inputs – field preparation including fertilization, cultivation and seed, water consumption, and pest control costs. They provided supporting evidence in favor of hemp fiber as a sustainable alternative to cotton in terms of economic competitiveness since the agricultural activities' costs of hemp fiber are 77.63% less than those of cotton fiber.

Despite all the environmental benefits elaborated in the previous paragraphs, in 2019, the percentage share of hemp concerning all natural fibers was 1.7% (60,000 tons of hemp fiber and tow) representing only 0.05% of all world textile fiber production (Zimniewska, 2022). The major causes are regulatory issues and price. As a consequence of hemp incomprehension in some regions of the world in which hemp cultivation is still prohibited, the distribution chain of industrial hemp lacks continuity. The cost of hemp fiber production ranges from 357.25 USD/t to 2100 USD/t, while cotton cost production is in the range from 1500 USD/t to 4200 USD/t (Schumacher et al., 2020; Vaisanen et al., 2017). However, the approximate prices

for plain hemp textiles are between 5 and 13 USD/kg (Santulli, 2019). The transformation of the fiber to textile fabric comprises several processes such as fiber preparation for spinning, weaving (knitting), and various finishing procedures that require energy, water, and chemical additives. It seems that hemp textiles are left behind in terms of technological development as compared to other end-use applications of hemp. The bottleneck for the hemp textile value chain is spinning, which makes the end price of hemp fabrics much higher than comparable cotton products. More than half of the total cost of yarn production comes from the fiber cost (Lord, 2000). However, the production of hemp yarn required significantly higher energy consumption as compared to cotton yarn due to relatively intense processing (Cherret et al., 2005). The necessity for the effective extraction of the fibers from hemp stalks places hemp at a disadvantage as compared to cotton fiber. For the traditional technology of hemp yarn production by wet spinning, the retting of fibers is unavoidable, which is considered to have a high environmental impact due to high water use and high oxygen demand of the wastewater (Spooner et al., 2005). In addition to ecological issues, the retting process is costly, long-lasting, and labor-intensive. The traditional hemp spinning systems are low productive and require a very specialized machine park that cannot be used in other spinning systems. As a consequence, there is a lack of modern harvesting and hackling and other specialized relevant machines for long hemp fibers. To avoid these constraints, the fiber extraction process is improved by developing the decortication system, which implies the mechanical extraction of fibers from raw non-retted hemp stalks (breaking the woody parts and mechanical separation of the fibers). This simple decortication process delivers ribbons of fibers which are further processed and degummed by wetting, chemical, or enzyme treatment. Whichever degumming treatment is applied, the fiber complexes divide into almost elementary fibers deliberated of noncellulose substances, which make them suitable to be processed on the cotton or woolen spinning systems. Such a development direction enabled the production of fine pure hemp yarns or yarns blended with cotton, wool, or staple chemical fibers. Costs of hemp fiber modification (cottonization or woollenization) are compensated by the fact that the fibers can be processed on more productive machinery as compared to the traditional ones as well as by the possibility of designing specific fiber blends. A degree of refined hemp fiber fineness allows the spinning of yarns with linear density between 50 and 20 tex, which is necessary for the aim of introducing hemp into the high-quality clothing sector (Ranalli & Venturi, 2004).

In conclusion, technological development seems crucial for the further development of the hemp textile industry. To maximize both the final product's performance and the economic value of hemp, sustained efforts are being made to reduce cost, labor requirements, and environmental impact, starting from the crop stage to the hemp product development stage. The evaluation of the environmental impacts of some hemp yarn production scenarios showed that a reduction in eutrophication in the crop production, as well as the reduction in energy use in the fiber processing and yarn production stages, can contribute to a reduction in the environmental impacts (Van der Werf & Turunen, 2008). To increase crop yield and hemp fiber

quality, agronomic practices and genotypes have been continuously adopted (Leoni et al., 2022). Harvesting techniques and degumming methods are targeted as being important factors for improving fiber quality and reducing labor requirements, production costs, and environmental pollution (Qin et al., 2022; Musio et al., 2018). Therefore, attempts are being made to improve hemp fiber processability (decorticability) and yarn production by developing more productive equipment and reducing energy costs (Lu et al., 2014). Although Ceyhan et al. (2022) have recently shown that processing hemp by modern technology is economically viable, the maximal potential for economic growth has not been reached yet. There is no doubt that there is still room for technological progress.

In addition to technological development and legal regulation in the industrial hemp sector, efforts toward increasing consumer awareness about positive health and sustainability aspects of hemp textiles are to be made although the public appears to be somewhat familiar with some facts related to hemp, at least as shown by a short online survey about hemp involving students, their parents, employees in education (or other sectors), and pensioners, all from Serbia. The first question in the survey was about the respondent's first association related to hemp. The next question was about the respondent's awareness of the hemp controversy. The last two questions were related to a participant's familiarity with the comfort of hemp clothing as well as with the sustainability aspects of hemp. A hundred responses were collected for each question in the survey. Knowledge about the versatility of hemp prevailed in the results of the survey (70% of the total number of answers to the first question). The respondents were also quite aware of the controversy caused in public due to hemp incomprehension (60%). When it comes to sustainability, the environmental benefits such as biodegradability and safety (health) of hemp due to its natural origin were predominated in the responses.

With increased consumer awareness of sustainability issues, the growing trend in sustainable resource use and production will continue. Therefore, the interest of textile suppliers and producers is to meet consumers' demand for more sustainable, comfortable, and healthy textiles. When it comes to the hemp textile sector, all stakeholders should have a proactive role in marketing hemp products to actively encourage consumers to buy and use them. A coordinated effort of scientists, engineers, and decision-makers in the agro- and textile industry production chain needs to continue to respond successfully to the global goal of achieving and preserving the well-being of humankind.

Acknowledgments This work was supported by the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia (Contract No. 451-03-47/2023-01/200135). The author would like to thank all the online survey participants.

References

Adesina, I., Bhowmik, A., Sharma, H., & Shahbaz, A. (2020). A review on the current state of knowledge of growing conditions, agronomic soil health practices and utilities of hemp in the United States. *Agriculture, 10*, 129. https://doi.org/10.3390/agriculture10040129

Ahmad, F., Mushtaq, B., Ahmad, S., Rasheed, A., & Nawab, Y. (2023). A novel composite of hemp and alginate hydrogel for wound dressings. *Journal of Polymers and the Environment*. https://doi.org/10.1007/s10924-023-02756-7

Ahmed, A. T. M. F., Islam, M. Z., Mahmud, M. S., Sarker, M. E., & Isalm, M. R. (2022). Hemp as a potential raw material towards a sustainable world: A review. *Heliyon, 8*(1), e08753.

Amaducci, S., Scordia, D., Liu, F. H., Zhang, Q., Guo, H., Testa, G., & Cosentino, S. L. (2015). Key cultivation techniques for hemp in Europe and China. *Industrial Crops and Products, 68*, 2–16. https://doi.org/10.1016/j.indcrop.2014.06.041

Angelova, V., Ivanova, R., Delibaltova, V., & Ivanov, K. (2004). Bio-accumulation and distribution of heavy metals in fibre crops (flax, cotton and hemp). *Industrial Crops and Products, 19*, 197–205. https://doi.org/10.1016/j.indcrop.2003.10.001

Baldini, M., Ferfuia, C., Piani, B., Sepulcri, A., Dorigo, G., Zuliani, F., Danuso, F., & Cattivello, C. (2018). The performance and potentiality of monoecious hemp (*cannabis sativa* L.) cultivars as a multipurpose crop. *Agronomy, 8*, 162.

Bevilacqua, M., Ciarapica, F. E., Mazzuto, G., & Paciarotti, C. (2014). Environmental analysis of a cotton yarn supply chain. *Journal of Cleaner Production, 82*, 154–165. https://doi.org/10.1016/j.jclepro.2014.06.082

Ceyhan, V., Turkten, H., Yildirim, C., & Canan, S. (2022). Economic viability of industrial hemp production in Turkey. *Industrial Crops and Products, 176*, 114354. https://doi.org/10.1016/j.indcrop.2021.11.114354

Cherrett, N., Barrett, J., Clemett, A., Chadwick, M., & Chadwick, M. (2005). *Ecological footprint and water analysis of cotton, hemp and polyester*. Report prepared for and reviewed by BioRegional Development Group and WWF Cymru. https://mediamanager.sei.org/documents/Publications/SEI-Report-EcologicalFootprintAndWaterAnalysisOfCottonHempAndPolyester-2005.pdf. Accessed 15 Dec 2022.

Cierpucha, W., Kozłowski, R., Mankowski, J., Wasko, J., & Mankowski, T. (2004). Applicability of flax and hemp as raw materials for production of cotton-like fibres and blended yarns in Poland. *Fibres Text Eastern Eur, 12*, 13–18.

Cleophas, F. N., Zahari, N. Z., Murugayah, P., Rahim, S. A., & Yatim, A. N. M. (2023). Phytoremediation: A novel approach of bast fiber plants (hemp, kenaf, jute and flax) for heavy metals decontamination in soil – A review. *Toxics, 11*(1), 5. https://doi.org/10.3390/toxics11010005

Corbin, A.-C., Ferreira, M., Labanieh, A. R., & Soulat, D. (2020). Natural fiber composite manufacture using wrapped hemp roving with PA12. *Materials Today: Proceedings, 31*, 5329–5334. https://doi.org/10.1016/j.matpr.2020.02.307

Crini, G., Lichtfouse, E., Chanet, G., & Morin-Crini, N. (2020). Applications of hemp in textiles, paper industry, insulation and building materials, horticulture, animal nutrition, food and beverages, nutraceuticals, cosmetics and hygiene, medicine, agrochemistry, energy production and environment: A review. *Environmental Chemistry Letters, 18*, 1451–1475. https://doi.org/10.1007/s10311-020-01029-2

Das, L., Liu, E., Saeed, A., Williams, D. W., Hu, H., Li, C., Ray, A. E., & Shi, J. (2017). Industrial hemp as a potential bioenergy crop in comparison with kenaf, switchgrass and biomass sorghum. *Bioresource Technology, 244*, 641–649.

Dong, Z., Hou, X., Haigler, I., & Yang, Y. (2016). Preparation and properties of cotton stalk bark fibers and their cotton blended yarns and fabrics. *Journal of Cleaner Production, 139*, 267–276. https://doi.org/10.1016/j.jclepro.2016.08.035

Ead, A. S., Appel, R., Alex, N., Ayranci, C., & Carey, J. P. (2021). Life cycle analysis for green composites: A review of literature including considerations for local and

global agricultural use. *Journal of Engineered Fibers and Fabrics, 16*, 1–20. https://doi.org/10.1177/15589250211026940

Fugazza, M., Nkurunziza, J., Mirizzi, F., & Riboulet-Zemouli, K. (2022). *Commodities at a glance: Special issue on industrial hemp*. United Nations. Available at https://unctad.org/system/files/official-document/osginf2022d1_en.pdf. Accessed 15 Dec 2022.

Garcia, S., Cordeiro, A., de Alencar, N. I., & de Oliveira Costa Neto, P. L. (2019). The sustainability awareness of Brazilian consumers of cotton clothing. *Journal of Cleaner Production, 215*, 1490–1502. https://doi.org/10.1016/j.jclepro.2019.01.069

Gutierrez-Moscardo, O., Canet, M., Gomez-Caturla, J., Lascano, D., Fages, E., & Sanchez-Nacher, L. (2022). Sustainable materials with high insulation capacity obtained from wastes from hemp industry processed by wet-laid. *Tex Res J, 92*(7–8), 1098–1112. https://doi.org/10.1177/00405175211046058

Ingrao, C., Giudice, L. A., Bacenetti, J., Tricase, C., Dotelli, G., Fiala, M., Siracusa, V., & Mbohwa, C. (2015). Energy and environmental assessment of industrial hemp for building applications: A review. *Renewable and Sustainable Energy Reviews, 51*, 29–42. https://doi.org/10.1016/j.rser.2015.06.002

Jinqiu, Z., & Jianchun, Z. (2010). Effect of refined processing on the physical and chemical properties of hemp bast fibers. *Textile Research Journal, 80*(8), 744–753. https://doi.org/10.1177/0040517509342317

Johnson, R. (2018). *Hemp as an agricultural commodity*. Congressional Research Service: Washington, DC, USA, https://sgp.fas.org/crs/misc/RL32725.pdf. Accessed 15 Jan 2023.

Ju, J., Jin, B., & Cho, H. (2016). US consumers' subjective hand, sensibility, and preference for textile products made of bast fiber. *Journal of the Textile Institute, 107*(12), 1554–1564. https://doi.org/10.1080/00405000.2015.1129780

Kozlowski, R., Grabowska, L., Baraniecki, P., & Mscicz, J. (1994). Recultivation by flax and hemp culture of soil polluted by heavy metals. *Natural Fibers*, 159–164.

Kozlowski, R., Baraniecki, P., & Barriga-Bedoya, J. (2005). Microbial processes in the degradation of Fibres. In R. S. Blackburn (Ed.), *Biodegradable and sustainable fibres* (pp. 36–88). Woodhead.

La Rosa, A. D., & Grammatikos, S. A. (2019). Comparative life cycle assessment of cotton and other natural fibers for textile applications. *Fibers, 7*(12), 101. https://doi.org/10.3390/fib7120101

Leoni, M., Musio, S., Croci, M., Tang, K., Magagnini, G. M., Thouminot, C., Mussig, J., & Amaducci, S. (2022). The effect of agronomic management of hemp (Cannabis sativa L.) on stem processing and fibre quality. *Industrial Crops and Products, 188*, 115520. https://doi.org/10.1016/j.indcrop.2022.115520

Lord, P. R. (2000). *Handbook of yarn production*. Woodhead Publishing Ltd..

Lu, J., Long, C., Ma, L., Liu, J., & He, H. (2014). Design and experiment on decorticator of hemp fresh stem. *Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering, 30*(14), 298–307. https://doi.org/10.3969/j.issn.1002-6819.2014.14.037

Manaia, J. P., Manaia, A. T., & Rodriges, L. (2019). Industrial hemp fibers: An overview. *Fibers, 7*, 106.

Miller, S. (2018). Natural fiber textile reinforced bio-based composites: Mechanical properties, creep, and environmental impacts. *Journal of Cleaner Production, 198*, 612–623. https://doi.org/10.1016/j.clepro.2018.07.038

Misnon, M. I., Islam, M. M., Epaarachchi, J. A., & Lau, K. T. (2015). Analyses of woven hemp fabric characteristics for composite reinforcement. *Materials Design, 66*, 82–92. https://doi.org/10.1016/j.matdes.2014.10.037

Morin-Crini, N., Loiacono, S., Placet, V., et al. (2019). Hemp-based adsorbents for sequestration of metals: A review. *Environmental Chemistry Letters, 17*, 393–408. https://doi.org/10.1007/s10311-018-0812-x

Musig, J., Amaducci, S., Bourmaud, A., Beaugrand, J., & Shah, D. U. (2020). Transdisciplinary top-down review of hemp fibre composites: From an advanced product design to crop variety selection. *Composite Part C: Open Access, 2*, 100010. https://doi.org/10.1016/j.jcomc.2020.100010

Musio, S., Mussig, J., & Amaducci, S. (2018). Optimizing hemp fiber production for high performance composite applications. *Frontiers in Plant Science, 9*, 1702. https://doi.org/10.3389/fpls.2018.01702

Qin, Z., Zhao, S., Chi, H., Ma, L., Liu, L., Zhang, R., & Cheng, L. (2022). Process optimization and recyclable utilization of organic solvent for the green degumming of hemp. *Industrial Crops and Products, 188*, 115594. https://doi.org/10.1016/j.indcrop.2022.11559

Ranalli, P., & Venturi, G. (2004). Hemp as a raw material for industrial applications. *Euphytica, 140*, 1–6.

Rehman, M., Fahad, S., Du, G., Cheng, X., Yang, Y., Tang, K., Liu, L., Liu, F.-H., & Deng, G. (2021). Evaluation of hemp (*Cannabis sativa* L.) as an industrial crop: A review. *Environmental Science and Pollution Research, 28*, 52832–52843. https://doi.org/10.1007/s11356-021-16264-5

Sabbatini, B., Cambriani, A., Cespi, M., Palmieri, G. F., Perinelli, D. R., & Giulia Bonacucina, G. (2021). An overview of natural polymers as reinforcing agents for 3D printing. *Chemical Engineering, 5*(4), 78. https://doi.org/10.3390/chemengineering5040078

Sadrmanesh, V., & Chen, Y. (2019). Bast fibres: Structure, processing, properties and applications. *International Materials Reviews, 64*(7), 381–406. https://doi.org/10.1080/09506608.2018.1501171

Santulli, C. (2019). Mechanical and impact damage analysis on carbon/natural fibers hybrid composites: A review. *Materials, 12*, 517. https://doi.org/10.3390/ma12030517

Schumacher, A. G. D., Pequito, S., & Pazour, J. (2020). Industrial hemp fiber: A sustainable and economical alternative to cotton. *Journal of Cleaner Production, 268*, 122180. https://doi.org/10.1016/j.clepro.2020.122180

Sebastian, J. S. V., Dong, X., Trostle, C., Pham, H., Joshi, M. V., Jessup, R. W., Burow, M. D., & Provin, T. L. (2023). Hemp agronomy: Current advances, questions, challenges, and opportunities. *Agronomy, 13*, 475. https://doi.org/10.3390/agronomy13020475

Smith-Heisters, S. (2008). Environmental costs of hemp prohibition in the United States. *Journal of Industrial Hemp, 13*(2), 157–170. https://doi.org/10.1080/15377880802391308

Sponner, J., Toth, L., Cziger, S., & Franck, R. R. (2005). Hemp. In R. R. Franck (Ed.), *Bast and other plant fibres* (pp. 176–206). Woodhead Publishing Ltd..

Toprakci, O., & Toprakci, H. A. K. (2021). Anode performance of sustainable, hemp-derived, elexible, binder-free, carbon fabrics in lithium-ion batteries. *International Journal of Environment and Geoinformatics, 8*(1), 28–32. https://doi.org/10.30897/ijegeo.796743

Vaisanen, T., Das, O., & Tomppo, L. (2017). A review on new bio-based constituents for fiber-polymer. *Journal of Cleaner Production, 149*, 582–596.

Van der Werf, H. M. G. (2004). Life cycle analysis of filed production of fibre hemp, the effect of production practices on environmental impacts. *Euphytica, 140*, 13–23.

Van der Werf, H. M. G., & Turunen, L. (2008). The environment impacts of the production of hemp and flax textile yarn. *Industrial Crops and Products, 27*, 1–10. https://doi.org/10.1016/j.indcrop.2007.05.003

Wang, Z., Zhang, P., Chen, S., Usman, K. A. S., Hegh, D., Kerr, R., Zhang, H., Qin, S., Zhang, C., Liu, D., Wang, X., Lei, W., & Razal, J. M. (2022). Highly stable lithium anodes from recycled hemp textile. *Chemical Communications, 58*, 1946. https://doi.org/10.1039/d1cc05928a

Wibowo, A. C., Cho, S. W., Hedenqvist, M. S., et al. (2004). Choped industrial hemp fibers reinforced cellulosic plastic biocomposites: Thermomechanical and morphological properties. *Industrial and Engineering Chemistry Research, 43*, 4883–7888.

Zhao, X., Wei, X., Guo, Z., Qiu, C., Long, S., Wang, Y., & Qiu, H. (2022). Industrial hemp – An old but versatile bast fiber crop. *Journal of Natural Fibers, 19*(13), 6269–6282. https://doi.org/10.1080/15440478.2021.1907834

Zimniewska, M. (2022). Hemp fibre properties and processing target textile: A review. *Materials, 15*(5), 1901. https://doi.org/10.3390/ma15051901

A Long-Time Approach to Promote Sustainability Awareness

Carolyn Hardaker, Buddy Penfold, and Sally Gaukrodger-Cowan

Abstract Environmental activism and the widespread acknowledgment of the impact of pollution from fashion and textile industries have driven an educational sustainability directive that promotes designer, buyer, and consumer awareness.

Centered on a long-time approach that encourages cathedral style thinking and the concept of being a good ancestor (Krznaric, 2020), contrasts sharply with current fast fashion practices. Long-time advocates Saltmarshe and Pembroke (2018) state "short termism is rapidly becoming an existential threat to humanity," while Fletcher (2010) suggests that developing systems' change for the fashion sector provides an opportunity to promote a slower culture.

At De Montfort University, the School of Fashion and Textiles has been acknowledged as a leader in sustainability education, with a "Green Gown Award for Next Generation Learning and Skills," (Sustainability Exchange, 2021), and recognizes that it is the responsibility of educators to ensure future designers and buyers are aware of the criticality of their professional decisions over their careers and the impact these decisions can have on consumers.

Based on long-time thinking, this chapter outlines a sustainability awareness case study that was initiated as a co-creation opportunity with buying and design staff and students. Launched in 2019 as T-extinction, the project was a provocation to think ahead to the year 2090, a time when the current students would be in their elder years and able to reflect on their careers. The first iteration involved fashion buying academics and students who set themselves the challenge to identify products or processes that would be extinct or taboo by 2090 (Hardaker et al., 2022). This negative premise led to positive thinking for the next iteration, where treasured textiles and associated craft skills are considered as heirlooms (Mignosa & Kotipalli, 2019), and has an immediate synergy with long-time thinking. Textile design students and academics developed this further to consider the fate of endangered crafts

C. Hardaker (✉) · B. Penfold · S. Gaukrodger-Cowan
School of Fashion and Textiles, De Montfort University, Leicester, UK
e-mail: chh@dmu.ac.uk; bpenfold@dmu.ac.uk; SGaukrodger-Cowan@dmu.ac.uk

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0_4

and developed innovative methods to revitalize them to ensure they would still be in existence in the year 2090.

The co-creation of responses and the promotion of the project, across social media platforms and through physical exhibitions in Leicester, showed that the thought-provoking memorable visual statements created and resonated not only with the student and academic audience but with fashion consumers. First, this chapter sets the environmental and industry contexts, followed by a review of current academic pedagogy and the philosophy of long-time thinking and its influence on education. The paper concludes with an educational case study that argues the value of a long-time thinking as a means of developing both industry professionals and consumer awareness of the environmental challenges posed by current fashion and textile industry practices.

Keywords Sustainability · Long-time thinking · Fashion · Textiles · Craft · Pedagogy · Fast fashion · Consumption

1 Introduction

Environmental activism and the widespread acknowledgment of the impact of pollution from fashion and textile industries have driven an educational sustainability directive that uses a long-time approach to promote fashion designer, buyer, and consumer awareness. This chapter starts by summarizing the background context to current fashion consumption with a focus on UK consumers, who are acknowledged to "buy more clothes per person than any other country in Europe" (UK Parliament, 2019). Major global political protocols to limit climate change have been agreed over the last 30 years; against this background, the concurrent globalization of the fashion industry and proliferation of the fast fashion business model are explored. The influence of fashion activism during this period and the increasing recognition of the value of circular methods are considered with the first section concluding with a discussion of the current retail landscape and a summary of the level of sustainability awareness of the UK consumer.

This is followed by a review of published research into the educational response to the climate crisis and the changing fashion industry. Influential stakeholders' guidance on embedding sustainability into higher education is summarized including the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (2018) who specified eight sustainable competencies.

The timescale of industry response to sustainability and even global agreements are short to medium term within one generation. The concept of a long-time model, which has a longer time span, greater than that of a typical human being is outlined which through its altruistic nature presents an innovative alterative. A long-time approach is explored in a case study of a sustainability initiative developed in the

School of Fashion and Textiles at De Montfort University in Leicester. Working on an extended time frame provided the provocation for an extracurricular project with fashion buying and design staff and students. De Montfort University's School of Fashion and Textiles is an acknowledged leader in sustainability education, with a Green Gown Award for Next Generation Learning and Skills (Sustainability Exchange, 2021), and recognizes that it is the responsibility of educators to ensure future designers and buyers are aware of the criticality of their professional decisions over their careers and the impact these decisions can have on consumers.

The final section reviews the efficacy of the long-time approach as a means of promoting sustainability awareness and suggests that by reviewing impact in this way across a range of educational initiatives provides a thought-provoking method to develop future industry professionals and consumer awareness of the environmental challenges posed by current fashion and textile industry practices.

2 Background Context

The eminent UK economist Paul Elkins in an early paper posed the question. "A sustainable consumer society: Contradiction in terms?" (Elkins, 1991). It is interesting to see the issues and complexities involved in this statement that hold so much potency in the 2020s were emerging 30 years ago. This section summarizes this context, considering the timeline of global agreements to limit the impact of climate change and the concurrent globalization of the fashion industry. Consumption is considered from a societal perspective, while the impact of climate activism in raising levels of consumer awareness in the face of mass production is discussed. The section concludes by outlining the current zeitgeist which includes a maelstrom of greenwashing alongside positive change.

2.1 Global Political Agreements

The impact of global warming on climate change caused by CO_2 emissions has been increasingly reported by the scientific community throughout the twentieth century. The accumulating evidence initiated the first global political response in 1987 with the establishment of the Intergovernmental Panel on Climate Change (IPCC) by the United Nations Environment Programme and the World Meteorological Organization (IPCC, 2003). The panel's initial remit was to review the current knowledge and the economic and social impact of climate change and to consider potential responses; the panel sets the foundations for global treaties and pacts. Through this work, the United Nations was instrumental in achieving the first political consensus to these challenges. The Kyoto Protocol, agreed in 1997, was the first international treaty to set legally binding targets to cut greenhouse emissions (United Nations, 1998). Superseded by Paris agreement in 2015, this has been adopted by 194 parties, "with

a view to reducing greenhouse emissions limiting the global temperature rise to 2 degrees in the twentieth century" (United Nations, 2023a, b, c). The Paris agreement was developed further in 2021, with the Glasgow Climate Pact aiming to limit global warming to 1.5 degrees, along with financial agreements whereby developed countries would provide support to developing countries to achieve the climate goals (United Nations, 2023a, b, c). These ambitions were further honed at COP27 hosted in Egypt in 2022.

2.2 Fast Fashion Business Model

Within this backdrop of political agreements, the early 1990s saw exponential growth in the production of clothing and footwear with many European and American retailers adopting a fast fashion business model. Peters et al. (2021) note that retailers saw there were opportunities in low-wage countries in Asia to outsource production. Offshoring of manufacturing enabled manufacturers to cut the costs of production significantly setting the scene for the fast fashion production model. By introducing many more seasons into the fashion calendar, providing more collections, fast fashion provides consumers with a wide range of choice, and a rapid turnaround of trends with the garments brought to market rapidly. The model is linear creating garments are cheap to buy, constructed from virgin low-quality synthetic often blended fabrics with in the early days no consideration given to a garment's end of life.

Currently, it is estimated that the revenue generated by the global fashion industry is $1.74 trillion dollars in 2023 and is projected to rise to $1.94 trillion dollars by 2027 (Smith, 2022a). This is for an industry producing an estimated 100,000 billion garments per year (Igini, 2022) for a global population of 8 billion people (United Nations, 2023a, b, c).

The fast fashion phenomenon has been fueled by e-commerce developments that have substantially altered the retail landscape in the twenty-first century. The move to omnichannel retailing was happening prior to the Covid-19 pandemic in 2020, with the digitization of the fashion industry accelerating throughout the pandemic. Indeed, McKinsey and Company entitle their 2020 annual report, "Fashion's digital transformation: Now or Never" (Gonzalo et al., 2020). They warn "that some companies will not survive the current crisis, others will emerge better positioned for the future, with much will depending on their digital and analytics capabilities." The shift to e-commerce has led to new marketing methods to entice consumers to purchase product (Guercini et al., 2018). Note that these include IT technologies such as search engine marketing, social media marketing, and the role of fashion influencers which are key areas of activity in addition to the need for online and offline activities to be integrated to provide the consumer with a seamless experience.

This activity has resulted in fast fashion businesses such as Inditex and H&M operating across the globe selling the same product at the same time to billions of consumers. To appreciate the scale of this, Inditex have currently 5815 stores

worldwide in 2022 (Smith, 2022b) producing 24 new collections a year, with sales of $32.57 billion dollars.

As a consequence of this globalization of manufacturing, Ritzer (2003) comments on the loss of local cultural capital. He notes that the ambition for growth by a corporation results in the proliferation of the homogenous which in the case of the fast fashion business model means that the same styles are available across the globe.

2.3 Fashion Consumption in the UK

The fast fashion business model including all its marketing ramifications has resulted in fashion consumption patterns changing immeasurably over the last 20 years. A prolific supply has the corresponding demand, with fast fashion consumers offered a myriad of choice, buying large numbers of garments, which they wear a small number of times before discarding. The fast fashion model has been seen to democratize fashion. Sumner (2019) states "fast fashion has allowed all segments of society, irrespective of class, income, or background to engage in the hedonistic and psychogenic pleasures of fashion. At no other time in human history has fashion been so accessible to so many people across our society." In this context, the number of garments a consumer buys has increased dramatically since 2000, while the wears per garment have reduced. Barely used garments are accumulated in wardrobes in wealthy countries or are thrown away, destined to contribute to landfill.

The demand for this mass production of fashion product can be viewed in terms of consumer society model. This construct connects the purchasing of product to a consumers' well-being and position. Elkins (1991) states "a consumer society is one in which the possession and use of an increasing number and variety of goods and services is the principal cultural aspiration and the surest perceived route to personal happiness, social status, and national success." Further, Durning (1992) notes the uneven nature of consumption and defines three socioecological classes of consumers, over consumers, sustainers, and marginals. He states that at the time of the study, "the over consumers constituted a fifth of the world's population and were responsible for consuming 80% of the world's resources" (Durning, 1992).

Although the consumer society construct takes an extreme view, it is useful when considering fashion product consumption in connection with not only social status but other motivations including personal happiness. Throughout this fast fashion period, there is a link to perceived consumer well-being and overconsumption. Roach et al. (2019) states "that consumption is tied closely to personal identity and it has become a means of communicating social messages." Social comparisons fuel the purchasing of product with sophisticated advertising providing a never-ending array of content. Activities and behaviors such as shop 'til you drop" and "retail therapy" predominant in the early twenty-first century which encourage consumption reflect this link to consumer well-being. However, there is evidence mounting that presents a negative relationship between materialism and well-being. Roach et al. (2019) continue "while a higher income tends to be associated with greater

well-being, an excessive focus on money, status, and material possessions tends to lower well-being."

The scale of this global issue is viewed through the lens of the UK as a developed nation. In the UK, fashion consumption has risen from 3.93 billion pieces per year in 2020 to 4.2 billion pieces in 2023, with further rises projected to 4.33 billion pieces by 2026 (Smith, 2022c). The main factor driving these purchases is noted to be price. A recent report by Cure Media notes that product price is the most important factor for over a quarter of UK consumers when deciding whether to shop with a brand or not among fashion and lifestyle buyers. Recommendations, brand familiarity, the shopping experience, and quality of the marketing including social media content were rated more important than a brand's sustainability credentials and a brand's record on social justice which were the lowest rated factors (Farla, 2023).

2.4 Activism

Of course, the picture is complex, and there are many behaviors at play in the fashion product purchasing ecosystem. Voices connecting the threat of climate change with the actions of the fashion industry, alerting consumers to the environmental impact of overconsumption, have grown louder over the years. Early proponents of fashion-based climate change activisms came from the design community. Williams (2015) notes that Katharine Hamnett was one of the first designers to alert consumers to the harmful effects of the fashion system. In the late 1980s, Hamnett's clear ethos based on esthetic beauty and shared benefit connected the maker and the wearer. Also from the design community, Vivienne Westwood had continuously argued against excessive consumerism in the early 2000s. This high-profile designer highlighting the dangers of buying too many clothes was one of the first major commentaries on clothing consumption in the UK.

These and other individuals have significant platforms to raise consumers' awareness of sustainability issues, but it was the Rana Plaza garment factory collapse in 2013 that was a pivot for activism. The disaster brought global attention to the unsafe working conditions of garment industry workers making fast fashion product in Bangladesh, when the factory building collapsed killing over 1000 workers. This led to the founding of the Fashion Revolution, a nongovernment organization by fashion activists Carry Somers and Orsola de Castro. Today, Fashion Revolution, with their vision to develop a "fashion industry that conserves and restores the environment and values people over growth and profit," has charity status and attracts support from the British Council, the European Union, and the Laudes Foundation. The annual Fashion Transparency Index published on the platform reviews and rates 250 of the world's largest fashion brands and retailers according to the information they disclose about their social and environmental policies, practices, and impacts in their operations and supply chain (Fashion Revolution, 2023). They note that they have 800,00 followers across their digital platforms and their campaigns have brought about change, from EU policy to the industry responses to the transparency index through to cultural change.

The platform today is a leading independent voice setting the scene for many other movements such as the Fashion for Good Museum based in Amsterdam in the Netherlands, who promote a sustainable ethos through, their work to promote good materials, a good economy, good energy, good water, and good lives (Fashion for Good, 2023) and providing impartial information for individual consumers. The Ellen MacArthur Foundation is a major advocate of a move to a circular economy and states "through using design to eliminate waste and pollution, circulate products and materials, and regenerate nature, creating an economy that benefits people business and the natural world' (Ellen MacArthur Foundation, 2023). These voices have continued to grow over the years with activists with notable individuals such as Greta Thunberg and high-profile protest groups such as Extinction Rebellion alerting the public to climate change through national and international platforms.

2.5 The Current Zeitgeist

The current retail landscape is increasingly developing sustainability initiatives to tackle climate change. The consumer is presented with a plethora of activity, but as Sharpe et al. (2022) state "the problem is many sustainability initiatives still place economic opportunity and growth before environmental concerns."

Interestingly, the Worth Global Style Network (WGSN) fashion prediction platform noted in its 2021 report forecasting fashion industry implications by 2023 states "beyond embracing circular design and manufacturing systems and having a credible core assortment of low-impact products, it will be imperative that fashion brands can evidence their ongoing efforts to be more ethical and inclusive. Sector leaders will be marked out by how invested they are in actions that go beyond their own operations, particularly around areas such as boosting biodiversity, helping to restore the planet, and promoting social justice. Brands will need to collaborate equitably and respectfully with all their partners to attract consumers looking to align spending with values" (Hall, 2021).

2.5.1 Industry Developments

While brands and retailers are developing their marketing materials to include a sustainability message to their consumers, these are often confusing and sometimes misleading. The Generation Climate Europe note that greenwashing is "the practice of marketing a business as "green," "ethical," or "sustainable" without being able to substantiate such claims" (Green Climate Europe, 2021). The UK's Competition and Markets Authority is conducting an ongoing investigation into how products and services claiming to be eco-friendly are being marketed and whether consumers are being misled (Gov.UK, 2023). This presents a confusing picture for the consumer and highlighting the need for forthcoming European regulation unfair commercial practice directive, which will require a company to back up any sustainability claims with evidence (European Commission, 2023).

The activity to promote sustainability across the brands is intense, but there is little evidence of the impact of actions being taken. However, examples of good practice are in place and include designer Christopher Raeburn who presents a holistic treatment on their website, from fabrics that are responsibly sourced, are recycled, or are surplus military fabrics through to a free lifetime repair service (Raeburn, 2023). Other designers in the same space include luxury designer Stella McCartney, who started measuring the environmental impact of material choices in 2014 through the use of an environmental profit and loss tool (Stella McCartney, 2023).

In the meantime, NGOs such as "Good on You" with their rating system available online and as a mobile app help consumers to check the sustainability credentials of a brand or retailer. B Corp certification of a brand or retailer is increasingly being adopted and signifies exemplary environmental standards and measurements of impact (B Corporation, 2023).

Further, a coordinated industry approach is in operation in the UK. The Textiles 2030 Roadmap was launched in 2019 by NGO Wrap as an initiative to bring organizations from across the clothing and textile sectors together to collaborate on making rapid, science-based progress on climate action. With 115 companies signing up the 2021 annual reports present "a tale of two halves," this states that there was evidence of a reduction in percentage carbon footprint of the signatories; however, it was not sufficient to provide an overall reduction due to the rise in volume of product being produced (Wrap, 2022).

2.5.2 Sustainability in the Media

There is a plethora of articles alerting consumers to the climate impact of the fashion industry in the mainstream press. Consumers are implored to follow Vivienne Westwood's mantra to "Buy less. Choose well. Make it last. Quality, not quantity. Everyone buys far too many clothes" (Telegraph, 2013). A recent article by Sharpe et al. (2022) specifies that consumers should act in the following ways:

(a) Limit consumption and buy less.
Consumers are urged to think about the price per wear. Buy one expensive item with inherent quality and wear it more, rather than three or four cheaper items for the same price.
(b) Expand the slow fashion movement.
They are asked to choose well, this includes fabrics credentials, try to avoid blends that are difficult to recycle, and opt for organic cotton where possible. Consumers are tasked with thinking about their existing wardrobes and outfit building potential as well as learning repair techniques to make items last.
(c) Embrace exchange systems, which includes selling, swapping, and sharing clothes and renting clothes. Consumers are increasingly shopping for preloved garments at charity shops and dedicated online platforms such as Vinted and Depop.

(d) Celebrating the diversity of clothing cultures.
Nurturing the diversity of clothing cultures and indigenous fashion design which has respect for the environment at its core.

In summary, there is evidence that there is a level of sustainability awareness among fashion consumers in the UK. These consumers are used to a vast choice of product; they have many motivations for purchasing and can access a confusing array of information relating to sustainability. Many brands and retailers are trying to improve their sustainability credentials, with efforts to move toward circularity, the impact of these initiatives is largely unreported, while the volume of product being created is projected to increase. Navigating this position is a complex task and as Fashion for Good (2023) state "we believe that the paradigm shift needed within the industry is only possible when individuals and industry alike are activated for change." As Cooper (2019) notes in his statement to the UK parliament, reducing the demand for cheap short-lived garments will require wider public debate. The potential for education to play a key role in this shift is explored in the next section.

3 Literature Review

As the necessity to act for climate change impacts every aspect of life, the onus falls not only on fashion and textiles to address issues within their industry but also on the education institutions that train people who will work within those industries and retailers, to shape positive attitudes and initiatives to create a viable, sustainable fashion and textile sector.

This literature review will consider the following key three themes to promote sustainability awareness. The first is the responsibility of educators to ensure that future designers and buyers are aware of the criticality of their professional decisions over the length of their careers and the impact that these decisions can have to nudge change in consumer behaviors.

The second theme is encouraging the concept of a long-time approach and of being a good ancestor. This concept contrasts sharply with current fast fashion practices.

The third theme considers how craft can be valued as items that are used every day as opposed to mass produced items that may be changed and replaced often, contributing to landfill.

3.1 Responsibility of Education to Embed Sustainability in the Curriculum

The European Clothing Action Plan 2019 (ECAP) states that up to 80% of a product's environmental impact is through design (WRAP, 2019). ECAP was funded by the European Climate, Infrastructure, and Environment Executive Agency aiming to

reduce waste clothing in Europe and support the introduction of a circular economy. The plan advocates "design for longevity":

> Designers and product developers have the power to make change for the better. Design impacts how clothing and textiles are produced, how long they will remain wearable and whether they can be reused or recycled. (WRAP, 2019)

The desire for a change in the educational approach toward sustainable understanding is coming from three areas: academics, the students, and from the agencies that provide quality standards for higher education.

As educators acknowledge the stark reality of the environmental impact of their subject area, academics recognize the importance of embedding sustainability within the curriculum. Future design graduates can have the knowledge to make decisions at the start of the design process that ultimately creates changes within fashion and textile sector and therefore the long-term impact on the environment. This section considers the changes and initiatives that nudge the higher education initiatives (HEI) curriculum to embed sustainability, to prepare students to solve future sustainable challenges.

Since 2010, the National Union of Students has conducted a longitudinal survey on student attitudes. Final year students are asked to rate their university experience across educational, pastoral, and extracurricular experiences. The survey is extremely important for student feedback on overall satisfaction, and results influence strategic direction of universities. In 2018, questions on HEI activities to promote sustainability and inclusion of the United Nations Sustainable Development Goals (SDG) into the curriculum were added to the National Student Survey (NSS) as optional responses. The results of the 2021 survey show that 79% of students surveyed want sustainability to be embedded into the curriculum and 88% for sustainability to be promoted by the institution, and 66% want to learn more about sustainable development (National Union of Students, 2021). The addition of a question on sustainability demonstrates how understanding sustainability is viewed as a key part of education in all subject areas and something students want HEIs to deliver within subject areas. This has led to education agencies that set subject benchmark standards to publish advice on how HEIs can deliver education on sustainability.

Two agencies have been involved in the development of standards; AdvanceHE is a British charity that has over 400 memberships globally across higher and further education institutions which recognizes teaching excellence through professional awards and the Quality Assurance Agency for Higher Education (QAA), also a charity, which sets subject benchmarks. These influential agencies have published revised subject guidance for HEIs and have set the expectation that sustainability will be embedded into the curriculum and be a key part of education learning outcomes.

In March 2021, AdvanceHE worked with QAA to publish "education for sustainable development guidance" to support education institutions with the aim of supporting students from any discipline to acquire the knowledge, understanding, and skills necessary to develop values and take actions to transition society toward sustainable futures (Advance HE QAA, 2021).

The AdvanceHE and QAA document references the United Nations SDGs (UN, 2015) as guidance for the strategic aims of teaching sustainability, to advise HEI on practical methods to embed sustainability within the curriculum. UN SDG 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all, with SDG 4.7 promoting education for sustainable development and global citizenship.

The United Nations (UN) recognized the importance of the role of educators to support sustainable development. In 2012, the Higher Education Sustainability Initiative (HESI) was set up with four action groups: to share embedding sustainability into the curriculum, to consider rankings of the performance of higher education institutions in supporting the UN SDGs, supporting jobs that promoted sustainable practices, and promoting the SDGs through publications.

HEIs have traditionally been ranked according to their research profile. An indication of the acceptance by the stakeholders in education of the need for subject benchmarks to now include sustainability within teaching and assessment is in an additional ranking publication. Times Higher Education (THE) has delivered global HEI ranking since 2004. In 2019, THE rankings of higher education introduced a new ranking of impact. This additional ranking table sits alongside global rankings based on research and teaching, reviewed HEI performance against the UN SDGs (Times Higher Education, 2022).

As a result of this activity by academics, students, and influential agents for standards and educational policies, to recognize that sustainability needed to be embedded into the curriculum, current graduates will be educated on the impact of their choices on climate change for future generations. Academics are researching how universities can best integrate sustainability into not just the curricula but also their campuses. Dr. Andrew Reeves, from De Montfort University (DMU), is DMU's Project Director for education for sustainable development (ESD) and leads on the Environmental Sustainability theme for DMU's "Universities for Leicester" partnership with the University of Leicester. In his paper, "Classroom Collaborations: Enabling sustainability education via student-community co-learning," Dr. Reeves argues universities have a third purpose beyond teaching and research which is "collective action for the public" (Reeves, 2019):

> The sustainable development goals (UN, 2015) are increasingly used as a way of framing contemporary societal challenges within the higher education sector. Universities are well positioned to harness and integrate their education, research, operations and externally facing activities to contribute to the achievement of the goals. (Reeves, 2019)

Dr. Reeves argues that UK universities have potential to change in purpose from being seen in recent decades by students and the public as a degree leading to employability to also being an institution that is important to contribute to the city and to research solutions to contemporary challenges for societal good. The challenge is creating a curriculum that encourages a holistic view of education rather than purely subject focused.

Table 1 UNESCO sustainable competencies (UNESCO, 2018)

	UNESCO sustainable competencies
1	Systems thinking
2	(Future thinking) anticipatory
3	(Values thinking) normative
4	Strategic
5	Collaboration
6	Critical thinking
7	Self-awareness
8	Integrated problem-solving

In 2018, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) "education for sustainable development and the SDGs" identified eight sustainable competencies; see Table 1 (UNESCO, 2018).

Systems thinking competency is a holistic approach to problems which teaches the student to consider how situations and organizations are complex and part of very different components interacting, such as human relationships, different departments, different systems at work, and different drivers and outcomes. By applying this thinking to understanding the different aspects of sustainability, it helps students understand the complexity of considering solutions and therefore reflect on the impact of their actions. By reviewing real-world problems, educators are considering introducing systems thinking competency into the curriculum. Williams (2017) in his article on "Systems thinking: A Review of Sustainability Management Research" states:

> Systems thinking competence helps sustainability change agents to realize the complexity of social, environmental, and economic environments. Systems thinking competence helps leaders of organizations to realize the impacts of their actions on others. (Williams et al., 2017)

By embedding consideration of sustainable goals within modules and systems thinking competence on creative practical design degree programs, students can start to understand the complexity of decisions that influence sustainability within their own creative practice. Simple changes, such as adding a different yarn so there is single fiber use or using a different material choice for a component, can affect the ultimate sustainability of the product. The decision that designers make when, for instance, designing a garment, feeds into what happens to that garment in 5 or 10 years ahead; can it biodegrade? Does it become landfill? This, in turn, develops the competency of the student for future thinking (anticipatory competency), what aspects of design they need to understand and how they need to work with others (critical thinking competency and collaboration competency) to create sustainable products, but also to reflect on their own social values and role within the society (normative competency).

AdvanceHE defines education for sustainable development as:

> the process of creating curriculum structures and subject relevant content to support and enact sustainable development. (Advance HE QAA, 2021)

By introducing systems thinking competency into the learning outcomes within the curriculum, students experience deeper learning and an understanding of making informed decisions and how their actions actively can influence a sustainable future. This combined with incorporating the SDG goals into the curricula enable learners to understand that the decisions they make can be part of acknowledging that the resources that are being used within the fashion and textile industry are finite. As shown by the National Union of Students survey, students acknowledge that they need to learn about sustainability in order to be responsible in the decisions they make that will affect future of the planet:

> ESD empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity. It is about lifelong learning, and is an integral part of quality education. ESD is holistic and transformational education which addresses learning content and outcomes, pedagogy and the learning environment. It achieves its purpose by transforming society. (UNESCO, 2018)

3.2 Long-Time Approach

Embedding sustainability into the curriculum, influenced by the holistic method of systems thinking competency, emphasizes that future generations will have to deal with the long-time impact of decisions fashion and textile designers are making now. For that to change, sustainable values must be as important if not more important than economic considerations in order to limit the cost to future generations:

> Dealing with time is intimately linked to sustainability, because sustainability, at its core, involves long-term ethical claims. To live up to them, decision and policy-making has to consider long-term development of society, economy, and nature. (Klauer et al., 2016)

In her 2014 book, *Sustainable Fashion and Textiles: Design Journeys*, Kate Fletcher, design activist in fashion, textiles, and sustainability, explored the life cycle of clothes and the potential for sustainability to be connected to design. In her 2014 article "Slow Fashion: An Invitation for Systems Change," Fletcher highlights the fact that "fast fashion" is shorthand for leading to environmental damage. However, fashion is not necessarily unsustainable because it is "fast"; fast fashion is merely a process. However, by promoting a need for continual newness, the fashion industry feeds sales which in turn creates waste. Fletcher advocates "slow fashion" as a completely different worldview, framed as an opportunity to begin to engage better with systems-level questions in the fashion sector in order to build deeper and longer-lasting change toward sustainability (Fletcher, 2014).

The concept of questioning how things are traditionally done and the speed and framework within which they are achieved is being challenged as the need to change habits and accepted practices is necessary to halt a future climate crisis. In 2019, the Business Roundtable, an influential group of top chief executive officers of US companies, published a statement that challenged Milton Friedman's 1970 view:

> There is one and only one social responsibility of business – to use its resources and engage in activities designed to increase its profits. (Friedman, 1970)

> We believe the free-market system is the best means of generating good jobs, a strong and sustainable economy, innovation, a healthy environment and economic opportunity for all. (Business Roundtable, 2019)

Businesses are recognizing that a sole purpose of increasing profits is no longer acceptable by the society. To be acceptable to the society, businesses need to consider all stakeholders affected by their business practices. Business Roundtable is acknowledging that companies must also ensure a healthy environment. Over the last two decades, as climate change has become increasingly urgent, the conflict of the "social contract" between sustainability and traditional business values is being considered by the society (LoMonaco-Benzing & Ha-Brookshire, 2016). Academics are publishing research on consumer expectations for corporate social responsibility (CSR) showing that this now influences consumer choice:

> It is important for the fashion brands to first understand the consumer expectation and then make the operational decisions that can benefit the fashion brands and manufacturers with the consideration of CSR commitment. (Chan et al., 2020)

In 2017, UNESCO stated that one of the aims of ESD goals was for human beings to consider their actions and the impact that would have on future environments.

The concept of considering the responsibility of current generations actions on future generations was highlighted in 2019 by Greta Thunberg. In her speech to the World Economic Forum, she said cathedral thinking was needed to develop solutions to solve the climate emergency (the Guardian 2019). Cathedral thinking is about considering a problem over and beyond the life span of a human being. This viewpoint is developed by the philosopher Roman Krznaric. Krznaric is a philosopher and research fellow of the "Long Now Foundation" (Long Now, 1996), established in America in 1996 to consider long-term thinking. He argues in his book *The Good Ancestor: How to Think Long Term in a Short-Term World* that the responsibility and desire to contribute and leave a thriving planet for future generations are in the hands of the current generation:

> Don't we have an obligation, a responsibility, to our planetary future and the generations of humans and other species to come?
>
> By making wise – and long – choices as we emerge from this crisis, we could well become the good ancestors that future generations deserve. (Krznaric, 2021)

Greta Thunberg's impassioned speech at the 2018 United Nations Climate Change Conference had worldwide coverage challenging every person on the planet to take responsibility for the actions they took toward climate change. The speech captured the impetus for the wider societal trend of acceptance of a call to action to halt climate change:

> These wider initiatives on the importance have influenced the creative arts. The idea of long time thinking, of being a good ancestor was captured in initiatives such as 'The Long Time Project' created in 2018. (Saltmarshe & Pembroke, 2018)

Saltmarshe and Pembroke created The Long Time Project to work with policymakers, believing that:

> Art and culture will be crucial to cultivating long-term attitudes and behaviours. They are foundational in shaping our collective direction of travel, from the kinds of laws we make, to the technology we develop, to the way we think about our role in shaping the future. (Saltmarshe & Pembroke, 2018)

The previous two themes consider the influences of influential agencies on the construction of future higher education curriculum and the move to long-time thinking on the responsibility to consider how actions now will affect future generations.

The final theme considers how the skills within the creative subject areas can move society's concept from an item being disposable to the concept that a beautifully crafted item is kept and valued as an object for the long time.

3.3 Craft as an Heirloom

In 1837, the UK government established the first school of design for technical education. The school became The Royal College of Art. Technical education was needed to support the local manufacturing industries as making moved from hand skills to machine made and mass produced. From the late 1800s, the global influence of Arts and Crafts movement valued objects made by skilled craftsmen against the decline of standards through industrialization of both of the object and the quality of life for the workers. One of the leaders of the Arts and Craft movement was William Morris. His belief that you should "have nothing in your houses that you do not know to be beautiful or believe to be useful" could be used as a modern-day mantra against consumerism that leads to landfill and overuse of resources.

As discussed in the previous sections, designers and consumers are becoming aware of the contribution of their actions to climate change. As a social conscience is developing among consumers, corporate social responsibility is influencing choices of where and what to buy. Buying decisions go beyond the design, and consumers want to know what fashion and textiles are made from, the life of who made your clothes or textiles plus an understanding of how any environmental effect has been mitigated.

Klamer argues that values-based economics is moving societies decision-making from a focus on numbers to what we value emotionally and that this is intrinsically linked to our cultural values including values related to our heritage (Klamer, 2017).

In 2003 at the Convention of the Safeguarding of Intangible Cultural Heritage, craft was defined by the United Nations Educational, Scientific, and Cultural Organization (UNESCO):

> This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity. (United Nations Convention for the Safeguarding of Intangible Cultural Heritage, 2003)

Kotipalli discusses the nature of craft, that through realization of skills becomes more than an object and that it can become an heirloom not just as a useful object but also of memories, when it was used, who gave it to you, who you were with, and where you bought it (Kotipalli, 2019).

This view of craft links to the long-time view as the opposite of the understanding of "fast" fashion, bought for the moment.

The *Craft Research* Journal describes the role of craft as:

> A vital and viable modern discipline that offers a vision for the future and for the sustainable development of human social, economical and ecological issues. This role of craft is rooted in its flexible nature as a conduit from design at one end to art at the other. It gains its strength from its at times experimental, at times developmental nature, which enables craft to explore and challenge technology, to question and develop cultural and social practices, and to interrogate philosophical and human values. (Niedderer & Townsend, 2021)

In summary, key influencers are moving design education to a curriculum that encompasses more than the skill of design. Future design education needs to link to the cultural and values-based economics through an understanding of the influences that designers can have at the beginning of the process, to ensure sustainability, usefulness, and skilled craftsmanship contribute to products developed for the long time. Through this, designers contribute to being "good ancestors."

4 Education for Sustainable Development

This section presents a case study of a long-time approach to sustainability awareness for students and staff as part of the School of Fashion and Textiles at De Montfort University based in the UK. To set the scene, the school's contribution to education for sustainable development is introduced, before moving onto the case study.

4.1 School of Fashion and Textile Approach

The School of Fashion and Textiles at De Montfort University is an acknowledged leader in sustainability education, with a Green Gown Award for Next Generation Learning and Skills, and recognizes that it is the responsibility of educators to ensure future designers and buyers are aware of the criticality of their professional decisions over their careers and the impact these decisions can have on consumers (Sustainability Exchange, 2021).

De Montfort University made a commitment to addressing the United Nations Sustainable Development in its strategic plan in 2018, with a university-wide education for sustainable development project addressing taught courses, and university operations. Staff and students from the School of Fashion and Textiles embraced this vision, with a cross school strategy where activities across the curricula have

engaged with sustainability and are mutually supportive, such as new research linking to teaching and external briefs with a social justice theme, and continued professional development activity connecting the industry to education.

Aligning to the United Nation's Sustainable Development Goals (SDGs) is an integral part of the school's work, with circularity principles considered throughout design practice: durability, reuse, recycle, and repurpose. The sustainability activities are far reaching, incorporating the UNESCO competencies, and have been summarized below.

4.1.1 Cross School Curriculum Change

In 2018–2019, all modules were mapped against the SDGs to review strategically curriculum engagement with sustainability. The result of this audit showed the elements of engagement and led to a block curriculum change across the whole school with all undergraduate courses tasked to demonstrate comprehensive links to the full complement of SDGS (Penfold & Hardaker, 2020).

4.1.2 Reduction of the Volume of Design Outcomes

Project outcomes have been refocused to reduce the number of physical garments made, to reduce the amount of materials used, and to improve the well-being of students. Circularity principles of reuse, recycle and repurpose are considered throughout design practice: For example, prior to this change a final-year fashion or contour fashion student would produce a graduating collection of six outfits, this has now been reduced with students having the option to produce between 2 and 4 outfits with extended 2D design portfolios.

4.1.3 Digital Transformation

A key driver for success in the fashion and textile industry following the pandemic is acknowledged to be the adoption of digital technologies across the value chain to reduce physical sampling and the school sees this as an important aspect of its future vision with digital craft and 3D virtual prototyping incorporated into teaching (ASBCI, 2022).

4.1.4 Working with Industry and External Organizations

A key strength of the school is its connections with the industry. These connections are mutually beneficial, with external client projects, placement opportunities feeding into the curriculum, along with academic expertise being accessible to an industry audience, via continued professional development and consultancy. The external

client work is varied and to give a flavor of the variety, recently, fashion students have worked on a social good project with UK charity shelter, while contour fashion students have worked on an athleisure client project for sportswear brand, Gymshark, where students were tasked to consider creative sustainability – "Fashion as usual is not an option."

4.1.5 Research to Develop Sustainable Textile Processes

Sustainable textile chemistry and biotechnology research projects feed into the curriculum. The Textile Engineering and Materials Research group's work into enzyme coloration, surface printing onto textiles using lasers, cottonization of bast fibers, and antimicrobial fabric coatings tackle some of the key issues of pollution and water stewardship (De Montfort University, 2023).

The school offers a rich experience by integrating education for sustainable development into the curriculum. This ensures that the next generation of designers, communicators, and buyers has the skills necessary to be responsible and relevant when they move on to the next phase of their careers.

4.2 T-Extinction

One of the innovative projects that demonstrates the school's thought-provoking approach to raise sustainability awareness across its staff and student population is the T-Extinction project. This project uses a long-time thinking approach, by working on an extended time frame for the year 2090. It was set up in response to public protests about climate change which were gaining momentum in 2018 with Greta Thunberg's speech to the UN, protesting about lack of world leaders' actions against climate change. At the same time as UNESCO published "education for sustainable development and the SDG's" (UNESCO, 2018), Extinction Rebellion, UK global environment activists, were holding a series of protests in major cities. Against this backdrop, colleagues within the School of Fashion and Textiles, De Montfort University, felt there was a need to raise awareness of sustainability within the staff and student community, and it was agreed to develop an extracurricular collaboration. This was something that had not been done before by the fashion and textile team and would create an exciting new challenge. From this ad hoc starting point, the concept, named T-extinction, was born.

The project incorporated the UNESCO (2018) eight sustainable competencies (UNESCO, 2018) to enable students to consider and understand the impact they could make, through their decisions, on the future fashion and textile industry. The project also built on Knowles assumptions of how adults have a motivation to learn (Knowles, 1984) and the theory developed by Van Rossum and Taylor (1987) that notes learning is a conscious process, fueled by personal interests and directed at obtaining harmony and happiness or changing society (Van Rossum and Taylor,

1987). The "happiness" aspect of the project was an important consideration. The was backed up by the 2019 UK government report that stated "In 2019/20 …the number of students reporting they have a mental health condition increased by more than 180% since 2014/15" (Bolton & Hubble, 2021).

4.2.1 Project Aims

The T-Extinction project aimed to promote the need for action within fashion and textiles and to consider the impact of the sector on sustainability. Educational aims were to enable co-creation between the students and academics. They would work to the same brief with the aim of creating positive student-staff relationships, to use active learning to facilitate a deeper engagement with the project and sustainability. Co-creation is an important part of moving the creative students to being independent designers through a deeper learning experience they could take into their assessed work. T-Extinction enabled students to create their own direction of research away from the pressure of the set curriculum and assessment and to understand the need to embed sustainability within their own practice.

4.2.2 Project Operation and Outcomes

Once the purpose and theory of the project were established, several options were explored. In order to raise awareness of sustainability, the outcomes would focus on showcasing the project. It was planned that the project would begin with the subject area of fashion buying but pass each year to a different subject area, each to consider their own contribution to promoting sustainability. This enabled the project to build on a legacy rather than a one-off gesture. The first step before the launch of the competition was to create a strong graphic identity to promote the T-Extinction brand. A final-year student intern from the graphic design department was recruited part-time to build a series of designs; these included logo, banner designs, competition poster, and exhibition displays. The key colors used initially were yellow, red, black, and blue with yellow and red representing danger with the first competition brief poster design shown in Fig. 1.

The initial competition brief was created with sustainability awareness as the primary focus, asking participants to predict which fashion and textile processes or products will be extinct by 2090. Seven student volunteers for the competition who were all in their first year of academic study and came from different BA Fashion Buying with Design and Marketing pathways were recruited. As future professionals within the fashion system, the students would have direct influence on sustainable product development. For academics and students, this was a novel extracurricular experience that allowed them to approach sustainability from different angles and benefit from one another. Three academics joined the group with specialisms in textile design, digital technology, and cultural contexts of design. This created a group with complementary experience and skills.

Fig. 1 First T-Extinction competition brief poster. ((Copyright De Montfort University 2020). Hardaker et al. (2022))

To decide the final outcomes, project founders Sally Gaukrodger-Cowan and Carolyn Hardaker coordinated students and staff to meet and discuss ideas. Due to the Covid-19 pandemic, the physical three-dimensional installed exhibition was delayed and replaced by an online showcase. Sequins, denim, rubber soles, and nylon tights and processes for sizing, buying, trends, and disposal of these items to landfill were examples of the goods and processes that students and academic responses considered would be taboo. Responses are shown in Fig. 2.

Curating the imagery for a social media showcase was a key co-creation opportunity. The student cohort proposed creating mini videos where they discussed their ideas of what fashion and textile product or process would be extinct by the year

Fig. 2 T-Extinction responses (Source: Hardaker et al. (2022))
Sally Gaukrodger-Cowan and Emily Baines (2020) *Nylon Tights*
Mohamed Zougari (2020) *Fashion Trends*
Chiara Goldthorpe (2020) *Denim*
Victoria Self (2020) *Incineration and Landfill*
Carolyn Hardaker (2020) *Size ranges* Istock/ De Montfort University
Sally Gaukrodger-Cowan (2020) *Trainer soles*
Tilda Eriksson (2020) *Fibres*

2090, using Instagram. The imagery and project were further disseminated nationally through articles and conference papers (Hardaker et al., 2022) with the novel approach being featured by Fashion United (Byrne, 2021).

A key part of T-Extinction was to create a legacy through continuing the project across the other School of Fashion and Textile subject areas. This ethos not only extended the educational values but also promoted the long-time thinking needed for tackling sustainability. The second iteration of the T-Extinction project challenged students in the textile design discipline, to consider craftsmanship.

Using the Heritage Crafts Red List (Heritage Crafts, 2021) and following the same format of co-creation and collaboration across academics and students, the cohort challenge was stated as follows:

> Many traditional British crafts are in danger of becoming extinct by 2090. T-Extinction, this year, wants to highlight this situation by considering craft processes and reinventing them for the contemporary market to ensure the skills are saved. Your challenge is to identify an endangered craft where you can see the potential to recreate the process but in a new sustainable context.

The brief acknowledged that sustainability was also about protecting cultural heritage, inspired by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Convention of the Safeguarding of Intangible Cultural Heritage in 2003. Transmitted from generation to generation, this is constantly recreated by communities and groups in response to their environment, their interaction with nature, and their history and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity (United Nations Convention for the Safeguarding of Intangible Cultural Heritage, 2003).

The project encouraged a long-term approach to craft valued as heirlooms, the opposite to "fast fashion." Students and academics considered their traditional heritage crafts, including Nigerian and Indian techniques. This project led to engagement with Leicester City as an exhibition at LCB Depot, Leicester's creative hub. The future potential of this work has been highlighted by Heritage Crafts and the Crafts Council who have requested to be sent information on T-Extinction as an example of HE engagement with craft.

4.2.3 Key Findings

Following the T-Extinction projects, students were asked to evaluate how the projected had impacted their thinking. Key observations from the students include the following:

- The benefits of co-creation were recognized; having the opportunity to share knowledge and learn from each other was highlighted.
- The timing of this extracurricular project in the first year meant that the learning could inform decisions in future projects.
- The extracurricular element was also seen to be an opportunity to explore new skills and ideas outside of the constraints of assessed coursework, providing the opportunity to learn new skills way in a stress-free environment.
- The use of the extended time frame was an "eye opener" to the extent of the impact of fashion product on the environment. This concept pushed creativity to a different level of awareness with a deeper understanding of impact.
- The long-time approach elicited a philosophical reflection on the short-term focus of fashion trends. Through the provocation of an extended time frame, the consideration of the impact of fashion product was superseded by a consideration of the nature of fashion system itself.

Both T-Extinction themes have enabled students and staff to understand their strategic influence throughout a career as professionals within the fashion system. By creating projects that encouraged intergenerational cooperation and sharing ideas, the outcomes went beyond the consideration of how future designers must consider sustainability and the impact of their actions. The academics also acknowledged the imperative to educate future designers and the value of sharing and promoting ideas through social media, encouraging discussion.

Students reported that this open approach to discussion of ideas prompted the freedom to experiment. Through co-creation, a sense of community was created, with a safe space to take risks with ideas and making, without fear of failing assessments. The enhanced well-being reported by the students involved was a well-received consequence and possibly speaks to the mental health status of students who have been studying throughout the pandemic.

Consumer interaction with the concept was generated via the external exhibition, social media showcases, and a variety of publications including Fashion United. The exhibitions provided the opportunity to highlight the impact that everyday fashion product can have long term. The enquiring responses from an audience with limited awareness of the design process further supported the long-time provocation.

5 Discussion

At the beginning of this chapter, a quote from the economist Paul Elkin posed the question "a sustainable consumer – contradiction in terms?" The commentary on climate change agreements, the globalization of the fashion manufacturing process, and the consumption of fast fashion product reveal an area full of complexities and large-scale environmental problems due to the linearity of production. It has shown that clothing production is projected to continue to rise and that even though there are emerging industry solutions, as outlined in the UK's Textiles 2030 Roadmap 2021–2022 progress report, currently they are not enough to counteract the impact of the industry due to increased production. While a coordinated industry response is promising, the fact that product volume is also projected to increase is of concern. In this context, the value of education of designers, buyers, and consumers cannot be underestimated. As WRAP (2019) notes 80% of a products' environmental impact is through design, future designers and buyers need to understand the impact that their careers in the industry can have. The consumers need to understand the issues involved and be able to connect their individual clothing consumption with the climate crisis.

Utilizing the long-time approach has been shown to be an excellent provocation to elicit deeper thinking about the impact of actions to enable designers, buyers, and consumers to connect the climate crisis with clothing consumption. The reasons for this maybe that it enables all stakeholders to think about the challenges in a different way by providing a novel approach to understanding the challenge.

Instead of bombarding the audience with large-scale facts and figures, where an individual's short-term actions can have minimal impact, this approach focuses on a lifetime of accumulated impact, which will affect primarily future ancestors. Taking the onus away from short-term actions that affect the individual to longer-term impacts that will affect the individual's future family provides a totally different perspective that is relatable. This approach is reflected in the T-Extinction case study whereby setting a date of 2090, so that it could be within the lifetime of the student participants, makes the approach easy to understand.

The impact of the long-time approach can be considered from both student and consumer perspectives by analyzing the outcomes of the two T-Extinction initiatives. The first iteration of the provocation was shown to have an impact with the participants in several ways. On a practical level, it provided the opportunity to consider the importance of selecting sustainable materials in design processes. These decisions are vital as the students enter the industry as graduate designers and buyers by having the understanding and ability to influence the impact of product being manufactured at scale. The timing in the first year of study enabled this practice to be built on over the full program of study. Co-creation with fellow students and staff led to a community of practice with shared learning and motivation across research and showcasing activities. The extracurricular nature highlighted the value of the creative community, in building confidence and engendering the power of intrinsic motivation to progress learning and joy for the subject. The project also elicited some philosophical discussions, with the consideration not only of the impact of specific products but of the fashion system itself and the future of the cyclical nature of trends. The long-time approach, being a concept that is easy to understand, has provided the platform for harnessing these creative thoughts that might otherwise not have been developed.

The creative community of practice continued with the second iteration on preserving endangered craft with staff and students sharing insight and knowledge into the artistry and technique of specific crafts. An unintended consequence was the opportunity for intergenerational learning, and this reflects the current celebration of craft that is permeating popular culture with TV shows such as the Repair Shop broadcast on UK prime time television. The endangered craft theme connects to the commentary in the media about choosing well, makes it last, and values local cultural capital.

The slow fashion movement that Fletcher (2010) promotes urges consumers and manufacturers to celebrate the provenance of a garment. This is often achieved through detailed descriptions of the origins of fabric and the craft skills utilized throughout the manufacturing process to develop the final garment. Sustainability commentators are urging the consumer to cherish this craftsmanship, treasure the items, and wear them regularly, breaking away somewhat from the rapid cycle of new fashion trends.

With an international student population, the opportunities to celebrate craft from different countries also add a global perspective. Providing students with the unique opportunity to understand a range of indigenous crafts is a practical way to highlight the contrast between this rich heritage and homogenous fast fashion product.

As an educational tool, the first two iterations of T-Extinction have shown it to be a successful vehicle within higher education for promoting sustainability awareness across the student population. By branding the long-time approach with the T-Extinction name, this has provided the opportunity to build momentum by theming projects annually with a different sustainability directive. From an educational perspective, the project showed that the focus of learning is not on the subject alone.

The project resulted in motivated staff and students and a sense of intrinsic joy, with an appetite to consider real-world issues facing the fashion and textile sector.

The value of the provocation also can be considered from a consumer perspective. With fashion theorists outlining how fast fashion has democratized fashion and with projections of the volume of product to be produced set to rise, there are huge opportunities to engage the long-time approach.

The local T-Extinction showcases and publications have already provided some attention-seeking headlines to encourage consumers to engage with the concept and think about their actions. Providing a method whereby consumers can understand how their actions and overconsumption may affect future generations is a powerful argument to make. But currently, this is another project, another additional element of information that is available to consumers, and they need to have the motivation to engage.

Shifting the mindset of the consumer away from the practice of buying disposable short-lived fashion product is the key issue. The consumer needs to have some way of navigating this information, and the authors suggest that the most effective way of developing the truly sustainable consumer is through a coordinated approach to education. Although higher education curricula have been addressed via the work of AdvanceHE and QAA, however, changes to primary and secondary school education in the UK are still in development. In 2018, the Environmental and Sustainable Citizenship Bill was proposed in the UK Parliament setting out changes to the national curriculum for primary and secondary pupils to incorporate a mandatory scheme of climate education. Pupils will be educated to understand how the climate changes will affect them and how climate action can reduce the effects for their generation and for future generations. This is supported by a comprehensive strategy for the education and children's services systems with a focus on environmental sustainability and climate change. This strategy published in 2022 shows that there is much intended activity and the desire for a coordinated approach; however, the parliamentary process is lengthy, and at the time of writing, there is still some distance to travel before the bill is on the statute books.

In the UK as the industry continues to respond and the primary and secondary educational directives are debated, the trend prediction agency WGSN notes that for the future consumer in 2025 there will be a new emphasis on time, how we spend it, how we defy it, and how we grow alongside it (WGSN, 2023). Their consumer profiles include references to valuing time well spent on daily rituals, to making transactions based on feelings and fairness, to the aim to rehumanize lives and value ethical commerce, and to entrepreneurship. These predictions augment the recognition that the fashion system needs to slow down. Coordinated efforts of industry and education are required to develop more sustainable product and shift consumers' mindset to pave the way for the truly sustainable consumer.

6 Conclusion

The T-Extinction case study presented here demonstrates potential for the long-time approach to be adopted more widely as a means of explaining the impact of climate changes. From the original intention to highlight products and processes that would be taboo by the year 2090, this extracurricular project has presented numerous benefits including highlighting the positive value of working within a creative community, the opportunity to engage more deeply with sustainability issues, and as a platform to highlight endangered craft.

While it is straightforward to connect the current designer, buyer and consumers' actions with their impact on future generations, this premise provides a compelling sustainability framework to feed into educational projects.

As AdvanceHE, QAA, and UNESCO all publish guidance on embedding the UN SDGs into global education, educators are challenged to find ways to develop delivering the subject area skills to include the eight sustainable competencies. It is no longer sufficient to specialize in an academic subject; students need to also understand the consequences of decisions made in application. By using co-creation to create a challenge for both the academic and student cohorts, there is a potential for further research on creative communities developing the educational framework that promotes systems thinking competence as a holistic approach to the complexities of tackling climate change within the curriculum.

References

AdvanceHE QAA. (2021). *Education for sustainable development guidance*, *education for sustainable development guidance | Advance HE*. Available at: https://www.advance-he.ac.uk/knowledge-hub/education-sustainable-development-guidance. Accessed:24 Mar 2023.

ASBCI. (2022, May). A digital world. *In Association* (pp. 38–40). Available at: https://www.flipsnack.com/asbci/in-association-may-2022/full-view.html. Accessed 23 Apr 2023.

B Corporation. (2023). *Making business a force for good.* Available at: https://www.bcorporation.net/en-us. Accessed 23 Apr 2023.

Bolton, P., & Hubble, S. (2021). *Support for disabled students in Higher Education in England.* Available at: https://commonslibrary.parliament.uk/research-briefings/cbp-8716/. Accessed 4 Apr 2023.

Business Roundtable. (2019). *Business roundtable redefines the purpose of a corporation to promote 'An economy that serves all Americans'*. www.businessroundtable.org. Available at: https://www.businessroundtable.org/business-roundtable-redefines-the-purpose-of-a-corporation-to-promote-an-economy-that-serves-all-americans. Accessed 31 Mar 2023.

Byrne, A. (2021). *DMU fashion buying specialists predict fashion practices to be abandoned by 2090*. Available at: https://fashionunited.com/education/news/dmu-fashion-buying-specialists-predict-some-fashion-practices-to-be-abandoned-by-2090/2021051839984. Accessed 10 Apr 2023.

Chan, H.-L., et al. (2020). Corporate social responsibility (CSR) in fashion supply chains: A multi-methodological study. *Transportation Research Part E: Logistics and Transportation Review, 142*, 102063. https://doi.org/10.1016/j.tre.2020.102063

Competition and Markets Authority Gov.UK. (2023). *Misleading environmental claims*. Available at: https://www.gov.uk/government/collections/misleading-environmental-claims. Accessed 11 Apr 2023.

Cooper, T. (2019). *Written evidence submitted by Professor Tim Cooper, Clothing Sustainability Research Group*. Nottingham Trent University Available at: https://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/environmental-audit-committee/sustainability-of-the-fashion-industry/written/88815.html. Accessed 13 Apr 2023.

De Montfort University. (2023). *Textile Engineering and Materials (TEAM).* Available at: https://www.dmu.ac.uk/research/centres-institutes/iad/team/team.aspx. Accessed 10 Apr 2023.

Durning, A. (1992). *How much is enough*. W. W. Norton and Company.

Elkins, P. (1991). A sustainable consumer society: A contradiction in terms? *International Environmental Affairs, 4*(4), 244.

Ellen MacArthur Foundation. (2023). *It's time for a circular economy.* Available at: https://ellenmacarthurfoundation.org/. Accessed 10 Apr 2023.

Environmental Audit Committee. (2019). *Fixing fashion: Clothing consumption and sustainability.* (House of Commons Sixteenth Report of Session 2017–19). Available at: https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/1952/full-report.html. Accessed 11 Apr 2023.

European Commission. (2023). *Unfair commercial practices directive*. Available at: https://commission.europa.eu/law/law-topic/consumer-protection-law/unfair-commercial-practices-law/unfair-commercial-practices-directive_en. Accessed 11 Apr 2023.

Farla, J. (2023). *Most important aspects while deciding whether to shop with a brand or not among fashion and lifestyle buyers in the United Kingdom as of spring 2022*. Available at: https://www.statista.com/statistics/1321495/purchase-decision-aspects-fashion-lifestyle-buyers-uk/?locale=en. Accessed 6 Mar 2023.

Fashion for Good. (2023). *Fashion for Good is here to make all fashion good.* Available at: https://fashionforgood.com/. Accessed 11 Apr 2023.

Fashion Revolution. (2023). *Fashion transparency index 2022*. Available at: https://www.fashionrevolution.org/impact/. Accessed 28 Mar 2023.

Fletcher, K. (2010). Slow fashion: An invitation for systems change. *The Journal of Design, Creative Process & the Fashion Industry, 2*(2), 259–265. https://doi.org/10.2752/175693810X12774625387594

Fletcher, K. (2014). *Sustainable fashion and textiles: Design journeys* (2nd ed.). Routledge.

Friedman, M. (1970, September 13). A Friedman doctrine – The social responsibility of business is to increase its profits. *The New York Times*. Available at: https://www.nytimes.com/1970/09/13/archives/a-friedman-doctrine-the-social-responsibility-of-business-is-to.html. Accessed 31 Mar 2023.

Generation Climate Europe. (2021). *Greenwashing position paper*. Available at: https://gceurope.org/wp-content/uploads/2021/10/Greenwashing-Policy-Paper.pdf. Accessed 2 Apr 2023.

Gonzalo, A., Harreis, H., Sanchez-Altable, C., & Villepelet, C. (2020, May 6). *Fashion's digital transformation: Now or never*. Available at: https://www.mckinsey.com/industries/retail/our-insights/fashions-digital-transformation-now-or-never. Accessed 31 Mar 2023.

Guercini, S., Bernal, P., & Prentice, C. (2018). New marketing in fashion e-commerce. *Journal of Global Fashion Marketing*, *9*(1). Available at: https://www.tandfonline.com/doi/full/10.1080/20932685.2018.1407018. Accessed 31 Mar 23.

Hardaker, C. H. M., Penfold, B., & Gaukrodger-Cowan, S. (2022). T-Extinction: A co-created fashion and textiles sustainability awareness project that takes a long-time approach. In *24th IFFTI Conference: Fashion Reimagine* (pp. 163–172). Nottingham Trent University. Available at: https://uploadsssl.webflow.com/608009d2f2599276a0e7df60/6322162418284803892f1416_IFFTI%202022%20Conference%20Proceedings_compressed.pdf. Accessed 11 Apr 2023.

Heritagecrafts.org.uk. (2021). *Red list of endangered crafts*. Available at: https://heritagecrafts.org.uk/wp-content/uploads/2021/05/HCA-Red-List-2021-leaflet-optimised.pdf. Accessed 4 Apr 2023.

Igini, M. (2022). *10 concerning fast fashion waste statistics.* Available at: https://earth.org/statistics-about-fast-fashion-waste/. Accessed 10 Apr 2023.

Klamer, A. (2017). *Doing the right thing: A value based economy*. Ubiquity Press.

Klauer, B., et al. (2016). *Sustainability and the art of long-term thinking.* Available at: https://www.taylorfrancis.com/search?key=Sustainability%20and%20the%20art%20of%20long-term%20thinking. Accessed 31 Mar 2023.

Knowles, M. S. (1984). *Andragogy in action*. Jossey-Bass Inc.

Kotipalli, P. (2019). Making sense of craft using cultural economics. In *A cultural economic analysis of craft* (pp. 39–48). Available at: https://doi.org/10.1007/978-3-030-02164-1_4. Accessed 29 Mar 2023.

Krznaric, R. (2020). *The good ancestor: How to think long term in a short-term world*. Penguin Books.

Krznaric, R. (2021). *Good ancestor: A radical prescription for long -term thinking*. WH Allen.

LoMonaco-Benzing, R., & Ha-Brookshire, J. (2016). 'Sustainability as social contract: Textile and apparel professionals' value conflicts within the corporate moral responsibility spectrum'. *Sustainability, 8*(12), 1278. https://doi.org/10.3390/su8121278

Long Now. (1996). *The long now foundation*. Available at: https://longnow.org/. Accessed 1 Apr 2023.

Mignosa, A., & Kotipalli, P. (2019). *A cultural economic analysis of craft* (pp. 235–244). Springer International Publishing.

National Union of Students. (2021). *Sustainability skills survey – Research: SOS-UK, students organising for sustainability UK*. Available at: https://www.sos-uk.org/research/sustainability-skills-survey. Accessed 29 Mar 29 2023.

Niedderer, K., & Townsend, K. (2021). Aims and scope. *Craft research*, *14*(1). Available at: https://www.intellectbooks.com/craft-research. Accessed 9 Dec 2021.

Penfold, B., & Hardaker, C. H. M. (2020). Developing a responsible culture: Aligning fashion and textiles education with the UN's sustainable development goals. In *22nd IFFTI conference: Between individual and society: Social justice through fashion* (pp. 19–28). Kent State University. Available at: https://oaks.kent.edu/iffti2020/iffti-2020-between-individual-and-society-individual/developing-responsible-culture. Accessed 10 Apr 2023.

Peters, G., Li, M., & Lenzen, M. (2021). The need to decelerate fast fashion in a hot climate – A global sustainability perspective on the garment industry. *Journal of Cleaner production*, *295*. https://www.sciencedirect.com/science/article/pii/S0959652621006107. Accessed 17 Mar 2023.

Raeburn. (2023). *Fabrics*. Available at: https://www.raeburndesign.co.uk/pages/fabrics. Accessed 27 Mar 2023.

Reeves, A. (2019). Classroom collaborations. *International Journal of Sustainability in Higher Education, 20*(8), 1376–1392. https://doi.org/10.1108/ijshe-11-2018-0220

Ritzer, G. (2003). Rethinking globalization: Glocalization/globalization and something/nothing. *Sociological Theory, 21*(3), 193–209.

Roach, B., Goodwin, N., & Nelson, J. (2019). *Microeconomics in context* (4th ed.). Routledge.

Saltmarshe, E., & Pembroke, B. (2018). *The long time*. Available at: https://medium.com/@the-longtimeinquiry/the-long-time-3383b43d42ab. Accessed 26 Feb 2021.

Sharpe, S., Retamal, M., & Brydges, T. (2022). *To make our wardrobes sustainable, we must cut how many clothes we buy by 75%*. Available at: https://www.theguardian.com/australia-news/2022/apr/13/to-make-our-wardrobes-sustainable-we-must-cut-how-many-new-clothes-we-buy-by-75. Accessed 2 Apr 2023.

Smith, P. (2022a). *Revenue of the apparel market worldwide from 2014 to 2017*. Available at: https://www.statista.com/forecasts/821415/value-of-the-global-apparel-market. Accessed 10 Apr 2023.

Smith, P. (2022b). *Number of stores of the Inditex Group worldwide from fiscal years 2010 to 2022*. Available at: https://www.statista.com/statistics/456409/global-number-of-stores-inditex-group/. Accessed 12 Apr 2023.

Smith, P. (2022c). *Volume of consumption in the apparel market in the United Kingdom (UK) from 2013 to 2026.* Available at: https://www.statista.com/forecasts/1156110/apparel-market-volume-of-consumption-in-the-uk. Accessed 17 Mar 2023.
Stella McCartney. (2023). *Measuring our impact*. Available at: https://www.stellamccartney.com/gb/en/sustainability/measuring-our-impact.html. Accessed 28 Mar 2023.
Sumner, M. (2019). *Written evidence submitted by Dr Mark Sumner, University of Leeds*. Available at: http://data.parliament.uk/WrittenEvidence/CommitteeEvidence.svc/EvidenceDocument/Environmental%20Audit/Sustainability%20of%20the%20fashion%20industry/Written/88396.html. Accessed 12 Apr 2023.
Sustainability Exchange. (2021) *Green Gown Awards 2021: Next generation learning and skills – De Montfort University – Winner.* Available at: https://www.sustainabilityexchange.ac.uk/green_gown_awards_2021_next_generation_learning3. Accessed 10 Apr 2023.
Telegraph. (2013, September 16). *Vivienne Westwood: Everyone buys too many clothes.* Available at: http://fashion.telegraph.co.uk/news-features/TMG10312077/Vivienne-Westwood-Everyone-buys-too-many-clothes.html. Accessed 21 Mar 23.
theGuardian.com. (2019, April 23). *The Guardian view on Greta Thunberg: seizing the future | Editorial'*. Available at: https://www.theguardian.com/commentisfree/2019/apr/23/the-guardian-view-on-greta- thunberg-seizing-the-future. Accessed 8 Dec 2021.
Times Higher Education (THE). (2022). *Impact ranking*, *Times Higher Education (THE)*. Available at: https://www.timeshighereducation.com/impactrankings. Accessed 29 Mar 2023.
UNESCO. (2018). *Education for sustainable development and the SDG's*. Available at: https://en.unesco.org/sites/default/files/gap_pn1_-_esd_and_the_sdgs_policy_brief_6_page_version.pdf. Accessed 29 Mar 2023.
United Nations. (2015). *The 17 goals.* Available at: https://sdgs.un.org/goals. Accessed 29 Mar 2023.
United Nations. (2023a). *The Paris Agreement*. Available at: https://www.un.org/en/climatechange/paris-agreement. Accessed 10 Mar 2023.
United Nations. (2023b). *The glasgow climate pact – Key outcomes from COP26*. Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26. Accessed 27 Mar 2023.
United Nations. (2023c). *Population*. Available at: https://www.un.org/en/global-issues/population. Accessed 10 Mar 2023.
United Nations Convention for the Safeguarding of Intangible Cultural Heritage. (2003). Available at: https://ich.unesco.org/en/convention. Accessed 9 Dec 2021.
Van Rossum, E. J., & Taylor, I. (1987). The relationship between conceptions of learning and good teaching: a scheme of cognitive development. In *American educational research association conference,* Washington (USA). Available at: https://journals.sagepub.com/doi/abs/10.1177/109634808801200243. Accessed 29 Mar 2023.
WGSN. (2023). *Future Consumer 2025.* Available at: https://www.wgsn.com/en/wgsn/press/press-releases/wgsn-releases-flagship-forecast-future-consumer-2025. Accessed 13 Apr 2023.
Williams, D. (2015). Fashion design and sustainability. In Blackburn, R. (Ed.), *Sustainable apparel* (pp. 163–185). Available at: https://doi.org/10.1016/B978-1-78242-339-3.00006-6. Accessed 10 Mar 2023.
Williams, A., et al. (2017). Systems thinking: A review of sustainability management research. *Journal of Cleaner Production, 148*, 866–881. https://doi.org/10.1016/j.jclepro.2017.02.002
WRAP. (2019). *European Clothing Action Plan*, *ECAP.* Available at: https://wrap.org.uk/taking-action/textiles/initiatives/ecap. Accessed 24 Mar 2023.
WRAP. (2022). *Textiles 2030 Annual Progress Report 2021/22*. Available at: https://wrap.org.uk/resources/report/textiles-2030-annual-progress-report-202122. Accessed 10 Apr 2022.

The Influence of Social Media Usage on Consumers' Sustainable Clothing Consumption Practices

M. A. Olwoch, N. C. Sonnenberg, and H. Taljaard-Swart

Abstract This chapter explores the influence of social media usage, specifically concerning social capital and social influence, on consumers' sustainable clothing consumption practices. Social media platforms have assumed a crucial function in nurturing sustainable communities and engaging consumers in the pursuit of an ethical marketplace. The COVID-19 pandemic has further propelled the acceptance of digital platforms, enabling widespread discussions on the social and environmental repercussions of the clothing and textile supply chain. Social media has therefore evolved into a powerful channel for fostering sustainable apparel consumption practices. The influence of individuals on others, especially online, highlights the social context of sustainable choices. Theories relating to social capital and social influence emphasize the value of social interactions in shaping consumer behavior. Social capital, forged by human interactions, develops over time and varies in strength and extent of connections. It provides valuable information on sustainable matters in the context of apparel consumption. Social influence also fulfills an important role in motivating consumers to behave sustainably, by leveraging social networks and influential individuals. The chapter is concluded with a proposed theoretical framework and research propositions for future investigations.

Keywords Social media · Sustainable practices · Clothing consumption · Fashion circularity · Social capital · Bridging · Bonding · Social influence

M. A. Olwoch · N. C. Sonnenberg (✉) · H. Taljaard-Swart
Department of Consumer and Food Sciences, University of Pretoria, Pretoria, South Africa
e-mail: olwochma@tut.ac.za; nadine.sonnenberg@up.ac.za; hanri.taljaard@up.ac.za

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0_5

1 Introduction

Consumers wield a pivotal influence in advancing an ethical marketplace through their deliberate adoption of socially conscious and well-informed purchasing decisions. Moreover, social media platforms have emerged as instrumental catalysts in nurturing sustainable communities, as consumer behaviors are profoundly shaped by the influence of others in an online environment. The COVID-19 pandemic elicited a notable upsurge in digital innovations, wherein platforms such as Instagram serve as facilitators of instantaneous and far-reaching dialogues concerning social and environmental concerns. Consequently, social media has become an influential channel for communication, particularly in promoting sustainable practices in clothing consumption.

The influence that individuals exert on others, particularly in online environments, highlights the social context in which sustainable choices are made by consumers. The social capital theory and related theories on normative and informational influence underscore the role of social interactions and their impact on consumer behavior. Social capital, which develops through human interactions in social settings, is seen as an organic outcome that evolves over time. The density of connections can vary as individuals engage with both close friends and other users on social media platforms. As a result, consumers interact not only within strong relationships ("bonding capital") but also with looser connections ("bridging capital") in online environments. These social dynamics shape consumption to varying degrees. Overall, social capital serves as a valuable source of information regarding environmental and social issues, providing insights on how to address these concerns within the clothing and textile industry.

In conjunction with social capital, the notion of "social influence" is broadly accepted as a crucial driving force for sustainable consumption. Overall, social influence as a concept underscores the importance of social dynamics in driving sustainable consumption. By harnessing the power of social networks, communities, and influential individuals, a collective movement toward a more sustainable future is created. Based on the aforementioned arguments, this chapter will explore and describe the influence of social media usage, specifically concerning social capital and social influence, on consumers' sustainable clothing consumption practices. The chapter will commence with an overview of the escalation of social media usage during the during the COVID-19 pandemic and the implications thereof for apparel consumption behavior. Thereafter, particular attention is devoted to the role of various social media platforms in broadening consumers' awareness and understanding of sustainable initiatives. The chapter is concluded with current theoretical insights surrounding social capital and social influence with a proposed theoretical framework for future investigations.

2 The Escalation of Social Media Usage During COVID-19 and Its Implications for Apparel Consumption Behavior

The COVID-19 pandemic had a profound global impact, affecting different sectors of society in unique ways (Eger et al., 2021). Governments around the world swiftly closed nonessential retail, including fashion, to prioritize public health and social distancing (Brydges & Hanlon, 2020). This led to disruptions in the global economy and supply chains, while various restrictions such as remote work and lockdown measures were imposed (Bilinska-Reformat & Dewalska-Opitek, 2021). This then led to the fashion industry encountering a profound economic decline, witnessing a staggering decrease in profits of up to 90% in 2020 compared to the preceding year (McKinsey & Company, 2020; Liu et al., 2021). Fashion and design sectors faced challenges in maintaining production, employment, financial stability, and adapting to the e-commerce landscape (Bilinska-Reformat & Dewalska-Opitek, 2021).

Millions of garment workers were rendered unemployed and confronted with significantly reduced wages as clothing production came to a halt amid the COVID-19 pandemic (Anner, 2020). The closure of numerous brick-and-mortar retail outlets, prompted by the imposition of necessary restrictions, exacerbated the already dire situation. Despite international pressure to support garment workers, orders were canceled, exacerbating wage insecurity in the clothing manufacturing sector and leaving workers vulnerable without social safety nets (Fashion Revolution, 2023). However, the plight of these workers gained attention on social media platforms, compelling various stakeholders in the fashion supply chain to take action. Retailers shifted to online sales, initiated fundraising efforts for charities, and devised support plans for their employees (Brydges & Hanlon, 2020).

The pandemic's impact on fashion supply chains coincided with significant shifts in consumer behavior (Bilinska-Reformat & Dewalska-Opitek, 2021). Lockdown measures compelled consumers to alter their buying patterns and adapt to new routines (Liu et al., 2021; Degli Esposti et al., 2021). With limited physical contact and an increased focus on health and safety, consumers embraced cashless payments, home deliveries, and online shopping (Truong & Truong, 2022). This surge in e-commerce resulted in a considerable increase in online retail sales. Offline-to-online purchasing behavior garnered attention, leading fast fashion retailers to invest in online channels and social media platforms (Bilinska-Reformat & Dewalska-Opitek, 2021).

Furthermore, consumers' preferences for clothing categories shifted as they spent more time indoors, prioritizing comfort over fashion and opting for basics in neutral colors and comfortable fabrics (Bilinska-Reformat & Dewalska-Opitek, 2021). The pandemic also heightened consumers' interest in sustainable fashion, with a greater emphasis on brands' treatment of employees and support for local businesses (Liu et al., 2021). Surveys conducted during this time revealed a strong willingness to prioritize pollution reduction and engage in recycling and environmentally friendly purchases (Granskog et al., 2020).

The changes induced by the pandemic may have lasting implications, as disruptions in daily life often lead to modifications in consumer requirements, attitudes, and behaviors, potentially increasing receptiveness to sustainable clothing consumption (Moschis, 2007). Social media platforms played a crucial role during social distancing, allowing people to interact and connect while fulfilling their need for human interaction (Singh et al., 2020). Therefore, the pandemic may have instigated long-term changes in consumers' utilization of social media platforms and their consumption behaviors (Mason et al., 2021).

3 Social Media Platforms

Amid the COVID-19 pandemic, there was a notable upsurge in the utilization of social media applications, but it is important to realize that social media has evolved over several years, thus resulting in various definitions over time. Kaplan and Haenlein (2010), for example, defined social media as a type of software or services that are designed to function on the internet and are aligned with Web 2.0 principles and technologies to generate user content, facilitate collaboration, and develop interactive experiences. McGowan et al. (2012) later emphasize the interactive and collaborative quality of the online environment, which allows users to contribute to the collective content pool while simultaneously consuming the contributions of others. Expanding on these definitions, Kapoor et al. (2018) conceptualized social media as platforms driven by users that enable the exchange of captivating content, collaborative discussions, and communication with wider audiences. They further describe social media as a virtual platform that enables individuals to interact and establish connections across different dimensions. This significance of social media and digital technology became pronounced during the pandemic, as they played a pivotal role in circumventing stringent lockdown measures and promoting adherence to social distancing guidelines (Demuyakor, 2020). The global digital population expanded significantly during this time, resulting in increased social media reach and usage (Dixon, 2022). According to the International Telecommunications Union (ITU), there are around 4.4 billion internet users, of whom approximately 3.5 billion actively participate on social media platforms (Dixon, 2023). These figures underscore the extensive global usage and appeal of the internet and social media, demonstrating their substantial impact in connecting and involving people worldwide.

The increasing adoption of social media can, to some extent, be attributed to the expanding demographic of individuals who are utilizing the internet more frequently, especially through mobile devices (Patricios & Goldstruck, 2021). The popularity and diversity of different social media applications, namely, Instagram, Twitter, Facebook, and Snapchat, have also had a substantial influence on how consumers engage with the fashion industry (Khandual & Pradhan, 2019). Social media exerts an influential role in shaping consumers' purchasing decisions as it serves as

a medium for connecting and disseminating product information while simultaneously enabling businesses to engage with existing and prospective customers (Saeed et al., 2019). This interaction is facilitated through a diverse array of social media platforms, encompassing sites for social networking, video and photo-sharing platforms, and messaging applications.

3.1 Social Networking Sites

Sites for social networking enable individuals to maintain relationships with family and friends residing in diverse geographical locations, thus extending their online communities even further (Phua et al., 2017). The geographical reach that social networking sites allow can create the opportunity for consumers to increase their connections with different communities (i.e., background, beliefs, or characteristics) which could potentially influence their clothing consumption practices. In terms of user numbers and audience reach, Facebook has been known to be the most favored social network (Lua, 2023). Facebook's user base has consistently increased over several years. As of the first quarter of 2022, Facebook had nearly three billion monthly active users globally (Dixon, 2022). The most represented age group on Facebook are individuals aged 25–34 (Beveridge & Lauron, 2023). The Facebook algorithm places emphasis on content that stimulates conversations and meaningful interactions among individuals, particularly those involving family and friends (Lua, 2023). Certain studies have discovered a positive correlation between receiving Facebook posts pertaining to environmentally relevant practices and the development of environmental responsibility (Oakley & Salam, 2014). Facebook posts by the Clean Clothes Campaign, as an example, regularly educate their networks about societal issues in the fashion industry and may impact on their future consumption choices.

LinkedIn, a well-known social networking platform established in 2003, places a strong emphasis on networking, career development, and knowledge sharing (Herling, 2022). It is widely regarded as an invaluable tool for cultivating personal branding (Patricios & Goldstruck, 2021). When it comes to professional connections, individuals are more inclined to connect with current and former colleagues, as well as other influential figures in their industry, on business-oriented networks like LinkedIn rather than on platforms such as Facebook (Utz, 2016). The configuration and substance of the social networks that individuals cultivate on LinkedIn are uniquely positioned to furnish them with professional insights and information (Utz, 2016). Moreover, LinkedIn serves as a vital source of practical and emotional support, offering opportunities for individuals who are unemployed or facing uncertainty in their current circumstances (Patricios & Goldstruck, 2021). By leveraging the platform's features and connections, individuals can gain access to valuable resources and support systems to navigate their professional journey and overcome challenges they may encounter.

3.2 Microblogging

Twitter, a microblogging platform founded by Jack Dorsey in 2006, exemplifies the concept of sharing concise messages within the realm of social networking, with its headquarters located in San Francisco (Forsey, 2021). Tweets, limited to 280 characters, constitute the main form of communication for Twitter users (Ghouse et al., 2022). The platform enjoys a substantial user base, with approximately 330 million individuals engaging on a monthly basis, of which 152 million are active on a daily basis, resulting in a staggering 500 million tweets exchanged daily (Ghouse et al., 2022). Regarding demographic composition, 38% of Twitter users are within the age range of 18 to 29, with an additional 26% falling between 30 and 49 years old (Ghouse et al., 2022). Financially, Twitter generated nearly $900,000 in revenue by February 2023 (Koetsier, 2023).

Beyond its various functions such as news consumption, celebrity following, and social connections, Twitter plays a vital role in swiftly disseminating information (Forsey, 2021). This also extends to promoting sustainability and encouraging sustainable practices in the realm of clothing consumption. For instance, Fashion Revolution utilized their Twitter platform to urge consumers to be more mindful of the origins of their clothing and to hold brands accountable (Fashion Revolution, 2023).

3.3 Photo-Sharing Sites

Pinterest and Instagram are two widely recognized platforms that facilitate the sharing of photos. Instagram, a mobile application-based social media platform, places a strong emphasis on photo and video sharing (Forsey, 2021). As of December 2021, it had accumulated approximately two billion monthly active users (Dixon, 2021). In terms of revenue, Instagram's monthly earnings within the app approached $1 million in February 2023 (Koetsier, 2023). Users, encompassing both businesses and consumers, possess the capacity to share a wide array of content on Instagram, including photos, videos, stories, reels, live videos, and longer-form videos via IGTV (Dixon, 2022). Given that 70% of shoppers rely on Instagram for their upcoming purchases, businesses can leverage these features to engage with customers and drive sales (Hill, 2022). Moreover, the seamless shopping experience offered by the platform may have an impact on consumers' clothing consumption habits, as they can easily communicate with businesses via direct messages to seek information or provide feedback. This makes Instagram an essential component of retailers' customer service offerings (Hill, 2022).

Pinterest, on the other hand, is another photo-sharing application where users can explore, share, and curate visual content that they find inspiring, helpful, or entertaining (Pinterest, 2023). It serves as a valuable resource for identifying emerging trends and enables businesses to target specific niche audiences (Hill, 2022). Users on Pinterest have the option to add or "pin" content to themed boards,

ensuring organized categorization that aids in the discovery of related content by other users (Pinterest, 2023). Within the domain of sustainable clothing products, for example, Pinterest offers an abundance of tutorials, infographics, do-it-yourself guides, and links to additional educational resources (Segura, 2023). These resources often focus on innovative approaches for consumers to repurpose and upcycle their clothing.

3.4 Video Sharing

YouTube is universally acknowledged as a platform for video sharing, where users reportedly dedicate a substantial portion of their daily time to consuming content (Lua, 2023). It holds the distinction of being the second-largest social media site, often likened to the second-largest search engine, following its parent company, Google (Lua, 2023). For brands seeking to connect with and engage their target audiences, YouTube provides an ideal platform (Hill, 2022). Among all social platforms, YouTube stands out with one of the highest average daily usage times, ranking second only to TikTok (Hill, 2022). A notable example of utilizing YouTube for brand promotion is Patagonia's "Buy Less Demand More" campaign, which showcases video clips highlighting sustainable practices, encouraging consumers to decrease how much they purchase, opt for products made from recycled materials, and support Fair Trade-approved options (Patagonia, 2023).

Snapchat, in contrast, primarily serves as a platform for sharing photos and short videos called "snaps" among friends (Lua, 2023). In 2023, Snapchat's daily revenue was estimated to be around $125,000 (Koetsier, 2023). Williams (2006) noted that Snapchat users typically interact with individuals who offer emotional support and guidance on important choices and are trusted to help solve problems. Additionally, Snapchat played a notable role in introducing and popularizing the vertical video format, which subsequently became prevalent on other social media platforms (Lua, 2023). However, the growth of Instagram stories has hindered Snapchat's further expansion and reduced marketers' interest in promoting their brands on the platform (Lua, 2023).

According to Lua (2023), TikTok can be described as an application for sharing short-form videos, which permits users to create and distribute video clips ranging from 15 to 60 s in duration, enriched with sound effects, music snippets, and filters. TikTok has experienced remarkable growth since its launch in 2017, surpassing Google to become the most visited internet site (Lua, 2023). In terms of application downloads, TikTok has outpaced social media giants like Instagram, Facebook, WhatsApp, and Snapchat in 2021 (Dixon, 2022). TikTok's emphasis on video recording, including dances and lip-syncing, primarily appeals to women aged 18–24, who make up a significant portion of its user base and is an important target market within the fashion industry. The second-largest demographic consists of men in the same age group (Dixon, 2022). Generation Z spends more time on TikTok than on Instagram, as highlighted by Dixon (2022). Furthermore, a study

conducted by Sprout Social revealed that 73% of users feel a stronger connection to brands they interact with on TikTok compared to other platforms (Hill, 2022).

3.5 Messaging Sites

Two prominent examples of messaging platforms are WhatsApp and WeChat. WhatsApp is a widely used and free messaging application known for its simple, secure, and reliable messaging and calling features (Patricios & Goldstruck, 2021). With over 2 billion users across more than 180 countries, WhatsApp has become a global phenomenon (WhatsApp, 2023). In addition to text messages, WhatsApp has expanded its capabilities to support the exchange of various media types, including photos, videos, documents, and locations (WhatsApp, 2023). While WhatsApp became a part of Facebook in 2014, it continues to operate as a separate app (WhatsApp, 2023). Between January and April 2021, there were 45 million downloads, with an additional 128 million downloads during that period (Patricios & Goldstruck, 2021).

Initially, WhatsApp was primarily used for personal communication among family and friends. However, there has been a gradual shift, and people started using WhatsApp to communicate with businesses (Lua, 2023). The business platform of WhatsApp facilitates businesses in delivering customer support and conveying updates to customers regarding their purchases (WhatsApp, 2023). As the most widely used messaging platform, WhatsApp has become an essential customer service channel for businesses, offering an opportunity to establish personal connections with customers worldwide and provide timely support and real-time updates (Hill, 2022).

WeChat, owned by Tencent, is a messaging service based in China and ranks as the sixth most used social platform globally (Kharpal, 2019). Similar to WhatsApp, WeChat initially started as a messaging app but has evolved into an all-in-one platform (Lua, 2023). Apart from messaging and calling, WeChat allows users to engage in online shopping, bill payments, grocery purchases, money transfers, reservations, taxi bookings, and much more (Lua, 2023). Businesses keep users informed and engaged by sharing posts on their profile pages (Manners, 2021).

In summary, social media applications such as the ones discussed above have transitioned from being predominantly associated with younger generations to being widely utilized by people of all ages for daily communication, dating, business interactions, and socializing (Dixon, 2022). This transformation extends to various domains, including the fashion industry, where social media platforms have significantly influenced how people engage with fashion-related content and interact with others in the industry. The fashion industry has experienced significant transformations in advertising, promotion, and consumption behavior as a result of the broad adoption and utilization of social media applications. These applications have provided new avenues for fashion brands, influencers, and consumers to connect, share, and shape trends in the industry.

4 The Primary Reasons for Social Media Usage

4.1 Communication and the Sharing of Information

The swift and widespread broadcasting of information, including fashion-related news, is a prominent attribute of social media usage (Sengupta & Vaish, 2023). Social media platforms have revolutionized the way information is shared, allowing for rapid transmission and immediate access to a wide audience. This characteristic of social media has significant implications for various domains, including news, marketing, activism, and public discourse. Twitter, in particular, is renowned for its effectiveness in facilitating swift, direct, and unfiltered communication with a broad audience (Craig & Amernic, 2020). These types of applications have become crucial tools for governments, organizations, and educational institutions to disseminate vital information to both the general public and specific target audiences (Tsao et al., 2021). According to González-Padilla and Tortolero-Blanco (2020), the accessibility and wide user base of social media can be linked to the availability of affordable internet access. Notably, social media platforms became the primary sources of communication and information sharing with the public during the COVID-19 pandemic (Sengupta & Vaish, 2023). Moreover, the pandemic underscored social media as the preferred platform for expressing public opinions, perceptions, and attitudes toward various issues and events (Pérez-Escoda et al., 2020).

The uptake of social media as an informational source is also rising in developing countries (e.g., South Africa, Kenya, Malaysia, and the Philippines) where an estimated 70% of adults are now relying on social media for news consumption (Dixon, 2022). According to Strähle and Gräff (2017), social media assumes a vital role in fostering awareness regarding global challenges such as climate change while simultaneously providing consumers with a platform to exert influence over industry norms. Sustainability discussions and the dissemination of knowledge are prevalent on social media platforms (Strähle & Gräff, 2017). Social media influencers, for example, promote responsible decision-making among their followers by sharing sustainability-focused "do-it-yourself" tips, showcasing product reuse and recycling, and promoting sustainable brands (Pittman & Abell, 2021). Social media has fulfilled a pivotal role in closing the gap between businesses and consumers, effectively addressing key barriers to sustainable behavior, including disinterest, limited knowledge, and cynicism (Kong et al., 2021). Hwang and Kim (2015) suggest that by delivering targeted messages to users, social media has the power to influence attitudes and behaviors associated with social movements, indicating a direct impact. Additionally, Beaudoin (2009) highlights how social networks serve as platforms for providing valuable information to their members, which can be effectively utilized to mobilize action, also within the fashion industry.

4.2 Establishing Social Connection and Interaction

Apart from serving as an information source, social media platforms hold a notable function in facilitating communication and connection with friends and family (Brooks et al., 2020). Social networking sites like Facebook are primarily designed to facilitate social interactions and foster a sense of belonging among family and friends (Triantafillidou & Siomkos, 2018). Through online social networks, social media platforms promote the formation of social connections (Hwang & Kim, 2015). During the pandemic, when social interaction restrictions were in place, nearly half of all social media users reported using these platforms to stay connected with their loved ones (Patricios & Goldstruck, 2021). It has been said that social media users provide emotional support to one another during and after public health emergencies by sharing personal experiences (Veil et al., 2011). The utilization of social networks, as highlighted by Wangberg et al. (2008) and Idriss et al. (2009), can lead to an amplified sense of social support and interconnectedness among individuals. Apart from strengthening existing relationships, social media platforms also facilitate the establishment of new online relationships (Hwang & Kim, 2015). The social media environment encourages interaction and the formation of social ties, which include sharing ideas, advocating issues, socializing with others, and co-creating (Brodie et al., 2013).

The time spent by individuals on social media platforms interacting with others has significantly altered the manner in which they perceive and engage in social relationships (Karatsoli & Nathanail, 2020). The role of social networking extends beyond the mere expansion of social connections, as it holds considerable significance in shaping and influencing the decision-making processes of users (Yamagishi et al., 2016). Through social networking, individuals are not only able to connect with others but also find themselves susceptible to various forms of influence that can impact the choices they make. Online interactions with people known or met through social networking sites can impact consumers' purchasing decisions (Felix et al., 2017). For instance, online fashion retailers have established connections with online influencers who promote current fast fashion trends by featuring them on their Instagram and other social media accounts (Khodabandeh & Lindh, 2021). These influencers have the potential to influence consumers' clothing consumption practices.

Considering the above, it is essential to explore current theoretical insights that can provide a suitable basis for understanding the impact of social media usage on consumers' sustainable pursuits and their resulting clothing consumption behavior.

5 Social Capital Theory

Jacobs (1961) first introduced "social capital" in her book titled "*The Death and Life of Great American Cities*", followed by Loury (1976), who further expanded the conceptualization of social capital in his scholarly contribution titled "*A dynamic*

explanation of racial economic inequalities." Loury (1976) argued that racial social connections impact an individual's achievement through diverse human capital gains. Later on, during the 1980s and 1990s, social scientists such as Bourdieu (1985), Coleman (1988), and Putnam (2000) contributed to the popularity of the theory. Bourdieu's (1985) perspective on social capital encompassed cultural aspects. He defined it as membership in distinct social classes, with social capital acquired through group participation (Bourdieu, 1985). Coleman emphasized the presence of rules and norms in tightly knit organizations, further demarcating quantitative and qualitative measures of social capital via reciprocity and trust (Pan et al., 2019). In their respective works, Bourdieu (1985) and Coleman (1988) studied the interrelationship between social, economic, and human capital. The definition of social capital used by Putnam emphasized its collective nature and its application at individual, societal, and political levels (Folland, 2014).

Across various disciplines, the concept of social capital is characterized by varying definitions, yet they consistently emphasize the significance of productive social relationships (Claridge, 2020). According to social capital theory, social interactions are subject to the influence of social norms and structures (Castandea et al., 2015; Coleman, 1988; Jin & Shriar, 2013; Putnam, 2000). As a result, they have the potential to enhance societal efficiency by enabling coordinated actions, particularly in promoting sustainable behaviors. Compared to other forms of capital, social capital is established within interpersonal connections and is intentionally used in action (Azarian, 2001). According to Duggan (2015), the evolution of social media platforms and digitalization has fundamentally transformed interpersonal interactions and along with it the development and continuation of social capital. Research conducted by Gil de Zúniga et al. (2012), for example, found that active participation in political dialogues and seeking information on social networking sites influenced the growth of social capital. In addition, social media platforms appear to influence users' social capital by maintaining existing relationships and establishing new connections with geographically dispersed individuals in a virtual space (Vitak et al., 2011).

It is important to discern between different types of social capital and in particular bonding capital and bridging capital. Some scholars argue for the inclusion of a third category called "linking social capital" to capture social relations involving power dynamics and hierarchical structures (Claridge, 2018; Woolcock, 2001). However, linking social capital may be viewed as a subcategory of bridging social capital, specifically addressing vertical connections within bridging social capital (Woolcock, 2001). Bonding and bridging capital capture the dynamics of both closed civil society and more exclusive organizations and therefore feature more prominently in seminal literature (Patulny & Lind Haase Svendsen, 2007). Bonding social capital is valuable for survival, whereas bridging social capital is essential for progress (Claridge, 2018). The following sections will further clarify the difference between these two types of social capital in the context of social media usage and sustainable consumption behavior in the clothing domain.

5.1 Bonding Social Capital

Claridge (2020) describes bonding social capital as the realization of social connections based on shared demographic attributes, attitudes, information, and resources. Self-disclosure and networked communication, both of which happen naturally on social networking sites, help people build relationships and allow them access to bonding social capital (Pan et al., 2019). Bonding social capital can thus be seen as a form of social connection that is introspective in nature and reinforces the cohesion of exclusive identities and homogeneous groups characterized by shared backgrounds, such as ethnic communities (Hsu & Tran, 2013). This type of social capital fosters a feeling of belonging and harmony within tightly knit networks, where individuals with similar cultural or ethnic affiliations find common ground and support one another. Family members, close friends, and neighbors are individuals with whom someone would most likely build bonding social capital (Claridge, 2020; Williams, 2006).

Based on the aforementioned information, bonding social capital suggests a cohesive network of intimate affiliations with individuals who possess the capacity to offer substantial support or facilitate access to valuable resources within a given community (Ellison et al., 2007; Leonard & Onyx, 2003; Williams, 2006). Groups that are relatively homogeneous in nature often exhibit distinct characteristics, including elevated trust and cooperation within the group, while displaying lower levels of trust and cooperation with the broader society (Padovan, 2008). Social media platforms, such as Snapchat, have facilitated the development of stronger bonding capital among its users compared to other popular social networking sites like Facebook and Instagram (Phua et al., 2017). This can be attributed to the ability of Snapchat users to form deeper emotional connections and foster a greater sense of trust among their followers. As a result, the platform has provided a conducive environment for building and strengthening bonds within its user community, thereby enhancing the level of trust and cooperation among its members.

Bonding social capital allows individuals access to similar network assets. While this type of social capital provides solidarity, it may not always prove useful for situations that extend beyond the boundaries of network assets (Claridge, 2018). Prior study findings do however remain somewhat inconclusive on the matter. For example, La Rosa and Jorgensen (2021) found that family and friends (i.e., those who provide bonding capital) had a positive influence on participants' purchase intentions toward eco-friendly products. In contrast, Zhang and Dong's (2021) study found that bonding social capital did not influence the acquisition of sustainable alternatives. The same study did however reveal the importance of bridging social capital in influencing purchase decisions (Zhang & Dong, 2021).

5.2 Bridging Social Capital

Bridging social capital encompasses connections with individuals from diverse backgrounds, spanning different social divisions and heterogeneous groups (Hsu & Tran, 2013; Putnam, 2000; Williams, 2006). Bridging social capital is formed through associations that act as bridges between communities, groups, and organizations, including nonprofit organizations focused on sustainability (Claridge, 2018). Social media influencers, known as "Greenfluencers," who have an extensive following, can use their platforms to shape consumer behavior, also contributing to bridging social capital (Audrezet et al., 2020; Fraser & Brown, 2002). Through their actions, such as promoting sustainable clothing consumption practices, Greenfluencers can influence others to adopt similar behavior (Kapoor et al., 2023).

Platforms such as Instagram and Twitter offer users the opportunity to engage with individuals they would never meet with face to face in person. This can include famous individuals and public figures, indicating the presence of bridging capital on the social media platform (Phua et al., 2017). Bridging capital encourages interaction with diverse individuals, leading to exposure to different worldviews and access to varied resources (Williams, 2006). This includes perspectives on the climate change crisis and information about sustainable clothing practices. Bridging capital enables individuals to access network resources that are typically beyond their reach, resulting in significant individual benefits (Putnam, 2000; Kavanaugh et al., 2005; Claridge, 2018). People are more likely to participate in social movements such as adopting sustainable clothing consumption practices if their social media network includes individuals who participate in such movements and if they possess a broader bridging social capital (Hwang & Kim, 2015).

Bridging social capital may even exert a more extensive influence on consumers' intentions to acquire environmentally and socially sustainable products compared to bonding social capital (Kim et al., 2020). However, the frequency of interactions with bonding and bridging social capital must also be considered. Consumers may engage more frequently with bonding social capital, and their consumption patterns may depend on whether those in their bonding network engage in sustainable practices or not. To better understand the influence of social capital on consumers' consumption patterns, further investigation is needed to pinpoint the specific type of social capital that has the most significant influence. Nevertheless, online interactions, whether with bonding or bridging social capital, present significant potential for social influence as individuals increasingly use the Internet to comment on news stories and blogs in their everyday lives (Rossander & Eriksson, 2012). The growing interest in understanding social influence on social networking and microblogging sites like Twitter indicates the need for further research (Zhang et al., 2017).

6 Social Influence

Social influence refers to the psychological response when individuals are persuaded to adopt a specific viewpoint or behavior (Zhang et al., 2017). In 1951, Asch conducted conformity tests to illustrate how other people's opinions can impact an individual's ability to make objective decisions, and his work continues to guide social psychologists in understanding social group influence (Asch, 1956; Levine, 1999). Building upon Asch's experiments, Deutsch and Gerard (1955) conducted further studies, introducing modifications such as anonymous environments and visual presentations to assess others' opinions. They found that face-to-face encounters had a greater social influence compared to the anonymous condition. Social influence has also been studied regarding how easily consumers' decisions are influenced by others (Bearden et al., 1989). Studies by Lee (2008) and Peattie (2010) have specifically highlighted the significance of social influence on individuals' sustainable consumption behavior. Lee's (2008) study discovered that social influence was the most influential predictor of green behavior among adolescent consumers. However, it is essential to acknowledge that there are diverse types of social influence.

Deutsch and Gerard (1955) specifically differentiated normative and informative influence. Normative social influence refers to conforming to other people's positive expectations, while informational social influence involves receiving information from other individuals as confirmation of current reality (Deutsch & Gerard, 1955). The normative social influence thus focuses on approval from others, while informational social influence seeks to reduce uncertainty in a specific situation (Prislin & Crano, 2012). The following sections will further explore the distinctions between normative and informational social influence, particularly as it relates to social media usage and sustainable clothing consumption practices.

6.1 Normative Influence

Normative influence refers to the personal and interpersonal processes that drive individuals to align their thoughts, feelings, and behaviors with societal norms, standards, and conventions (Garcia et al., 2021). It involves the inclination to meet others' positive expectations, including those encountered on social media platforms (Khan & Khan, 2008). Normative influence is further subdivided into value-expressive and utilitarian influences (Chew & Leng, 2016). Value-expressive influences arise from the consumer's aspiration to augment their self-image through association with specific social groups, such as those characterized by bonding or bridging social capital (Chew & Leng, 2016). On the other hand, utilitarian influence becomes apparent when consumers pursue rewards or circumvent penalties by living up to other individuals' expectations (Bearden et al., 1989). This implies that individuals' consumption choices are affiliated with the values and norms upheld by

their social circles in order to express their identities or fulfill practical objectives. Although value-expressive and utilitarian influences are conceptually distinct, empirical research has found them challenging to differentiate (Chew & Leng, 2016). Nonetheless, these normative influences, when combined, can significantly impact consumer behavior.

Individuals receptive to normative influence are easily persuaded to align themselves with others in, for example, supporting a boycott (Sen et al., 2001). Normative influence also reflects individuals' tendency to use purchases, such as acquiring ethical clothing, as a means to identify with others or gain admiration from peers (Deutsch & Gerard, 1955; Khan & Khan, 2008). It arises from a desire to fit in, regardless of correctness, and ultimately results in public conformity without necessarily indicating private acceptance (Deutsch & Gerard, 1955; Levine, 2021). This suggests that consumers may sporadically purchase eco-friendly clothing to conform to their peers' preferences, without fully subscribing to the underlying principles of sustainable practices on a long-term basis.

Peers, particularly friends who constitute their bonding social capital networks, exert the greatest influence over the brands consumers choose (Khan & Khan, 2008). Interestingly, males tend to be more influenced by their peers' brand choices within their bonding social capital networks (Khan & Khan, 2008). In the context of social media, product approval seems to positively impact consumers' purchase intentions (Lee et al., 2015). Therefore, if consumers observe their bonding and/or bridging social capital networks expressing approval for sustainable clothing products on social media, it may influence them to also make such purchases.

Conversely, consumers with a strong interest in fashion are typically motivated to explore fashion-related information independently, regardless of normative influence. They would typically spend more time searching for suitable alternatives and are more open to informational persuasion (Chae et al., 2006).

6.2 Informational Influence

Informational influence describes individuals' propensity to acknowledge information from others as a basis for obtaining a better understanding of the world around them (Deutsch & Gerard, 1955; Bearden et al., 1989). It suggests that people are prone to rely on the knowledge and perspectives shared by others when forming their own understanding of reality. This can involve accepting information from individuals within bonding or bridging capital networks. Direct informational influence occurs through conversation and persuasion, while indirect informational influence arises from exposure to knowledge and comparison with others (Garcia et al., 2021). It stems from the belief that the group possesses superior knowledge (Levine, 2021).

Salazar et al.'s (2013) research findings demonstrated that consumers' consumption of socially and environmentally friendly products can be influenced by information shared by particular social groups, including family and friends. This

information may also be shared within the social media environment, as consumers interact with family and friends as well as other bonding social capital networks on various social media platforms. Koh and Leng (2017), focusing on sports apparel consumption, found that highly sports-involved male consumers were particularly susceptible to informational influence from others (even more so than female consumers or less sports-involved consumers). Informational influence can also impact other behaviors, such as consumers boycotting brands that do not provide fair wages, as a result of information disseminated through their social capital networks.

In summary, social influence, particularly through online networks (thus including both bonding social capital and bridging social capital), appears to be a crucial factor in determining consumer behavior (Khare et al., 2022), including the purchasing of eco-friendly clothing items (Lee, 2009; Kim et al., 2020; Zhao et al., 2019).

7 A Proposed Conceptual Framework for Future Investigation

Although much has been reported to date on sustainable fashion consumption changes, starting with earlier works such as those of Fletcher (2008) and Niinimaki (2010), comparatively limited scholarly works have specifically explored the link between social media usage and consumers' adoption of sustainable clothing consumption practices. The clothing and textile sectors are currently confronted with several critical environmental and social challenges. These challenges have been increasingly recognized by the public, leading to a growing demand for sustainable clothing among consumers (Mandarić et al., 2022). Consumers were confronted with how much needless spending they engage in during the COVID-19 pandemic, when they were left with limited choices other than adopting simpler lifestyles and shifting away from purchasing goods that provide immediate pleasure through hedonic shopping (Cinar, 2020). Another significant change that occurred during the pandemic due to social distance measures and less face-to-face contact was consumers' increased use of social media to satisfy their need for human relations and deal with the repercussions of the pandemic (Singh et al., 2020). Along with increased social media interaction, consumers also shifted their shopping habits to online platforms since they had to stay indoors due to lockdown measures and the fear of infection (Pang et al., 2022). These shifts in consumer behavior and social media usage are expected to have lasting implications and will further shape the fashion industry going forward. Therefore, there is a pressing need to devote immediate attention to bridging the gap in the current literature concerning the influence of social media on consumers' sustainable choices and associated clothing consumption behavior. Figure 1 depicts a proposed conceptual framework that may guide future empirical investigation. The framework is based on current theoretical insights surrounding social capital and social influence, presented by scholars such

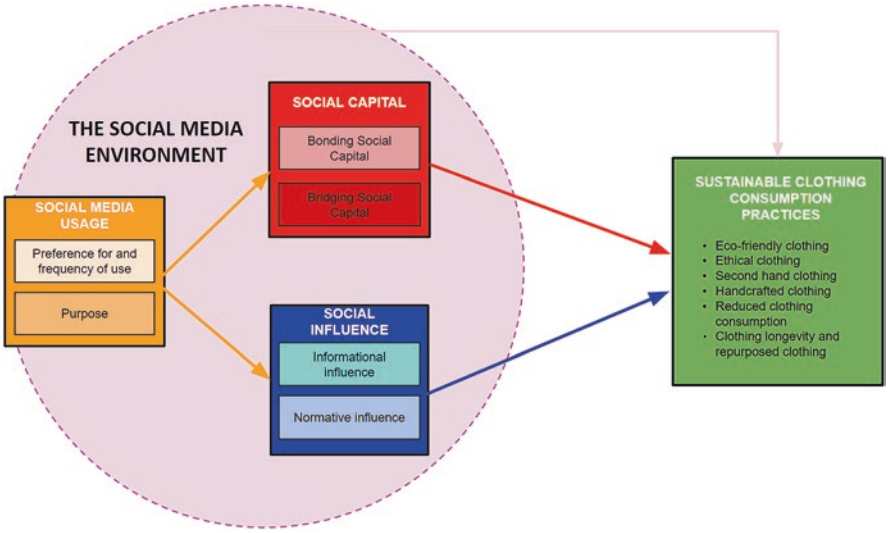

Fig. 1 A proposed conceptual framework for the investigation of social media influence on sustainable clothing consumption practices

as Beareden et al. (1989) and Putman (2000), and modified to the context of social media usage and the influence it may have on consumers' sustainable clothing consumption practices.

Social media applications have received considerable recognition for their capacity to magnify environmental concerns and encourage sustainable consumer behavior. Social media has become prominent in consumers' decision-making processes, along with the influence on their interactions with others (Kapoor et al., 2023). Scholars argue that consumers' engagement with others, which includes the cultivation of bonding and bridging social capital, has the potential to shape sustainable consumption behaviors (Johnstone & Hooper, 2016). Previous studies have observed a link between participation in social networking sites and increased social capital (Burke et al., 2011; Valenzuela et al., 2008). Therefore, it is worthwhile to further investigate consumers' use of social media on the development of their social capital in various contexts. Notably, Hwang and Kim's (2015) research revealed that "heavy" social media users (relating to the frequency, preference, and purpose of use) exhibited an increased scope of bonding and bridging social capital. In accordance with the proposed conceptual framework (Fig. 1), the first research proposition for future investigation thus follows:

P[1]: Increased levels of social media usage contribute to consumers' bridging social capital and bonding social capital.

Online interactions, whether it relates to bonding or bridging social capital, offer enormous potential for social influence, as people increasingly use the Internet to comment on everyday news stories and blogs (Rossander & Eriksson, 2012).

Whereas social media might have been primarily used to remain in contact with family and friends in the past, it has now evolved into a platform where users can interact with people who are external to their homogenous circles and obtain information from them regarding certain issues such as climate change. Wang et al.'s (2012) research found that study participants who frequently engaged on social media tended to adopt the norms of their social group. Furthermore, social media can aid the dissemination of information, ideas, and opinions as well as amplify the influence of various groups on an individual (Usman & Okafor, 2019). Therefore, a second research proposition for future investigation is as follows:

P^2: Social media usage is positively associated with consumers' receptiveness to social influence both normative and informational.

The online interactions that consumers have with individuals via social networking sites can significantly impact their purchasing decisions (Felix et al., 2017). Notably, numerous product brands have made concerted efforts to cultivate emotional connections and foster more personal relationships with consumers through social media platforms, thereby establishing networks of social capital (Khandual & Pradhan, 2019). According to Duggan (2015) and Hampton et al. (2011), social media platforms have become pivotal in enabling the establishment and sustenance of social capital. Consequently, conversations between consumers and their social capital networks can directly influence their clothing consumption practices. Zhang et al. (2020) found that heightened social media influence along with raised levels of social capital relates to consumers' responsible apparel consumption behaviors, including the acquisition of second-hand clothing and participation in garment reuse initiatives. For these reasons, the following research proposition offers fertile ground for further investigation:

P^3: Bridging and bonding social capital influence consumers' willingness to adopt sustainable clothing consumption practices.

Notwithstanding the consensus among scholars that bonding social capital is distinct from bridging social capital, there are a limited number of studies that have closely explored the potential divergent consequences of these two types of social capital from an individual perspective (Zhang et al., 2011). Together, bridging social capital and bonding social capital are considered valuable information sources regarding environmental and social issues and also on what can be done to address these issues within the clothing and textile domain. Hence, besides investigating social capital as a collective influence, future research endeavors could be directed toward acquiring a more profound comprehension of the distinct effects exerted by these two types of social capital on consumers' practices concerning sustainable clothing consumption.

When consumers view the different social media pages within their social capital networks, normative or informational influence may occur. For instance, their social networks can expose them to sustainability-related information, thereby enhancing their awareness of sustainable clothing consumption practices. Consequently, this heightened awareness may influence their decision-making process and motivate

them to actively participate in such practices. Consumers may feel that their social media connections are more knowledgeable about sustainability than they are and hence emulate their behavior by participating in comparable sustainable clothing consumption practices. Sun and Xing's (2022) research findings indicate that information disseminated through social media platforms can effectively promote products that have been produced sustainably and influence consumers' intentions to purchase eco-friendly items. In addition, the scholarly investigation conducted by Khare et al. (2022) revealed that the social influence exerted by online networks swayed consumers' consumption of sustainable clothing. Normative influence is reported to be a significant factor in sustainable clothing purchase behavior (Hiller Connell & Kozar 2012). If consumers perceive their social group to be promoting environmentally friendly behavior, they are more likely to conform to those behaviors. For these reasons, a fourth research proposition can be posited as follows:

P^4: Normative and informational social influence contributes to consumers' willingness to adopt sustainable clothing consumption practices.

Consumers can actively participate in diverse sustainable clothing consumption practices, encompassing the acquisition of eco-friendly garments, ethically produced items, and handcrafted products and engaging in second-hand clothing consumption. In addition to those consumption practices, consumers can reduce their consumption along with repurposing their clothing to increase clothing longevity. Better care practices that lengthen the life span of the clothing item can also increase its longevity. These types of sustainable clothing practices are pivotal in the pursuit of circularity in the fashion industry and should therefore be widely promoted via social media platforms. The question just remains as to what extent social media is successful in facilitating the desired behavioral changes, and for these reasons, future investigation is imperative.

8 Conclusion

Embracing a more sustainable future necessitates a drastic shift in fashion consumption. There exists a multitude of compelling reasons behind this imperative. Consumers have an important role to play as brands are starting to listen to their demands and are creating products to suit their needs. Due to increased environmental and social awareness, consumers are lending their support to companies that embrace ethical production practices and demonstrate environmental responsibility. This awareness has increased due to consumers utilizing social media platforms to discover more sustainable ways to consume. Social media thus fulfils an essential role in developing more sustainable communities because consumers' behaviors are significantly influenced by others. Social media platforms have exposed consumers to a broader scope of sustainable approaches to clothing consumption. This exposure can either come from their friends and/or families (bonding social capital) or people that fall outside of their communities (bridging social capital), such as

brands. By fostering a deeper comprehension of how interactions on social media can shape behavior, consumers, businesses, and marketers can optimize the utilization of social media platforms to effectively promote eco-conscious fashion choices. These practices are in alignment with the principles of the circular economy, which represent a critical objective that the clothing and textile industries strive to attain. Social media has allowed each sector of the fashion industry to connect and communicate on a more direct and regular basis; therefore, its usage and role in the sustainable fashion industry should receive more immediate and widespread attention in current literature.

References

Anner, M. (2020). *Abandoned? The impact of Covid-19 on workers and businesses at the bottom of global garment supply chains*. Paper presented at 7th conference of the regulating for decent work network, Switzerland. https://www.ilo.org/wcmsp5/groups/public/%2D%2D-dgreports/%2D%2D-inst/documents/genericdocument/wcms_818090.pdf. Accessed 26 Apr 2023.

Asch, S. E. (1956). Studies of independence and conformity: I. A minority of one against a unanimous majority. *Psychological Monographs: General and Applied, 70*(9), 1–70.

Audrezet, A., De Kerviler, G., & Moulard, J. G. (2020). Authenticity under threat: When social media influencers need to go beyond self-presentation. *Journal of Business Research, 117*, 557–569.

Azarian, R. (2001). Social capital: A theory of social structure and action. *Acta Sociologica, 44*(4), 341–343.

Bearden, W. O., Netemeyer, R. G., & Teel, J. E. (1989). Measurement of consumer susceptibility to interpersonal influence. *Journal of Consumer Research, 15*(4), 473–481.

Beaudoin, C. E. (2009). Bonding and bridging neighborliness: An individual-level study in the context of health. *Social Science & Medicine, 68*(12), 2129–2136.

Beveridge, C., & Lauron, S. (2023). *160+ social media statistics marketers need in 2023*. https://blog.hootsuite.com/social-media-statistics-for-social-media-managers/. Accessed13 Mar 2023.

Bilińska-Reformat, K., & Dewalska-Opitek, A. (2021). E-commerce as the predominant business model of fast fashion retailers in the era of global COVID 19 pandemics. *Procedia Computer Science, 12*, 2479–2490.

Bourdieu, P. (1985). The social space and the genesis of groups. *Theory and Society, 14*(6), 723–744.

Brodie, R. J., Ilic, A., Juric, B., & Hollebeek, L. (2013). Consumer engagement in a virtual brand community: An exploratory analysis. *Journal of Business Research, 66*(1), 105–114.

Brooks, S. K., Webster, R. K., Smith, L. E., Woodland, L., Wessely, S., Greenberg, N., & Rubin, G. J. (2020). The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. *Lancet (London, England), 395*, 912–920.

Brydges, T., & Hanlon, M. (2020). Garment worker rights and the fashion industry's response to COVID-19. *Dialogues in Human Geography, 10*(2), 195–198.

Burke, M., Kraut, R., & Marlow, C. (2011). Social capital on Facebook: Differentiating uses and users. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 571–580).

Castaneda, M. G., Martinez, C. P., Marte, R., & Roxas, B. (2015). Explaining the environmentally-sustainable consumer behavior: A social capital perspective. *Social Responsibility Journal, 11*(4), 658–676.

Chae, M.-H., Black, C., & Heitmeyer, J. R. (2006). Pre-purchase and post-purchase satisfaction and fashion involvement of female tennis wear consumers. *International Journal of Consumer Studies, 30*, 25–33.

Chew, S. S., & Leng, H. K. (2016). The role of social influence in purchasing sports apparel. *Athens Journal of Sports., 3*(4), 276–284.

Cinar, D. (2020). A research on the evaluation of consumers' voluntary simplicity lifestyle tendency in the Covid-19 period. *International Journal of Social Sciences and Education Research, 7*, 25–38.

Claridge, T. (2018). Functions of social capital–bonding, bridging, linking. *Social capital research, 20*(1), 1–7.

Claridge, T. (2020). Social capital at different levels and dimensions: A typology of social capital. *Social Capital Research*, 1–8.

Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology, 94*, S95–S120.

Craig, R., & Amernic, J. (2020). Benefits and pitfalls of a CEO's personal Twitter messaging. *Strategy & Leadership, 48*(1), 43–48.

Degli Esposti, P., Mortara, A., & Roberti, G. (2021). Sharing and sustainable consumption in the era of COVID-19. *Sustainability, 13*(4), 1903.

Demuyakor, J. (2020). Social media and COVID-19 pandemic: Enhancing panic or preventing it? *International Journal of Humanities, Arts and Social Sciences, 6*(5), 211–222.

Deutsch, M., & Gerard, H. B. (1955). A study of normative and informational social influences upon individual judgement. *The Journal of Abnormal and Social Psychology, 51*(3), 629.

Dixon, S. (2021). Time taken for selected social media platforms to reach 2 billion active users worldwide as of December 2021. https://www.statista.com/statistics/1285008/time-taken-social-media-platforms-two-billion-users/. Accessed 22 Oct 2023.

Dixon, S. (2022). *Social media use during COVID-19 worldwide – Statistics & Fact*. https://www.statista.com/topics/7863/social-media-use-during-coronavirus-covid-19-worldwide/. Accessed 25 Mar 2023.

Dixon, S. (2023). *Number of social media users worldwide from 2017 to 2027*. https://www.statista.com/statistics/278414/number-of-worldwide-social-network-users/#:~:text=In%202021%2C%20over%204.26%20billion,almost%20six%20billion%20in%202027. Accessed 13 Apr 2023.

Duggan, M. (2015). *Mobile messaging and social media 2015*. https://www.pewresearch.org/internet/2015/08/19/mobile-messaging-and-social-media-2015/. Accessed 13 July 2021.

Eger, L., Komárková, L., Egerová, D., & Mičík, M. (2021). The effect of COVID-19 on consumer shopping behaviour: Generational cohort perspective. *Journal of Retailing and Consumer Services, 61*, 102542.

Ellison, N. B., Steinfield, C., & Lampe, C. (2007). The benefits of Facebook "friends:" Social capital and college students' use of online social network sites. *Journal of Computer-Mediated Communication, 12*(4), 1143–1168.

Fashion Revolution. (2023). *About*. https://www.fashionrevolution.org/about/. Accessed 30 Mar 2023.

Felix, R., Rauschnabel, P. A., & Hinsch, C. (2017). Elements of strategic social media marketing: A holistic framework. *Journal of Business Research, 70*, 118–126.

Fletcher, K. (2008). *Sustainable fashion and textiles design journeys*. Earthscan.

Folland, S. (2014). *The economics of social capital and health*.

Forsey, C. (2021). *What is twitter and how does it work?* [online] Available from: https://blog.hubspot.com/marketing/what-is-twitter. Accessed 15 Mar 2023.

Fraser, B. P., & Brown, W. J. (2002). Media, celebrities, and social influence: Identification with Elvis Presley. *Mass Communication & Society, 5*(2), 183–206.

Garcia, R. J., Shaw, E. V., & Scurich, N. (2021). Normative and informational influence in group decision making: Effects of majority opinion and anonymity on voting behavior and belief change. *Group Dynamics: Theory, Research, and Practice, 25*(4), 319.

Ghouse, S. M., Duffett, R. G., & Chaudhary, M. (2022). How twitter advertising influences the purchase intentions and purchase attitudes of Indian millennial consumers? *International Journal of Internet Marketing and Advertising, 16*(1–2), 142–164.

Gil de Zúñiga, H., Jung, N., & Valenzuela, S. (2012). Social media use for news and individuals' social capital, civic engagement and political participation. *Journal of Computer-Mediated Communication, 17*(3), 319–336.

González-Padilla, D. A., & Tortolero-Blanco, L. (2020). Social media influence in the COVID-19 pandemic. International braz j urol: Official journal of the Brazilian society of. *Urology, 46*(suppl.1), 120–124. https://doi.org/10.1590/S1677-5538.IBJU.2020.S121

Granskog, A. L., Magnus, K., & Sawers, C. (2020). *Survey: Consumer sentiment on sustainability in fashion*. https://www.mckinsey.com/industries/retail/our-insights/survey-consumer-sentiment-on-sustainability-in-fashion. Accessed 13 Mar 2020.

Hampton, K. N., Sessions, L. F., & Her, E. J. (2011). Core networks, social isolation, and new media. *Information, Communication & Society, 14*(1), 130–155.

Herling, T. (2022). *Networking on LinkedIn: Why you should and how to do it*. https://www.linkedin.com/pulse/networking-linkedin-why-you-should-how-do-tzufit-herling/?trk=pulse-article_more-articles_related-content-card. Accessed 25 Mar 2023.

Hill, C. (2022). *15+ social media platforms your brand should use in 2022*. https://sproutsocial.com/insights/social-media-platforms/. Accessed 13 Apr 2023.

Hiller Connell, K. Y., & Kozar, J. M. (2012). Sustainability knowledge and behaviors of apparel and textile undergraduates. *International Journal of Sustainability in Higher Education., 13*(4), 394–407. https://doi.org/10.1108/14676371211262335

Hsu, Y., & Tran, T. H. C. (2013). Social relationship factors influence on EWOM behaviors in social networking sites: Empirical study: Taiwan and Vietnam. *International Journal of Business, Humanities and Technology, 3*(3), 22–31.

Hwang, H., & Kim, K. O. (2015). Social media as a tool for social movements: The effect of social media use and social capital on intention to participate in social movements. *International Journal of Consumer Studies, 39*(5), 478–488.

Idriss, S. Z., Kvedar, J. C., & Watson, A. J. (2009). The role of online support communities: Benefits of expanded social networks to patients with psoriasis. *Archives of Dermatology, 145*(1), 46–51.

Jacobs, J. (1961). *The death and life of great American cities*. Random House.

Jin, M. H., & Shriar, A. J. (2013). Linking environmental citizenship and civic engagement to public trust and environmental sacrifice in the Asian context. *Environmental Policy and Governance, 23*(4), 259–273.

Johnstone, M.-L., & Hooper, S. (2016). Social influence and green consumption behaviour: A need for greater government involvement. *Journal of Marketing Management, 32*(9–10), 827–855. https://doi.org/10.1080/0267257X.2016.1189955

Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of social media. *Business Horizons, 53*(1), 59–68.

Kapoor, K. K., Tamilmani, K., Rana, N. P., Patil, P., Dwivedi, Y. K., & Nerur, S. (2018). Advances in social media research: Past, present and future. *Information Systems Frontiers, 20*(3), 531–558.

Kapoor, P. S., Balaji, M. S., & Jiang, Y. (2023). Greenfluencers as agents of social change: The effectiveness of sponsored messages in driving sustainable consumption. *European Journal of Marketing, 57*(2), 533–561.

Karatsoli, M., & Nathanail, E. (2020). Examining gender differences of social media use for activity planning and travel choices. *European Transport Research Review, 12*(1), 44.

Kavanaugh, A., Carroll, J. M., Rosson, M. B., Zin, T. T., & Reese, D. D. (2005). Community networks: Where offline communities meet online. *Journal of Computer-Mediated Communication, 10*(4), JCMC10417. https://doi.org/10.1111/j.1083-6101.2005.tb00266.x

Khan, G., & Khan, N. (2008). Gender differences in susceptibility to normative social influence on the purchase decisions of designer label apparel. *International Business & Economics Research Journal (IBER), 7*(8), 11–19.

Khandual, A., & Pradhan, S. (2019). Fashion brands and consumers approach towards sustainable fashion. In S. S. Muthu (Ed.), *Fast fashion, fashion brands and sustainable consumption*. Singapore.

Khare, A., Sadachar, A., & Chakraborty, S. (2022). Influence of celebrities and online communities on Indian consumers' green clothing involvement and purchase behavior. *Journal of Fashion Marketing and Management: An International Journal, 26*(4), 676–699.

Kharpal, A. (2019). *Everything you need to know about WeChat – China's billion-user messaging app* [online] Available from https://www.cnbc.com/2019/02/04/what-is-wechat-china-biggest-messaging-app.html. Accessed 13 June 2023.

Khodabandeh, A., & Lindh, C. (2021). The importance of brands, commitment, and influencers on purchase intent in the context of online relationships. *Australasian Marketing Journal, 29*(2), 177–186.

Kim, J., Kang, S., & Lee, K. H. (2020). How social capital impacts the purchase intention of sustainable fashion products. *Journal of Business Research, 117*, 596–603.

Koetsier, J. (2023). *TikTok Earned $205 Million More Than Facebook, Twitter, Snap And Instagram Combined On In-App Purchases In 2023*. https://www.forbes.com/sites/johnkoetsier/2023/03/01/tiktok-earned-205-million-more-than-facebook-twitter-snap-and-instagram-combined-on-in-app-purchases-in-2023/?sh=145f3a5442d4. Accessed 25 Mar 2023.

Koh, J. Y., & Leng, H. K. (2017). Marketing sport coaching services on social network sites: An examination of social influence and country-of-origin effect. *Managing Sport and Leisure, 22*(5), 390–399.

Kong, H., Witmaier, A., & Ko, E. (2021). Sustainability and social media communication: How consumers respond to marketing efforts of luxury and non-luxury fashion brands. *Journal of Business Research, 131*, 640–651.

La Rosa, A., & Johnson Jorgensen, J. (2021). Influences on consumer engagement with sustainability and the purchase intention of apparel products. *Sustainability, 13*(19), 10655.

Lee, K. (2008). Opportunities for green marketing: Young consumers. *Marketing Intelligence & Planning, 26*(6), 573–586. https://doi.org/10.1108/02634500810902839

Lee, K. (2009). Gender differences in Hong Kong adolescent consumers' green purchasing behavior. *Journal of Consumer Marketing, 26*(2), 87–96.

Lee, K., Lee, B., & Oh, W. (2015). Thumbs up, sales up? The contingent effect of Facebook likes on sales performance in social commerce. *Journal of Management Information Systems, 32*(4), 109–143.

Leonard, R., & Onyx, J. (2003). Networking through loose and strong ties: An Australian qualitative study. *International Journal of Voluntary and Nonprofit Organizations, 14*(2), 189–203.

Levine, J. M. (1999). Solomon Asch's legacy for group research. *Personality and Social Psychology Review, 3*(4), 358–364.

Levine, J. M. (2021). *Normative Influence*. https://www.britannica.com/topic/conformity/Normative-influence. Accessed 12 Nov 2021.

Liu, C., Xia, S., & Lang, C. (2021). Clothing consumption during the COVID-19 pandemic: Evidence from mining tweets. *Clothing and Textiles Research Journal, 39*(4), 314–330.

Loury, G. (1976). A dynamic theory of racial income differences. In P. A. Wallace & A. LeMund (Eds.), *Chapter of women, minorities, and employment discrimination* (pp. 153–186). Lexington Books.

Lua, A. (2023) *21 top social media sites to consider for your brand in 2023*. [online] Available from: https://buffer.com/library/social-media-sites/. Accessed 25 Mar 2023.

Mandarić, D., Hunjet, A., & Vuković, D. (2022). The impact of fashion brand sustainability on consumer purchasing decisions. *Journal of Risk and Financial Management, 15*(4), 176.

Manners, J. (2021). *What is we chat intro to wechat marketing for business*. [online] Available from https://blog.hootsuite.com/wechat-marketing. Accessed 13 June 2023.

Mason, A. N., Narcum, J., Mason, K., & Awan, U. (2021). Social media marketing gains importance after Covid-19. *Cogent Business & Management, 8*(1), 1870797. https://doi.org/10.1080/23311975.2020.1870797

McGowan, B. S., Wasko, M., Vartabedian, B. S., Miller, R. S., Freiherr, D. D., & Abdolrasulnia, M. (2012). Understanding the factors that influence the adoption and meaningful use of social media by physicians to share medical information. *Journal of Medical Internet Research, 14*(5), 117.

McKinsey and Company. (2020). *The state of fashion 2021*. https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/state%20of%20fashion/2021/the-state-of-fashion-2021-vf.pdf. Accessed 24 Feb 2021.

Moschis, G. P. (2007). Life course perspectives on consumer behavior. *Journal of the Academy of Marketing Science, 35*, 295–307.

Niinimäki, K. (2010). Eco-clothing, consumer identity and ideology. *Sustainable Development, 18*(3), 150–162.

Oakley, R. L., & Salam, A. F. (2014). Examining the impact of computer-mediated social networks on individual consumerism environmental behaviors. *Computers in Human Behaviour, 35*, 516–526.

Padovan, D. (2008). Social capital, lifestyles and consumption patterns. In *System innovation for sustainability. perspectives on radical changes to sustainable consumption and production* (pp. 271–287).

Pan, Y., Coleman, L. J., & Manago, S. M. (2019). Effects of social media usage on social integration of university students. *International Journal of Technology in Teaching and Learning, 15*(1), 1–17.

Pang, W., Ko, J., Kim, S. J., & Ko, E. (2022). Impact of COVID-19 pandemic upon fashion consumer behavior: Focus on mass and luxury products. *Asia Pacific Journal of Marketing and Logistics, 34*(10), 2149–2164.

Patagonia. (2023). *Home page*. https://www.patagonia.com/home/. Accessed 30 Mar 2023.

Patricios, O., & Goldstruck, A. (2021). *Social media landscape report 2021* [online] Available from https://website.ornico.co.za/wp-content/uploads/2021/06/The-SA-Social-Media-Landscape-Report-2021.pdf. Accessed 10 Mar 2022.

Patulny, R. V., & Lind Haase Svendsen, G. (2007). Exploring the social capital grid: Bonding, bridging, qualitative, quantitative. *International Journal of Sociology and Social Policy, 27*(1/2), 32–51.

Peattie, K. (2010). Green consumption: Behavior and norms. *Annual Review of Environment and Resources, 35*, 195–228.

Pérez-Escoda, A., Jiménez-Narros, C., Perlado-Lamo-de-Espinosa, M., & Pedrero-Esteban, L. M. (2020). Social networks' engagement during the COVID-19 pandemic in Spain: Health media vs. healthcare professionals. *International Journal of Environmental Research and Public Health, 17*(14), 5261.

Phua, J., Jin, S. V., & Kim, J. (2017). Uses and gratifications of social networking sites for bridging and bonding social capital: A comparison of Facebook, twitter, Instagram, and snapchat. *Computers in Human Behaviour, 72*, 115–122.

Pinterest. (2023). *All about pinterest*. [online] Available from: https://help.pinterest.com/en/guide/all-about-pinterest. Accessed 13 Apr 2023.

Pittman, M., & Abell, A. (2021). More trust in fewer followers: Diverging effects of popularity metrics and green orientation social media influencers. *Journal of Interactive Marketing, 56*(1), 70–82.

Prislin, R., & Crano, W. D. (2012). 15 a history of social influence research. In A. W. Kruglanski & W. Stroebe (Eds.), *A history of social influence research*. Psychology Press.

Putnam, R. D. (2000). *Bowling alone: The collapse and revival of American community*. Simon and Schuster.

Rosander, M., & Eriksson, O. (2012). Conformity on the Internet–The role of task difficulty and gender differences. *Computers in Human Behavior, 28*(5), 1587–1595.

Saeed, M. A., Farooq, A., Kersten, W., & Ben Abdelaziz, S. I. (2019). Sustainable product purchase: Does information about product sustainability on social media affect purchase behavior? *Asian Journal of Sustainability and Social Responsibility, 4*(1), 9.

Salazar, H. A., Oerlemans, L., & van Stroe-Biezen, S. (2013). Social influence on sustainable consumption: Evidence from a behavioural experiment. *International Journal of Consumer Studies, 37*(2), 172–180.

Segura, A. (2023). *The picture perfect guide on how to use pinterest* [online] Available from https://mailchimp.com/resources/the-picture-perfect-guide-to-pinterest/. Accessed 13 June 2023.

Sen, S., Gürhan-Canli, Z., & Morwitz, V. (2001). Withholding consumption: A social dilemma perspective on consumer boycotts. *Journal of Consumer Research, 28*(3), 399–417.

Sengupta, S., & Vaish, A. (2023). A study on social media and higher education during the COVID-19 pandemic. *Universal Access in the Information Society.* https://doi.org/10.1007/s10209-023-00988-x

Singh, S., Dixit, A., & Joshi, G. (2020). Is compulsive social media use amid COVID-19 pandemic addictive behavior or coping mechanism? *Asian Journal of Psychiatry, 54*, 102290.

Strähle, J., & Gräff, C. (2017). The role of social media for a sustainable consumption. In J. Strähle (Ed.), *Green fashion retail. springer series in fashion business*. Springer. https://doi.org/10.1007/978-981-10-2440-5_12

Sun, Y., & Xing, J. (2022). The impact of social media information sharing on the green purchase intention among generation Z. *Sustainability, 14*(11), 6879.

Triantafillidou, A., & Siomkos, G. J. (2018). The impact of Facebook experience on consumers' behavioral brand engagement. *Journal of Research in Interactive Marketing, 12*, 164–192.

Truong, D., & Truong, M. D. (2022). How do customers change their purchasing behaviors during the COVID-19 pandemic? *Journal of Retailing and Consumer Services, 67*, 102963.

Tsao, S.-F., Chen, H., Tisseverasinghe, T., Yang, Y., Li, L., & Butt, Z. A. (2021). What social media told us in the time of COVID-19: A scoping review. *The Lancet Digital Health, 3*(3), 175–194.

Usman, A. & Okafor, S (2019) Exploring the relationship between social media and social influence. In *Leveraging computer-mediated marketing environments*. IGI Global.

Utz, S. (2016). Is LinkedIn making you more successful? The informational benefits derived from public social media. *New Media & Society, 18*(11), 2685–2702.

Valenzuela, S., Park, N., & Kee, K. F. (2008). Lessons from Facebook: The effect of social network sites on college students' social capital. In *9th international symposium on online journalism.*

Veil, S. R., Buehner, T., & Palenchar, M. J. (2011). A work-in-process literature review: Incorporating social media in risk and crisis communication. *Journal of Contingencies and Crisis Management, 19*(2), 110–122.

Vitak, J., Zube, P., Smock, A. D., Carr, C. T., Ellison, N. B., & Lampe, C. (2011). It's complicated: Facebook users' political participation in the 2008 election. *Cyberpsychology, Behavior and Social Networking, 14*(3), 107–114.

Wang, X., Yu, C., & Wei, Y. (2012). Social media peer communication and impacts on purchase intentions: A consumer socialization framework. *Journal of Interactive Marketing, 26*(4), 198–208.

Wangberg, S. C., Andreassen, H. K., Prokosch, H.-U., Santana, S. M. V., SØRensen, T., & Chronaki, C. E. (2008). Relations between internet use, socio-economic status (SES), social support and subjective health. *Health Promotion International, 23*(1), 70–77.

WhatsApp. (2023). *About us* [online] Available from: https://www.whatsapp.com/about/. Accessed 13 June 2023.

Williams, D. (2006). On and off the 'net: Scales for social Capital in an Online era. *Journal of Computer-Mediated Communication, 11*(2), 593–628.

Woolcock, M. (2001). *The place of social capital in understanding social and economic outcome*. Paper Presented at the contribution of human and social capital to sustained economic growth and well-being, Ottawa.

Yamagishi, Y., Saito, K.. & Ikeda, T. (2016). Modeling of travel behavior processes from social media. In *PRICAI 2016: Trends in artificial intelligence: 14th pacific rim international conference on artificial intelligence* (pp. 626–637). Springer International Publishing.

Zhang, X., & Dong, F. (2021). How virtual social capital affects behavioral intention of sustainable clothing consumption pattern in developing economies? A case study of China. *Resources, Conservation and Recycling, 170*, 105616.

Zhang, S., Anderson, S. G., & Zhan, M. (2011). The differentiated impact of bridging and bonding social capital on economic well-being: An individual level perspective. *Journal of Sociology and Social Welfare, 38*, 119.

Zhang, X., Han, D.-D., Yang, R., & Zhang, Z. (2017). Users' participation and social influence during information spreading on twitter. *PLoS One, 12*, e0183290. https://doi.org/10.1371/journal.pone.0183290

Zhang, H., Gupta, S., Sun, W., & Zou, Y. (2020). How social-media-enabled co-creation between customers and the firm drives business value? The perspective of organizational learning and social capital. *Information & Management, 57*(3), 103200.

Zhao, L., Lee, S. H., & Copeland, L. R. (2019). Social media and Chinese consumers' environmentally sustainable apparel purchase intentions. *Asia Pacific Journal of Marketing and Logistics, 31*(4), 855–874.

Measuring Textile (Un)sustainability to Raise Purchasing Choices Awareness: The Case of Cotton Fabrics

Maria Pia Spinelli, Giovanni Lagioia, Christian Bux, and Vera Amicarelli

Abstract Accounting textile material flows at the macro-level and assessing their environmental impacts turns out to be of great importance to monitor progress and raise awareness toward the adoption of circular economy strategies and better purchasing choices. The lack of useful schemes aimed at this purpose leads to the use of methodological expedients that have many limits. The present chapter deals with the unsustainable production and consumption of textiles in the European Union (EU) by tracking their flows with Material Flow Analysis (MFA) and evaluating the related environmental impacts by Life Cycle Assessment (LCA), focusing on the case of cotton fabrics. The domestic production and the apparent consumption of woven cotton are mainly responsible for ecotoxicity and freshwater eutrophication impacts. The impacts attributable to the apparent consumption are higher than those of domestic production since the EU is an importer of textiles from developing countries. This begs questions of an ethical nature relating to the EU demand and consumption of textiles. Enhancing circular economy actions seems critical, but measuring and characterizing the material flows at macro-level today remain difficult making the assessment of policy effectiveness and the implementation of consumer awareness action complex.

Keywords Textile industry · Circular economy · Material flow analysis · Life cycle assessment · Environmental sustainability

M. P. Spinelli (✉) · G. Lagioia · C. Bux · V. Amicarelli
Department of Economics, Management and Business Law, University of Bari Aldo Moro – Largo Abbazia Santa Scolastica, Bari, Italy
e-mail: maria.spinelli@uniba.it; giovanni.lagioia@uniba.it; christian.bux@uniba.it; vera.amicarelli@uniba.it

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0_6

1 Introduction

In the field of natural fibers, cotton is the most used worldwide and is employed to produce several typologies of products. More than 30 million hectares of land are cultivated with cotton in over 80 countries, for an amount of over 50 million farmers. Europe is a well-established market for cotton, accounting for 5.2 billion euro of imports in 2018, with Italy representing the first importer in Europe (954 million euro), followed by Germany (729 million euro), and Portugal (571 million euro) (CBI, 2020). Cotton is a plant-based natural fiber obtained from plant seeds, which are covered with short and long white hairs. Long ones are classified as fibers, while the shorter are called linters (Muthu & Gardetti, 2020). They exist dozens of species of cotton plant *Gossypium* with hairs of different quality, from extra-fine to medium, including coarse count and padding (Radhakrishnan, 2017). The most cultivated is *Gossypium hirsutum*, due to its high yield (Jabran & Chauhan, 2019). Among natural plant fibers, cotton is the one with the highest density (1.5–1.6 g/cm3) and the smallest diameter (12–38 μm) (Muthu & Gardetti, 2020). Thanks to its characteristics, cotton fibers are mainly used for spinning to yarn, weaving of fabric, and manufacturing of nonwoven; on the contrary, cotton linters become raw material for padding mattresses and cushions as regards textiles but also for manufacturing plastics, explosives, and paper products (Radhakrishnan, 2017). On the global scale, 80% of cotton is used in clothes, especially denim, representing 1/5 of the overall cotton use; house furnishings (sheets and towels) account for 15%, and 5% is nonwoven utilization mainly for filters and padding (FAO, 2021). In terms of demand, cotton has lost its importance due to the increase in market share of man-made fibers. During the 1960s and 1970s, cotton accounted for approximately 60%, whereas since 2002, polyester has never stopped its growth becoming the first fiber consumed (Textile World, 2015; FAO, 2021). Nowadays, only 1% of the world production of cotton takes place in Europe, mostly in Greece, Spain, and Bulgaria (European Commission, 2022), while Asia and America are major producers (Radhakrishnan, 2017; Jabran & Chauhan, 2019).

Cotton is a tropical and subtropical plant; however, it does not stand high (as well as low) temperatures, so it is of primary importance to select the proper sowing time (Ali et al., 2014; Jabran & Chauhan, 2019). Thermal changes and other abiotic stresses (e.g., drought, salinity, flooding) can influence germination and subsequent vegetative development, compromising fiber yield and quality; so nutrient supply through fertilization and the use of pesticides are important to make cotton plant less vulnerable (Lord, 2003; Jabran & Chauhan, 2019). As the seed ripens, fibers develop, taking 45–50 days from sowing (Lord, 2003; Jabran & Chauhan, 2019). After defoliation, machine picking or machine stripping processes can take place to harvest mechanically, paying attention to machine settings to avoid spoiling the product by machine aggressiveness (Lord, 2003). Then, the fibers are separated from the seeds by the ginning process, which also cleans them from unwanted

matter, and compressed into bales. Once supplied to the spinning mill, cotton bales are opened, and the fibers are divided into small clumps, cleaned, and homogeneously blended to be carded getting straightened and oriented in the same direction. So, they are assembled into the so-called slivers, strips of loose textile fibers, which are aligned in the drawing process, improving their evenness (Lord, 2003). Combing, as an additional step, can further improve fiber alignment for high-quality yarns (Lord, 2003). The slivers thus processed become an intermediate product called "roving," now ready to be spun. Fibers are twisted or bound together to provide a fine continuous length of thread (Lawrence, 2010) and then processed to be suitable for fabric formation. During weaving preparation, yarns are transferred from cones to the beam to form a sheet to be chemically treated to preserve them from damage through the slashing process, which can also modify some characters of the yarns (e.g., weight or stiffness), giving to fabrics a specific effect (Lord, 1982; Gandhi, 2012). Finally, the resulted wrap can be positioned to the back of the loom for weaving (Gandhi, 2012). The woven fabric is then further treated with chemicals and colorants in the wet processing, to give precise features to the final product (e.g., color, softening, waterproofing) (Madhav et al., 2018).

Under the environmental and managerial perspective, cotton cultivation, processing, and manufacturing result to be water and chemical intensive. Monocropping, extensive irrigation, use of fertilizers and pesticides, application of toxic and nonrecyclable chemicals, and massive discharge of effluents are the aspects of major concern related to the supply chain sustainability and affecting the developing or underdeveloped countries in which the production is mostly held (Madhav et al., 2018; Radhakrishnan, 2017). About 2.5% of water (Esteve-Turrillas & de La Guardia, 2017), as well as 4.7% of the pesticides and 10% of insecticides used on the global scale are associated with the production of cotton fibers (Transformers Foundation, 2021).

In the following paragraphs, the methodological expedient illustrated in the chapter "Measuring Textile (Un)sustainability to Raise Purchasing Choice Awareness: Theoretical Background" is applied to the case of cotton fabrics circulating in the European Union (EU) in 2020. The example is proposed as an applicative and non-exhaustive case study, to highlight the difficulties concerning the application of tools not designed for tracking and tracing flows but which at the moment remain the only ones available to supporting the estimation of the environmental impacts related to the consumption model of specific products toward sustainability policies. The results and discussion (Sect. 3) highlight the limits of the research framework and the combined methodology used (i.e., MFA and LCA), discussing the outcomes from an environmental perspective, as to illustrate the main challenges and the possible opportunities to enhance the sustainability in the textile sector.

2 Materials and Methods

2.1 Research Framework

The aim of the current research is determining, estimating, and comparing the impacts related to the domestic production and apparent consumption of woven cotton fabrics in the EU. Production is intended as domestic production, while apparent consumption stands for the textiles put on the market, coming from national production and imports, minus exports (Köhler et al., 2021). The decision to consider both domestic production and apparent consumption is the need to determine and to attribute the right share of impacts to those responsible for demand. The methodology used involved two different steps: the estimation of material flows by using the Material Flow Analysis (MFA) and the assessment of the associated environmental impacts by using the Life Cycle Assessment (LCA). Secondary data from ProdCom and Comext Eurostat data sets, plus Agribalyse database, were used. In this way, the authors determined two functional units (FUs), corresponding the first to the amount of the EU domestic production of woven cotton fabrics (FU1) and the second to the sum of domestic production and imports, minus exports (FU2) (apparent consumption). Figure 1 illustrates the research framework.

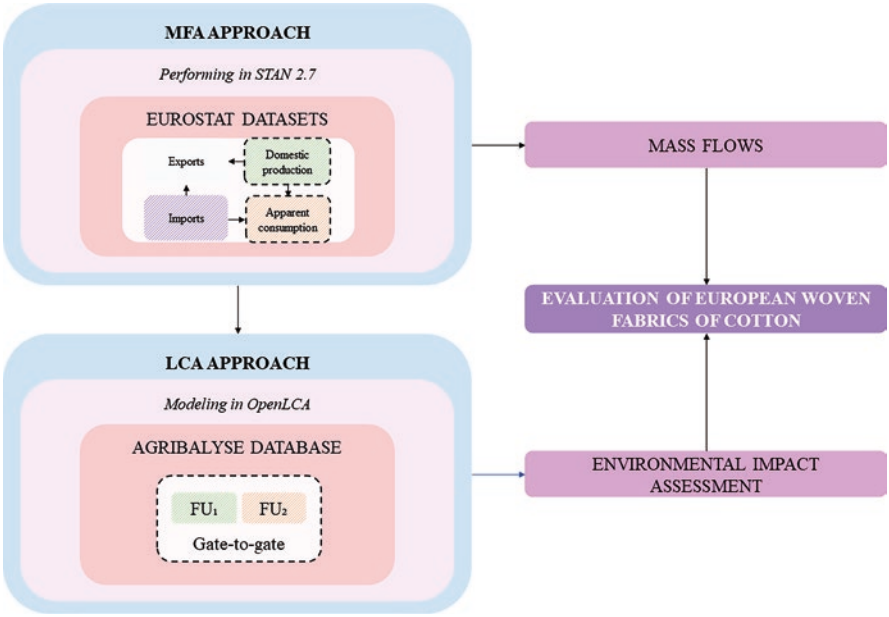

Fig. 1 Research framework. (Source: Personal elaboration by the authors)

2.2 Flow Estimation

In this context, the MFA maps the movement of fibers, yarns, and woven fabrics of cotton within the EU, giving the possibility to perform the LCA comparing domestic production and apparent consumption.

As already reported in several studies on the accounting of textile flows by the European Commission Joint Research Centre (JRC) (Beton et al., 2014; Köhler et al., 2021) and taken up by Amicarelli et al. (2023), ProdCom and Comext Eurostat data sets were used to collect data on the amounts of fibers, yarns, and woven fabrics produced and consumed in the $EU\text{-}27_{2020}$. ProdCom data sets used were DS-066341 "Sold production, exports and imports" and DS-066342 "Total production." Comext data sets used were DS-045409 "Trade Since 1988 by HS2, 4, and 6 and CN8" and DS-056120 "Sold production, exports, and imports" (Eurostat, 2022). Product categories included were those corresponding to the classification of economic activity codes (NACE codes) "13.10 Preparation and spinning of textile fibers" and "13.20 Weaving of textiles" within the ProdCom list 2020. In particular, the classification of products by activity codes (CPA codes) shown in Table 1 were those considered for flow estimation.

Data on total production by DS-066342 referring to the codes 13.20.20.20 and 13.20.20.60 are not made available; therefore, it was decided to consider the sold production by DS-056120 and DS-066341 (Amicarelli et al., 2023). This was only an expedient to get closer to the most probable quota of the volumes, but it is clear the impossibility of obtaining precise estimates.

Since the data set used to assess the environmental impacts takes into account only the units of mass and considering that the data referring to production, imports, and exports of woven fabrics by DS-066341, DS-066342, and DS-056120 are provided in square meters (m^2), the estimation was made according to Amicarelli et al. (2023), i.e., using weight data of trade from DS-045409 and referring to the corresponding codes of the External trade nomenclature reference (HS/CN) reported in the ProdCom list 2020 (see Table 2).

The following is the conversion equation according to Amicarelli et al. (2023) (1):

$$\text{Production t}_{n,y} = \left[\frac{\left(\frac{\text{Import t}_{n,y}}{\text{Import km}^2_{n,y}} \right) + \left(\frac{\text{Export t}_{n,y}}{\text{Export km}^2_{n,y}} \right)}{2} \right] \times \text{Production km}^2_{n,y} \quad (1)$$

Notes: t = tons; n = product code; y = year; km^2 = square kilometers.

Table 1 CPA codes considered for flow estimation

CPA codes	Description
13.10.25	Cotton, carded or combed
13.10.61.32	Yarn of uncombed cotton, n.p.r.s., for woven fabrics (excluding for carpets and floor coverings)
13.10.61.33	Yarn of uncombed cotton, n.p.r.s., for knitted fabrics and hosiery
13.10.61.35	Yarn of uncombed cotton, n.p.r.s., for other uses (including carpets and floor coverings)
13.10.61.52	Yarn of combed cotton, n.p.r.s., for woven fabrics (excluding for carpets and floor coverings)
13.10.61.53	Yarn of combed cotton, n.p.r.s., for knitted fabrics and hosiery
13.10.61.55	Yarn of combed cotton, n.p.r.s., for other uses (including carpets and floor coverings)
13.10.61.60	Cotton yarn, p.r.s. (excluding sewing thread)
13.10.61.Z1	Cotton yarn of uncombed fibers, n.p.r.s.
13.10.61.Z2	Cotton yarn of combed fibers, n.p.r.s.
13.10.62	Cotton sewing thread
13.20.20.14	Woven fabrics of cotton, not of yarns of different colors, weighing ≤200 g/m^2, for clothing
13.20.20.17	Woven fabrics of cotton, not of yarns of different colors, weighing ≤200 g/m^2, for household linen or home furnishing textiles
13.20.20.19	Woven fabrics of cotton, not of yarns of different colors, weighing ≤200 g/m^2, for technical or industrial uses (excluding gauze, medical gauze)
13.20.20.20	Woven fabrics of cotton weighing ≤100 g/m^2, for medical gauzes, bandages, and dressings
13.20.20.31	Woven fabrics of cotton of yarns of different colors, weighing ≤200 g/m^2, for shirts and blouses
13.20.20.42	Woven fabrics of cotton, not of yarns of different colors, weighing >200 g/m^2, for clothing
13.20.20.44	Woven fabrics of cotton, not of yarns of different colors, weighing >200 g/m^2, for household linen or home furnishing textiles
13.20.20.49	Woven fabrics of cotton, not of yarns of different colors, weighing >200 g/m^2, for technical or industrial uses
13.20.20.60	Woven fabrics of denim cotton weighing >200 g/m^2 (including denim other than blue)
13.20.20.72	Woven fabrics of cotton of yarns of different colors, for other clothing
13.20.20.74	Woven fabrics of cotton of yarns of different colors, for household linen or home furnishing textiles
13.20.20.79	Woven fabrics of cotton of yarns of different colors, for technical or industrial uses
13.20.20.Z1	Cotton fabrics, ≤ 200 g/m^2 (excluding gauze and colored yarns)
13.20.20.Z2	Cotton fabrics, > 200 g/m^2 (excluding colored yarns)
13.20.20.Z3	Woven fabrics of cotton of yarns of different colors (excluding denim)
13.20.42.00	Terry toweling and similar woven terry fabrics of cotton

Note: Aggregated headings (Z-codes) allow to compare ProdCom and trade data: 13.10.61.[Z1 + Z2] aggregate 13.10.61.[32 + 33 + 35 + 52 + 53 + 55] and 13.20.20.[Z1 + Z2 + Z3] aggregate 13.20.20.[14 + 17 + 19 + 31 + 42 + 44 + 49 + 72 + 74 + 79]

Table 2 Correspondence between ProdCom CPA and external trade nomenclature reference (HS/CN) codes

CPA codes	External trade nomenclature reference (HS/CN) codes
13.20.20.20	52.08.[11.(10) + 21.(10)]
13.20.20.60	52.09.42 + 52.11.42
13.20.20.Z1	52.08.[11.(90) + 12.(16 + 19 + 96 + 99) + 13 + 19 + 21.(90) + 22.(16 + 19 + 96 + 99) + 23 + 29 + 31 + 32.(16 + 19 + 96 + 99) + 33 + 39 + 51 + 52 + 59.(10 + 90)] + 52.10.[11 + 19 + 21 + 29 + 31 + 32 + 39 + 51 + 59] + 52.12.[11.(10 + 90) + 12.(10 + 90) + 13.(10 + 90) + 0.15.(10 + 90)]
13.20.20.Z2	52.09.[11 + 12 + 19 + 21 + 22 + 29 + 31 + 32 + 39 + 51 + 52 + 59] + 52.11.[11 + 12 + 19 + 20 + 31 + 32 + 39 + 51 + 52 + 59] + 52.12.[21.(10 + 90) + 22.(10 + 90) + 23.(10 + 90) + 25.(10 + 90)]
13.20.20.Z3	52.08.[41 + 42 + 43 + 49] + 52.09.[41 + 43 + 49] + 52.10.[41 + 49] + 52.11.[41 + 43 + 49.(10 + 90)] + 52.12.[14.(10 + 90) + 24.(10 + 90)]
13.20.42.00	58.02.[11 + 19]

Notes: 13.20.20.[Z1 + Z2 + Z3] are representative of 13.20.20.[14 + 17 + 19 + 31 + 42 + 44 + 49 + 72 + 74 + 79]

Finally, the apparent consumption of fibers, yarns, and woven fabrics of cotton in the EU during 2020 was determined according to Köhler et al. (2021) (Eq. 2):

$$\text{Apparent consumption} = \text{Production t}_{n,y} + \text{Import t}_{n,y} - \text{Export t}_{n,y} \quad (2)$$

Notes: t = tons; n = product code; y = year.

These material flows were handled through STAN 2.7 (substance flow analysis).[1] STAN 2.7 has been built and updated by the Institute for Water Quality, Resources, and Waste Management at Vienna University of Technology. It is a useful tool to balance, within a specific system, material, and substance flows (Cencic & Rechberger, 2008).

2.3 Environmental Impact Assessment

The LCA methodology was used for the environmental impact assessment. The LCA is an internationally standardized procedure and for this reason one of the most suitable tools to make assessments replicable and comparable. It examines the potential environmental impacts throughout the life cycle of a product, based on an inventory analysis, in which a list of inputs and outputs are assigned to impact categories (Klöpffer & Grahl, 2014). System boundaries consider material flows in the EU-27_{2020} referring to the production, imports, and exports of woven cotton fabrics in the year 2020 and take into account all the relevant flows of gate-to-gate

[1] https://www.stan2web.net

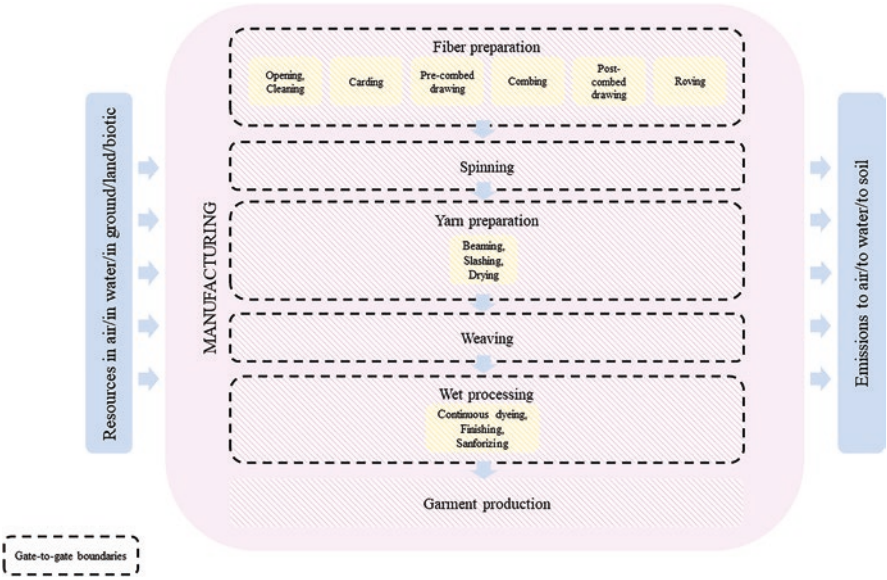

Fig. 2 LCA system boundaries. (Source: Personal elaboration by the authors)

manufacturing processes, excluding transportation. Since in 2021 recycled cotton accounted only for approximately 1% of the overall cotton production (Textile Exchange, 2022), the authors decided to consider the manufacturing phases relating to virgin cotton, from cotton fiber gin to woven fabric. Therefore, the following processes preparing cotton fiber for weaving into fabric with desired properties (e.g., color and texture) are included: opening/cleaning, carding, pre-drawing/pre-preparation, combing, drawing, roving, spinning, beaming/slashing/drying, weaving, continuous dyeing, finishing, and sanforizing. Figure 2 illustrates the in-depth LCA system boundaries considered in the research.

The assessment was performed using OpenLCA software, while agribalyse_v301_27052021 database was used as source for the background data upon which the amounts of production and apparent consumption of woven cotton fabrics were modelled. The ReCiPe 2016 Midpoint (I) method was used for life cycle impact assessment (LCIA). Eighteen impact categories were considered, namely, water consumption, fine particulate matter formation, marine eutrophication, terrestrial ecotoxicity, fossil resource scarcity, ozone formation (human health, terrestrial acidification, freshwater ecotoxicity, marine ecotoxicity, stratospheric ozone depletion, land use, ozone formation) terrestrial ecosystems, human carcinogenic toxicity, mineral resource scarcity, human noncarcinogenic toxicity, ionizing radiation, freshwater eutrophication, global warming. Finally, the normalization was made according to World (2010) (I) set. The main assumptions adopted in this study are the following: (i) the amount of recycled cotton fiber is not considered in the inventory analysis; (ii) the inventory is modelled for global; (iii) the macroeconomic scenario is business as usual.

3 Results and Discussion

During 2020, the production of cotton fibers (carded or combed) represented 4% of the total fiber production in Europe, with an amount of 88,000 t. Further 23,559 t were imported and 1,778 t exported, resulting in a supply of 109,780 t. Considering that cotton yarns (excluding sewing threads) produced to put up for retail store amounted to 9,099 t and those destined for further processes were equal to 126,610 t and 24,317.3 t, respectively, it seems that the supply of cotton fibers is not sufficient to cover the national production of cotton yarns. This may be due to incorrect estimates or the use of fiber stocks for national production, which we do not know about. For sure, this data unreliability does not make estimating flows simple and therefore does not allow reaching exhaustive results. This turns out to be a major limitation when building the LCA model considering the geographical origin of material flows, an essential information for a correct impact estimation. Imports of cotton yarns in 2020 were equal to 250,673 t, while exports were equal to 22,329 t, for a total supply of 389,117 t. More than 97% of the cotton yarn supply was destined for further processing, including the domestic production of woven cotton fabrics. Figure 3 illustrates the recorded flows.

According to the flows considered, the EU turns out to be an importer of woven cotton fabrics rather than a producer or exporter, with imports exceeding both domestic production and exports, by +35% and +182%, respectively. In 2020, the domestic production of woven cotton fabrics was equal to 169,907 t (FU1), while the apparent consumption accounted for 318,851 t (FU2), as shown in Fig. 4.

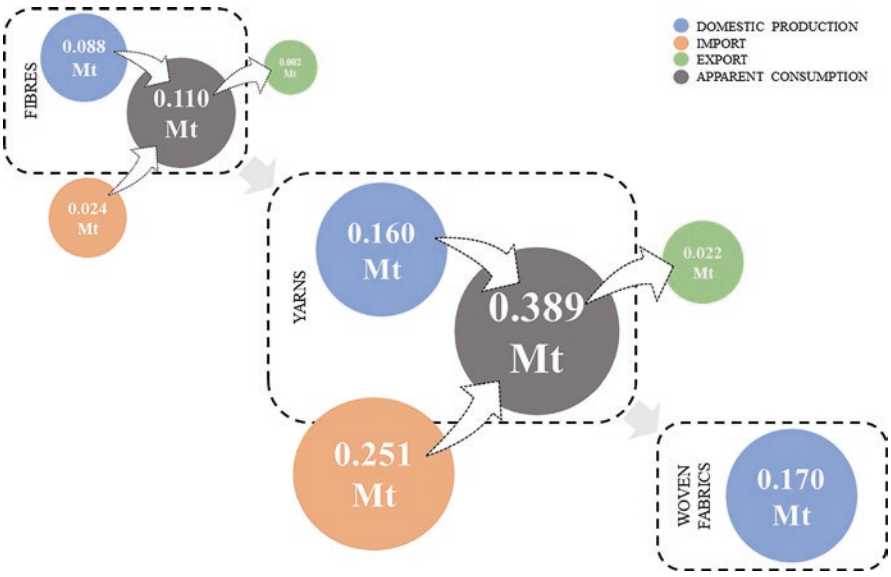

Fig. 3 EU-27$_{2020}$ cotton fibers and yarns flows. (Source: Personal elaboration by the authors)

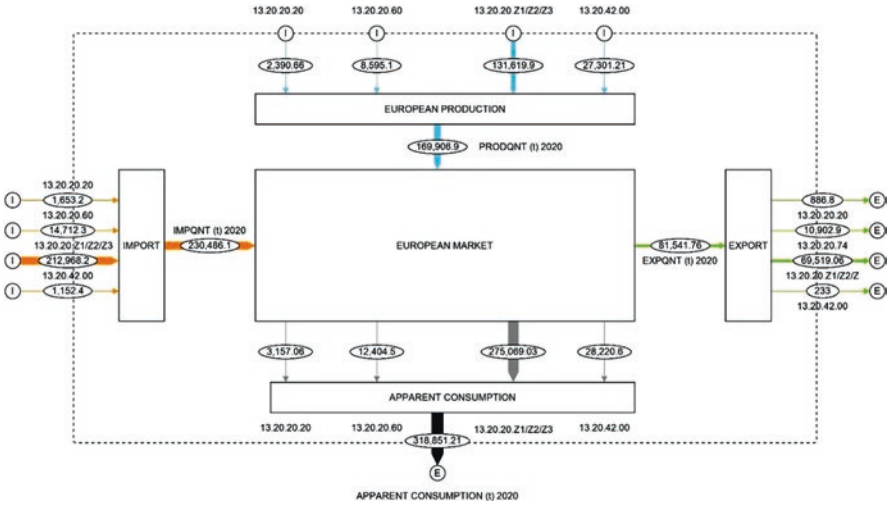

Fig. 4 Woven cotton fabrics flow estimation in the $EU27_{2020}$ by STAN 2.7. Notes: blue flows = European production flows; orange flows = import flows; green flows = export flows; gray flows = apparent consumption flows. (Source: Personal elaboration by the authors)

Woven cotton fabrics for technical and industrial uses, household linen or home furnishing textiles, and clothing (excluding denim) represent most EU flows (domestic production, 77.7%; imports, 92.4%; exports, 85.3%; apparent consumption, 86.3%). The only item that appears to be produced and consumed predominantly in the EU is the woven cotton fabric for gauze, bandages, and medical dressings. The need to aggregate different categories for the estimation of the overall EU flows shows the difficulty in representing and consequently attributing the impacts to individual products. This is a key criticality to stress since knowing the overall impact certainly helps to describe the size of the problem, but being able to characterize the flows would give the possibility to distinguish the origin of the market demand underlying the impacts to intervene with targeted strategies upstream. The overall impacts related to the manufacturing of woven cotton fabrics according to EU flows are described in Table 3.

By ascertaining that the EU is an importing country, it is easy to understand that the impacts attributable to apparent consumption are higher than those of domestic production. As regards the global warming potential, the gap between domestic production and apparent consumption is over 261,000 t of CO2 eq. Likewise, water consumption records more than 22 million m^3, fine particulate matter formation other 248,000 kg of PM2.5 eq, fossil resource scarcity additional 53,681 t of oil eq, and so on. Therefore, EU domestic production only partially reflects the impacts for which the EU market is responsible. The textile market is divided into producing countries (developing countries) and consuming countries (developed countries) (Palamutcu, n.d.). Indeed, in 2020, the top exporters of textiles were China (billion 276 USD), Vietnam (billion 38.9 USD), and Bangladesh (billion 37.3 USD), while

Table 3 Environmental impacts related to domestic production and apparent consumption of woven cotton fabrics in $EU27_{2020}$

Impact category	Reference unit	Result	
		Domestic production	Apparent consumption
Fine particulate matter formation	kg PM2.5 eq	2.81E + 05	5.29E + 05
Fossil resource scarcity	kg oileq	6.12E + 07	1.15E + 08
Freshwater ecotoxicity	kg 1.4-DCB	1.1E + 07	2.07E + 07
Freshwater eutrophication	kg Peq	1.3E + 05	2.44E + 05
Global warming	kg CO_2eq	2.97E + 08	5.58E + 08
Human carcinogenic toxicity	kg 1.4-DCB	1.54E + 05	2.89E + 05
Human noncarcinogenic toxicity	kg 1.4-DCB	2.15E + 07	4.03E + 07
Ionizing radiation	kBq Co-60 eq	2.6E + 07	4.87E + 07
Land use	m^2a cropeq	1.07E + 08	2E + 08
Marine ecotoxicity	kg 1.4-DCB	3.13E + 06	5.88E + 06
Marine eutrophication	kg Neq	6.63E + 04	1.24E + 05
Mineral resource scarcity	kg Cueq	3.125 + 05	5.86E + 05
Ozone formation, human health	kg NO_xeq	5.73E + 05	1.07E + 06
Ozone formation, terrestrial ecosystems	kg NO_xeq	5.79E + 05	1.09E + 06
Stratospheric ozone depletion	kg CFC_{11}eq	8.11E + 02	1.52E + 03
Terrestrial acidification	kg SO_2eq	1.06E + 06	1.99E + 06
Terrestrial ecotoxicity	kg 1.4-DCB	1.58E + 08	2.96E + 08
Water consumption	m^3	2.57E + 07	4.83E + 07

Source: Personal elaboration by the authors

the top importers were the United States (billion 122 USD), Germany (billion 63 USD), and the United Kingdom (billion 35.3 USD) (OEC, 2023). To reduce manufacturing costs, textile and clothing companies outsource the production to developing countries, where workers deal with unsafe and unhealthy environments (Boström & Micheletti, 2016). This also means that a significant share of impacts for which EU demand is responsible occurs in other regions of the world, raising questions of an ethical nature relating to the environmental consequences of a production linked to EU demand but often suffered by others. That is why allocating responsibility and acting considering only the domestic production of goods is not the right way to tackle the sustainability issues linked to overproduction. Globalized supply chain and market demand must be a priority of the EU strategy, which needs to overcome cultural, geographical, and political obstacles. From a global perspective, the domestic production (approx. 0.17 Mt) and the apparent consumption (approx. 0.32 Mt) of woven cotton fabrics within the EU are mainly responsible for freshwater ecotoxicity, marine ecotoxicity, human noncarcinogenic toxicity, terrestrial ecotoxicity, and freshwater eutrophication. Figure 5a, b illustrate normalized LCA results related to impact categories <5,000,000 and >5,000,000 respectively.

Main results show that the impacts from gate-to-gate manufacturing processes originate mainly from chemicals and nutrients dissolved to the air, water, and soil,

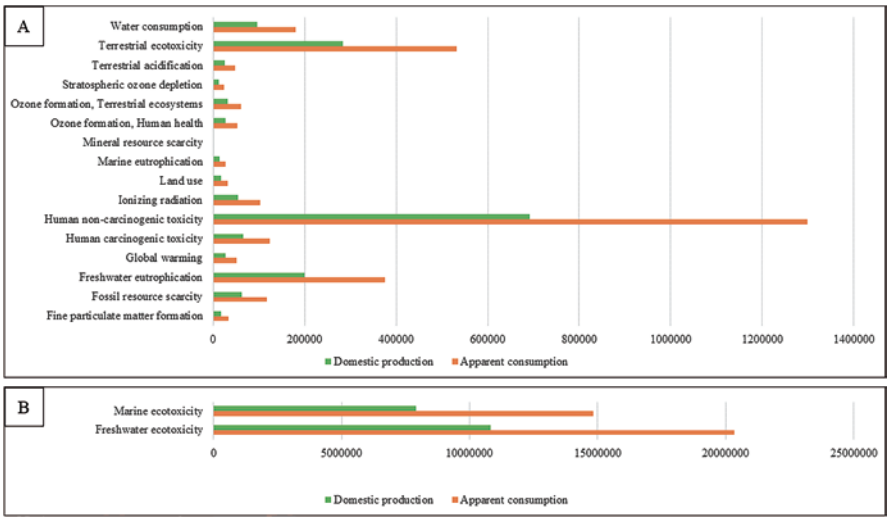

Fig. 5 Normalized LCA results. (Source: Personal elaboration by the authors)

potentially causing ecotoxic impacts and eutrophication on aquatic and terrestrial ecosystems. The increase in chemical concentration into the environment determines an increased exposure of species and humans to these substances, causing damage to ecosystems and human health (Huijbregts et al., 2017a). On the other hand, the rise in nutrient levels in water or soil increases the uptake by organisms such as cyanobacteria and algae, causing the loss of species richness particularly in freshwaters ecosystems (Huijbregts et al., 2017b). Pesticides and fertilizers used in cotton cultivation are responsible for ecotoxicity and eutrophication impacts (Zhang et al., 2015; Esteve-Turrillas & de La Guardia, 2017; La Rosa & Grammatikos, 2019; Avadí et al., 2020; Moazzem et al., 2021). The overuse of fertilizers causes environmental problems and health concerns, linked to the massive infusion of nitrogen and phosphorus and the release of heavy metals and other compounds into soil (Morari et al., 2011). Wet processing is mainly responsible for the release of chemical substances in aquatic and terrestrial ecosystems, since water is employed to spread dyes and other chemicals on the fabrics, with high water consumption rates and toxic emissions (Khattab et al., 2020; Zhang et al., 2022). Indeed, wet processing has high environmental impact, and its subprocesses have often the most impact in gate-to-gate manufacturing of textiles according to several studies reported in the literature (Costa et al., 2021; L'Abbate et al., 2018; Powar et al., 2021; Schmutz et al., 2020; Yuan et al., 2013; Zhang et al., 2022; Zhang et al., 2018). These processes increase cotton performances and provide the properties that customers value in purchase decision of any item. That is why tracking of flows can be functional for attributing responsibility for impacts and identifying hot spots directly linked to market demand. Substituting the virgin cotton with recovered fibers allows to avoid the impacts linked to the cultivation and dyeing processes (Esteve-Turrillas & de La Guardia, 2017); therefore, closed-loop recycling is the goal that the textile

industry should aim for to mitigate the environmental impacts. However, it is important to remark that yarns produced based on 100% recovered cotton fiber show a lower-quality degree compared to virgin ones mainly in terms of strength, elongation, length, and fineness (Arafat & Uddin, 2022). Today, about 50% of collected textiles is downcycled in products of lower value (Sandin & Peters, 2018), not allowing to effectively replace virgin fiber for new productions.

4 Conclusions

With the aim to highlight the issue of accounting textile material flows at the macro-level and assessing their environmental impacts, in this chapter woven cotton flows within the EU were tracked, considering either the domestic production, the apparent consumption, the import, and the export flows. The associated environmental impacts were then estimated by using the LCA methodology according to the ISO 14040:2006/AMD 1:2020 and the14044:2006/AMD 2020. Considering the impact categories proposed in the ReCiPe 2016 Midpoint (I) method, it results that the domestic production and the apparent consumption of woven cotton in the EU, across several processes (i.e., opening/cleaning, carding, pre-drawing/pre-preparation, combing, drawing, roving, spinning, beaming/slashing/drying, weaving, continuous dyeing, finishing, sanforizing), are mainly responsible for freshwater ecotoxicity, marine ecotoxicity, human noncarcinogenic toxicity, terrestrial ecotoxicity, and freshwater eutrophication. The global warming potential has been evaluated at 2.97E + 08 kg CO_2eq in the domestic production and at 5.58E + 08 kg CO_2eq in the apparent consumption, whereas the water consumption has been estimated at 2.57E + 08 m^3 and 4.83E + 07 m^3, respectively. It results that the impacts attributable to the apparent consumption are higher than those of domestic production since the EU is an importer of textiles from developing countries. Questions of an ethical nature arise relating to the EU demand of textiles, which environmental consequences must be mitigated by enhancing reuse and recycling practices supported by measuring and assessment tools applied at macro-level both to evaluate policy effectiveness and to raise awareness on purchasing choices.

The main limitation of the present research framework concerns data. As already pointed out in the chapter "Measuring Textile (Un)sustainability to Raise Purchasing Choice Awareness: Theoretical Background," Eurostat data sets utilized do not allow to characterize cotton flows within multi-material products (e.g., clothing) since the value in units of mass does not distinguish between the different types of fibers and other metal or plastic components; this is the reason why cotton fabric has been used as an example case in this chapter. In addition, CPA codes and their description do not always allow to follow material flows. Therefore, it is difficult to establish the exact quantity of materials flowing within the entire EU system. This turns out to be a problem when evaluating the improvements achieved thanks to the implementation of circular economy strategies, which need feedback in terms of avoided waste production and less use of virgin materials. In this matter, the

European Commission started a preparatory study which will analyze the environmental impacts of textile products and the potential to enhance their sustainability, providing support and scientific evidence for the future establishment of eco-design, GPP, and EU ecolabel requirements and criteria for textiles. However, future research should also focus on tools, schemes, and methodologies for the estimation of the abovementioned macro-level material flows, since struggling in measuring and characterizing them makes it difficult to obtain results from the environmental assessment which are functional to the implementation of policies by the institutions and to guide consumers on more sustainable purchasing choices.

References

Ali, H., Hussain, G. S., Hussain, S., Shahzad, A. N., Ahmad, S., Javeed, H. M. R., & Sarwar, N. (2014). Early sowing reduces cotton leaf curl virus occurrence and improves cotton productivity. *Cercetări Agronomice în Moldova, 47*(4), 71–81.

Amicarelli, V. Spinelli, M.P., Bux, C., Lagioia, G. (2023). Production and consumption trends in European textile sector and main sustainability challenges. In Lagioia, G., Paiano, A., Amicarelli, V., Gallucci, T., & Ingrao, C. (Eds.), *Innovation, quality and sustainability for a resilient circular economy*. The Role of Commodity Science, Series: Circular Economy and Sustainability, Springer Nature.

Arafat, Y., & Uddin, A. J. (2022). Recycled fibers from pre- and post-consumer textile waste as blend constituents in manufacturing 100% cotton yarns in ring spinning: A sustainable and eco-friendly approach. *Heliyon, 8*(11), e11275. https://doi.org/10.1016/j.heliyon.2022.e11275

Avadí, A., Marcin, M., Biard, Y., Renou, A., Gourlot, J.-P., & Basset-Ment, C. (2020). Life cycle assessment of organic and conventional non-Bt cotton products from Mali. *The International Journal of Life Cycle Assessment, 25*, 678–697. https://doi.org/10.1007/s11367-020-01731-x

Beton, A., Dias, D., Farrant, L., Gibon, T., Le Guern, Y., Desaxce, M., et al. (2014). Environmental improvement potential of textiles (IMPRO-textiles). *European Commission, 20*.

Boström, M., & Micheletti, M. (2016). Introducing the sustainability challenge of textiles and clothing. *Journal of Consumer Policy, 39*(4), 367–375. https://doi.org/10.1007/s10603-016-9336-6

CBI (Ministry of Foreign Affairs). (2020). *The European market potential for sustainable cotton*. https://www.cbi.eu/market-information/apparel/sustainable-cotton/market-potential. Accessed 8 Nov 2022.

Cencic, O., & Rechberger, H. (2008). Material flow analysis with software STAN. *Environmental Engineering and Management Journal, 18*(1), 3–7.

Costa, A. F., Aragao, J. V., Duarte, A. D., Macedo, J. S., Galdino, C. J., Jr., Milanez, V. F., & Sarubbo, L. A. (2021). Analysis of the environmental life cycle of dyeing in textiles. *Chemical Engineering Transition, 86*, 727–732. https://doi.org/10.3303/CET2186122

Esteve-Turrillas, F. A., & de La Guardia, M. (2017). Environmental impact of recover cotton in textile industry. *Resources, Conservation and Recycling, 116*, 107–115. https://doi.org/10.1016/j.resconrec.2016.09.034

European Commission. (2022). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. EU Strategy for Sustainable and Circular Textiles. COM(2022) 141 final. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0141. Accessed 11 Apr 2023.

Eurostat. (2022). Manufactured goods (PRODCOM). Data. Database. https://ec.europa.eu/eurostat/web/prodcom/data/database. Accessed 16 Jan 2022.

FAO. (2021). *Recent trends and prospects in the world cotton market and policy developments*. https://www.fao.org/3/cb4589en/cb4589en.pdf. Accessed 23 Nov 2022.

Gandhi, K. L. (2012). Yarn preparation for weaving: Warping. *Woven Textiles*, 62–84. https://doi.org/10.1533/9780857095589.1.62

Huijbregts, M. A. J., Steinmann, Z., Elshout, P. M. F., Stam, G., Verones, F., Vieira, M. D. M., … & van Zelm, R. (2017). ReCiPe 2016 v1. 1 a harmonized life cycle impact assessment method at midpoint and endpoint level report I: Characterization. RIVM report 2016-0104a. National Institute for Public Health and the Environment RIVM: Bilthoven, The Netherlands.

Huijbregts, M. A., Steinmann, Z. J., Elshout, P. M., Stam, G., Verones, F., Vieira, M., et al. (2017a). ReCiPe 2016: A harmonised life cycle impact assessment method at midpoint and endpoint level. *The International Journal of Life Cycle Assessment, 22*, 138–147.

Huijbregts, M., Steinmann, Z., Elshout, P., Stam, G., Verones, F., Vieira, M., … & Zijp, M. (2017b). ReCiPe 2016 v1. 1-A harmonized life cycle impact assessment method at midpoint and endpoint level: Report I. Characterization (No. RIVM report 2016–0104a). National Institute for Public Health and Environment.

Jabran, K., & Chauhan, B. S. (Eds.). (2019). *Cotton production*. Wiley.

Khattab, T. A., Abdelrahman, M. S., & Rehan, M. (2020). Textile dyeing industry: Environmental impacts and remediation. *Environmental Science and Pollution Research, 27*(4), 3803–3818. https://doi.org/10.1007/s11356-019-07137-z

Klöpffer, W., & Grahl, B. (2014). *Life cycle assessment (LCA): A guide to best practice*. Wiley.

Köhler, A., Watson, D., Trzepacz, S., Löw, C., Liu, R., Danneck, J., Konstantas, A., Donatello, S. & Faraca, G. (2021). Circular economy perspectives in the EU textile sector, EUR 30734 EN, publications Office of the European Union, Luxembourg, doi:https://doi.org/10.2760/858144, JRC125110.

L'Abbate, P., Dassisti, M., Cappelletti, G. M., Nicoletti, G. M., Russo, C., & Ioppolo, G. (2018). Environmental analysis of polyester fabric for ticking. *Journal of Cleaner Production, 172*, 735–742. https://doi.org/10.1016/j.jclepro.2017.10.045

La Rosa, A. D., & Grammatikos, S. (2019). Comparative life cycle assessment of cotton and other natural fibers for textile applications. *Fibers, 7*, 101.

Lawrence, C. A. (Ed.). (2010). *Advances in yarn spinning technology*. Elsevier.

Lord, P. R. (1982). *Weaving: Conversion of yarn to fabric* (Vol. 12). Woodhead Publishing.

Lord, P. R. (Ed.). (2003). *Handbook of yarn production: Technology, science and economics*. Elsevier. https://doi.org/10.1533/9781855738652.18

Madhav, S., Ahamad, A., Singh, P., & Mishra, P. K. (2018). A review of textile industry: Wet processing, environmental impacts, and effluent treatment methods. *Environmental Quality Management, 27*(3), 31–41. https://doi.org/10.1002/tqem.21538

Moazzem, S., Crossin, E., Daver, F., & Wang, L. (2021). Assessing environmental impact reduction opportunities through life cycle assessment of apparel products. *Sustainable Production and Consumption, 28*, 663–674. https://doi.org/10.1016/j.spc.2021.06.015

Morari, F., Vellidis, G., & Gay, P. (2011). Fertilizer. In J. Nriagu (Ed.), *Encyclopedia of environmental health*. Elsevier.

Muralikrishna, I.V., & Manickam, V. (2017). *Environmental management*. Butterworth-Heinemann, Elsevier. Science and Engineering for Industry.

Muthu, S. S., & Gardetti, M. A. (Eds.). (2020). *Sustainability in the textile and apparel industries* (pp. 163–187). Springer. https://doi.org/10.1007/978-3-030-37929-2

OEC. (2023). *Textiles*. Retrieved from https://oec.world/en/profile/hs92/textiles?disaggregationButton=hs4Button. Accessed 11 Apr 2023.

Palamutcu, S. (n.d.) *Moral issues in textile production*. https://www.isem.info/PastConferences/ISEM2014/ISEM2014/papers/A7-ISEM2014ID19.pdf. Accessed 09 Dec 2022.

Powar, A., Perwuelz, A., Behary, N., Hoang, L. V., Aussenac, T., Loghin, C., & Chen, G. (2021). Environmental profile study of ozone decolorization of reactive dyed cotton textiles by utilizing life cycle assessment. *Sustainability, 13*(3), 1225. https://doi.org/10.3390/su13031225

Radhakrishnan, S. (2017). Sustainable cotton production. In *Sustainable fibres and textiles* (pp. 21–67). Woodhead Publishing. doi:https://doi.org/10.1016/B978-0-08-102041-8.00002-0.

Sandin, G., & Peters, G. M. (2018). Environmental impact of textile reuse and recycling – A review. *Journal of Cleaner Production, 184*, 353–365. https://doi.org/10.1016/j.jclepro.2018.02.266

Schmutz, M., Hischier, R., Batt, T., Wick, P., Nowack, B., Wäger, P., & Som, C. (2020). Cotton and surgical masks – what ecological factors are relevant for their sustainability? *Sustainability, 12*, 10245. https://doi.org/10.3390/su122410245

Textile Exchange. (2022). *Preferred fiber & materials*. Market Report 2022. https://textileexchange.org/app/uploads/2022/10/Textile-Exchange_PFMR_2022.pdf. Accessed 8 Nov 2022.

Textile World. (2015). *Man-made fibers continue to grow*. https://www.textileworld.com/textile-world/fiber-world/2015/02/man-made-fibers-continue-to-grow/. Accessed 23 Nov 2022.

Transformers Foundation. (2021). *Cotton: A case study in misinformation*. https://www.worldcottonday.com/location/cotton-a-case-study-in-misinformation/. Accessed 8 Nov 2022.

Yuan, Z. W., Zhu, Y. N., Shi, J. K., Liu, X., & Huang, L. (2013). Life-cycle assessment of continuous pad-dyeing technology for cotton fabrics. *The International Journal of Life Cycle Assessment, 18*(3), 659–672. https://doi.org/10.1007/s11367-012-0470-3

Zhang, Y., Liu, X., Xiao, R., & Yuan, Z. (2015). Life cycle assessment of cotton T-shirts in China. *The International Journal of Life Cycle Assessment, 20*(7), 994–1004. https://doi.org/10.1007/s11367-015-0889-4

Zhang, Y., Kang, H., Hou, H., Shao, S., Sun, X., Qin, C., & Zhang, S. (2018). Improved design for textile production process based on life cycle assessment. *Clean Technology Environmental Policy, 20*(6), 1355–1365. https://doi.org/10.1007/s10098-018-1572-9

Zhang, S., Xu, C., Xie, R., Yu, H., Sun, M., & Li, F. (2022). Environmental assessment of fabric wet processing from gate-to-gate perspective: Comparative study of weaving and materials. *Science of the Total Environment, 159495*. https://doi.org/10.1016/j.scitotenv.2022.159495

Consumer Awareness and Textile Sustainability: Sensory Evaluation of Hemp Textiles by Consumers as a Prospective Market Research Method for New Textile Products

Snežana Stanković

Abstract In the modern world, the consumer's perception of comfort and esthetic performance of clothing is often a deciding factor in purchasing. In this chapter, research aimed at investigating and improving the comfort properties of hemp-based clothing textiles were reviewed. In addition to a systematic presentation of the comfort potential of hemp, the subjective consumers' assessment of a chosen range of hemp-based undershirts in the wear trial tests is presented and discussed in the chapter. Consumers expressed a preference for the pure hemp undershirt in terms of thermal sensation, while the hemp/acrylic undershirt was perceived as the best choice concerning thermal comfort. The hemp undershirt appeared to be at an advantage in terms of thermal and comfort sensations during great physical efforts. Apart from scientific research, the method of the real-life human sensory evaluation of a garment in the wear trial tests can serve as a practical clothing design tool as well as an effective way of educating consumers in terms of purchasing preferences.

Keywords Textiles · Comfort · Industrial hemp · Acrylic · Sensory evaluation · Wear trial test · Knitted fabric

1 Introduction

Positive sustainability aspects, which are elaborated in Chap. 3, along with the excellent textile properties of hemp fiber resulted in current research aimed at investigating and improving the comfort properties of hemp-based clothing textiles to introduce this valuable natural fiber into the high-quality clothing sector. Most of these investigations included testing and evaluation of the comfort properties of

S. Stanković (✉)
Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia
e-mail: stankovic@tmf.bg.ac.rs

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0_7

hemp-based textiles objectively using standard testing procedures. These studies provide quantitative and reproducible data which can be used as guidance on how to design and manufacture hemp-based textiles with consistent quality. However, there are no physical instruments for measuring a consumer's feelings or the level of its satisfaction in terms of comfort while wearing a particular garment. Bearing all this in mind, in addition to a systematic presentation of the comfort potential of hemp, the subjective consumers' assessment of a chosen range of hemp-based textile fabrics in the wear trial tests will be presented and discussed in this chapter.

In a broader sense, the purpose of this chapter is to present the method of the real-life human sensory evaluation of a garment as a simple but effective way to educate the consumer about new-developed textile materials as well as increase their awareness of various positive aspects (sustainability, health) of new products. This way, the textile companies have the opportunity to influence the personal experience of the consumer and thereby change their purchasing preferences. In addition, conducting wear trial tests for collecting human sensation in real-life experience can be a very useful clothing design tool enabling the engineers and decision-makers in the textile companies to develop new products which will "get closer to the consumer" and be competitive on the market. On the other hand, when buying clothes, modern consumers are interested in clothing with good esthetic performance and comfort-related properties, with increased sustainability awareness. Therefore, consumers' participation in the wear trial tests will result in their more thoughtful decision-making during future purchases.

2 The Comfort Aspects of Hemp Textiles

Textile materials and clothing stopped being used in everyday life only for protection a long time ago. People are interested in clothing with good esthetic performance, easy care, durability, and comfort. Since the end of the twentieth century, there has been a global trend on human well-being and a healthy lifestyle. Therefore, the role of clothing in everyday life is not only to ensure that the physical conditions around the human body are suitable for survival but also to ensure physiological and psychological comfort. Modern consumers involve their visual sense, touch, intuition, and emotion in making their purchasing decisions. As a result, comfort became an essential requirement for clothing.

As clothing is in continuous and dynamic contact with the human body during wear, it stimulates thermal, mechanical, and visual sensations. According to a kind of universal definition, comfort is "a state of satisfaction indicating physiological, psychological, and physical balance among the person, his/her clothing and his/her environment" (Slater 1985). Accordingly, there are three main aspects of comfort – psychological, thermal, and tactile comfort. Physiological comfort bears no direct relation to the properties of clothing materials. This comfort component is mainly based on subjective feelings, fashion trends, and acceptability in the society. Thermal comfort can be defined as the absence of any unpleasant sensation of being

too cool or too warm or having too much sweat on the skin. The human body is a complicated thermodynamic system in which energy generated by metabolic activity has to be dissipated into the environment to keep a balance between heat generated and heat dissipated. About 90% of the heat generated by the body dissipated from the skin surface by thermal conduction, convection, radiation, and evaporation or perspiration (Hardy et al. 1953). The role of textile material is to support the thermoregulation system of the human body to keep its temperature balanced even if the atmospheric conditions or physical activity change. Therefore, the heat and mass transfer capacity of textile materials is responsible to a great extent for a person's thermal comfort perception. The key properties of textile materials by which they affect the heat and mass transfer from the dressed body's skin to the environment are thermal properties, water vapor permeability, and air permeability. When physical activity level or environmental conditions change, the human skin produces liquid perspiration which should be transported away from the skin surface so that the next-to-skin fabric is dry and the wearer feels comfortable. Thus, the liquid moisture management ability is often considered to be the fourth key property of textile fabric concerning thermal comfort perception. Tactile comfort is related to the mechanical interaction between the textile material and the human body. A dressed human body is continuously subjected to a complex mechanical load arising from the garment weight or the load accompanying the garment deformation. Therefore, the deformation ability of textile fabrics under stretching, bending, shearing, compression, etc. is responsible for a person's tactile sensations (Bertaux et al. 2007). As textile fabrics are nonhomogeneous and anisotropic, their deformation properties are determined by the load direction and considerably change under moderate strain. In ideally elastic material, all of the strain energy imparted to the material is recoverable as mechanical energy after removing deformation, which is the elastic deformation. Being imperfectly elastic, textile materials do not return to their original unloaded state due to incomplete recovery (Hamburger 1948). Considering the fact that the load transmits to the body at skin-fabric contact areas, the surface characteristics of textile materials are also very important for tactile sensory perception.

There is no universal solution for the properties of clothing textiles responsible for thermal and tactile comfort. Optimal comfort properties of clothing materials are influenced by the garment's purpose (underwear, activewear, protective clothing, fashion clothing) and climate (winter wear, summer wear). Besides the positive sustainability aspects of hemp growing, processing, and utilization, it should be emphasized that hemp-based clothing textiles create the optimal environment for wearers, ensuring physiological comfort. The hemp fibers' properties, such as breathability, high absorbent, hygroscopic, and good thermal and electric properties, make them very worthwhile for the development of healthy and comfortable clothing textiles. However, there are some limitations in terms of tactile comfort that need to be addressed. As a consequence of the low elasticity and low flexibility of hemp fiber, hemp textile fabrics are characterized by reduced softness and rough handle (Asad et al. 2015; Stankovic 2008a). An additional drawback of hemp textiles is their easy creasing with poor recovery. Therefore, to provide hemp textile

consumers with the highest level of comfort and esthetics, some comfort aspects of hemp textiles have to be enhanced to compete successfully on the global market with those of traditional comfort materials such as cotton. There are two approaches to resolving these comfort issues. One is the conventional chemical approach of applying various chemical treatments to improve the softness of hemp textiles. The second, more sustainable approach to improvement in hemp textiles' comfort properties is based exclusively on mechanical processing operations. Considering the hierarchical structure of textile fabrics (woven or knitted), research efforts covered all three levels (fiber, yarn, and fabric).

One of the traditional methods for improving the softness and spinnability of hemp fibers is the chemical treatment by sodium hydroxide. It has been shown that a suitable treatment procedure can dramatically soften hemp fibers (Liu et al. 2013). During the refining process of hemp fibers (prebiological treatment, alkaline treatment, beating, washing, fiber opening, and carding), the rigidity of the fibers is reduced gradually, which improves their softness and flexibility. In addition, hemp processing depresses moisture regain of the fiber by about 40 percentage points (Jinqiu and Jianchun 2010). Pejic et al. (2008) showed that a reduction in the content of either hemicellulose or lignin by treatment with sodium hydroxide or sodium chlorite caused the wicking ability (capillary height) of hemp fiber to increase. Viscusi et al. (2021) have recently proposed a green mechanochemical treatment of hemp fiber in a mild alkaline medium by which a decrease in fiber diameter and a reduction in moisture adsorption were indicated. Various investigations have confirmed that the liquid ammonia treatment reduces hemp fiber crystallinity by which not only the wettability of fiber improved but also its softness as a consequence of a reduction in Young's modulus (Zhang et al. 2014).

As a result of scientific efforts, the liquid ammonia (L/A) treatment is proposed for improving the softness, flexibility, and crease recovery of hemp fabrics. Ammonia penetrates cellulose relatively easily and reacts with the hydroxyl group after breaking hydrogen bonds, which results in wrinkle recovery and the soft hand of the treated hemp fabric. It has been shown that the crease recovery and bending modulus, as well as the water vapor and air permeability of pure hemp woven fabric, can be improved by L/A treatment followed by cross-link finishing (Li et al. 2010). Besides crease recovery, Hwang and Ji (2012) indicated a decrease in the washing shrinkage and an increase in the wicking speed and drying ratio of the hemp fabric treated with liquid ammonia. The effect of L/A treatment on the tactile comfort properties of plain hemp woven fabrics was investigated using the KES-FB (Kawabata Evaluation System for Fabrics). It has been found that tensile energy and tensile resilience increase with the L/A treatment. The compression linearity and compression energy are higher, whereas the compression resilience is lower than the untreated counterparts. The values of bending (bending rigidity and bending moment) and shearing (shearing rigidity and shear hysteresis) parameters are lower as compared to the untreated fabrics. Therefore, the authors believe that the L/A treatment is quite effective in improving the flexibility and softness of the fabrics (Ji and Lee 2016). The same authors also investigated the liquid moisture management properties of hemp woven fabrics treated with liquid ammonia and found that all the

tested parameters, such as the wetting time, absorption rate, maximum wetted radius, spreading speed, and one-way transport capability, were improved after the L/A treatment (Lee and Ji 2017). Zhang and Zhang (2010) proposed the method of chitosan and epoxy-modified silicone oil treatment to improve the softness of hemp fabrics.

In an attempt to create more sustainable hemp clothing textiles, efforts have been made to improve the tactile comfort of hemp textiles by exclusively mechanical processing. Textiles are often produced from blended yarns nowadays to improve the wear comfort or appearance of the product. The ability of hemp long (technical) fibers to divide by mechanical, chemical, or enzymatic treatments enables manufacturers to achieve fiber properties, which allow spinning hemp in blends with cotton, wool, and chemical fibers by different spinning methods (ring, rotor) (Cierpucha et al. 2004; Czekalski et al. 2000). In the spinning sector, blended yarns can be produced as a mixture of different fibers in the blow room before carding, drawing, roving, and spinning or by blending different fiber-containing slivers in the drawing stage. Kim and Kim (2018) compared the mechanical properties of the knitted fabrics prepared using blended staple hemp/Tencel yarns (blending ratio 30%/70%) spun by ring, Siro-spun, and air vortex spinning frames and showed the softer tactile sensation of the knit made from the air vortex hemp/Tencel yarn. As a consequence of the bulky structure of the air vortex yarn and its lower tensile modulus compared to the ring and Siro-spun yarns, the knit made from this yarn was highly compressible and extensible with low bending rigidity which made it soft and compressible. A method for producing hemp blended yarns by forming hybrid staple/filament yarns using the folding technique was proposed. By folding hemp single yarn with viscose or polyamide textured (Tactel®) filament, the complex hybrid yarns were produced in which the accommodation of the components provided a high bulk structure which subsequently caused the higher compressibility of knitted fabrics made thereof (Stankovic 2008b). These hybrid yarns exhibited the capillary height and wicking rate higher than those of the homogeneous hemp yarn, which resulted in the higher wicking height of the knitted fabrics made of hybrid yarns (Stankovic et al. 2006). Generally, the process of folding or plying yarns improves single yarns to an appreciable degree by combining them. This operation improves yarn evenness (diameter), strength, liveliness, and surface characteristics, and it appeared to have a positive effect on the deformation properties of hemp knitted fabrics. According to the KES parameters, the hemp knitted fabric produced from two-folded hemp yarn is more extensible, flexible, and compressible (softer) as compared to the hemp knit produced from single hemp yarn. The course-directional shear deformation was improved, whereas higher resistance to wale-directional shear deformation was noticed, which resulted from reduced two-folded yarn mobility in the wale direction. The KES parameters for the surface roughness (MIU, MMD, and SMD) indicated an improvement in the surface properties (smoother surface with improved uniformity) of the knitted fabric produced from two-folded hemp yarn. The thermal comfort properties of the two-folded hemp knitted fabric, such as air and water vapor permeability, were also improved. An improvement in the transport and deformation properties of the two-folded hemp knitted fabric was

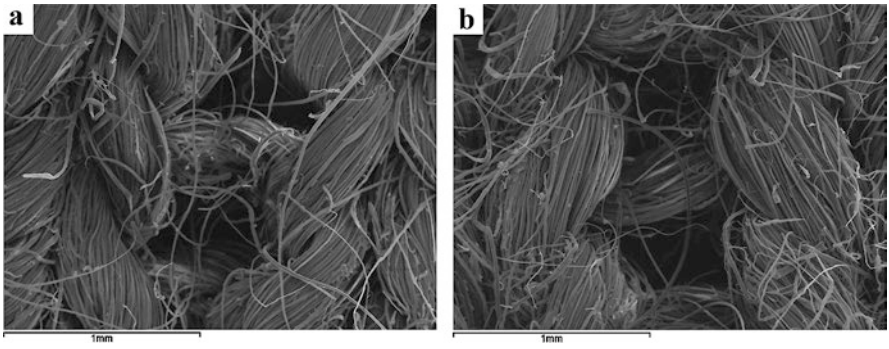

Fig. 1 Geometry of the knitted fabrics made from single (**a**) and two-folded (**b**) hemp yarns. (Kocic et al. 2016)

followed by an improvement in the uniformity of the measured comfort parameters (Stankovic and Bizjak 2014). These positive effects resulted from the modification of yarn packing density by folding (almost twice reduced compared to the single hemp yarn) which, in turn, enhanced the fiber and yarn mobility within the fabric. The reduced compactness of the two-folded hemp yarn implies its reduced bending rigidity which leads to changes in loop configuration and consequently to changes in pore distribution, as can be seen in Fig. 1 (Kocic et al. 2016). The two-folded hemp knitted fabric (Fig. 1b) has larger open pores which are known to be the most responsible for air and water diffusion through the fabric.

It has been shown in the investigation conducted by Stankovic et al. (2022) that the rib knitted fabrics having single hemp yarn as a component enabled enhanced heat transfer, whereas the knits with two-folded hemp yarn offered better thermal insulation. A step forward has been taken by incorporating the different levels of folding twist intensity which was recognized as an effective design method for fine adjustment of the fabric's thermal behavior.

To improve the softness of hemp-based knitted fabrics, a method was proposed in which the hemp/cellulose fiber blends were made in the knitting stage by simply assembling two homogeneous (pure hemp, pure viscose, and pure cotton) yarns with no secondary twist. In other words, plain hemp/cotton and hemp/viscose (staple) knitted fabrics were produced by feeding two single yarns simultaneously side by side through the same hole in the feeders. The effectiveness of the method was confirmed by improved compressibility and extensibility of the hemp/cotton knitted fabrics as compared to the pure hemp counterpart, which was indicated by KES parameters. The better retention ability of the blended knits was confirmed by the greater values of the compression and tensile resilience than those of the pure hemp knit (Stankovic 2009). A study on the thermal behavior of hemp/cellulose knitted fabrics indicated the trend toward increasing the thermal conductivity and overall heat transfer coefficient (Stankovic et al. 2008). The transient thermal response of the knits was also confirmed to be manageable by introducing other cellulose fibers. Assembling hemp yarn with cotton or viscose components in knitted fabrics had a

beneficial effect on their thermal diffusivity, whose increased values meant the quickly reaching thermal balance. In addition, an increase in the thermal absorptivity of the hemp/cotton and hemp/viscose knitted fabrics was observed, which implied a cooler touch of the blended knits compared to the pure hemp knitted fabric (Pavlovic et al. 2014). Research also indicated the enhanced water vapor permeability and liquid transfer ability of the hemp/viscose knitted fabric, which resulted from the increased water absorption affinity of the viscose fiber (Novakovic et al. 2015). When producing the hemp/cotton knitted fabrics, three variants of cotton yarns differing in twist level were used. This enabled not only to combine different fiber properties but also to take advantage of the specific intrinsic properties of component yarns. KES parameters indicated an improvement in the flexibility and softness of the hemp/cotton knitted fabrics compared to the pure hemp knit. The surface coefficient of friction of the hemp/cotton knits was reduced, but the variation of the surface friction coefficient was increased. The surface geometrical roughness of the hemp/cotton knitted fabrics was also modified with respect to the pure hemp knit (Stankovic 2009). Simultaneously, the thermal comfort properties (air and water vapor permeability, thermal resistance) of the hemp/cotton knitted fabrics were not seriously deteriorated, with the trend to improve some in relation to the pure hemp knit (Stankovic et al. 2019). These investigations showed that not only the tactile and thermal comfort properties could be modified by involving the cotton component but also the extent to which these properties were changed could be regulated by the yarn twist intensity.

Synthetic fibers are considered to be inferior to cellulosic ones with regard to thermal comfort. However, it has been shown that the use of acrylic fibers in textile fabrics can improve some comfort aspects related to water management, such as wicking properties (Cil et al. 2009; Ozturk et al. 2011). In terms of tactile comfort, acrylic knitted fabrics exhibited better softness and fullness (Kumar 2017). The elastic properties of acrylic fibers are comparable to wool, and they are porous, soft, and resilient (good shape retention after washing) (Cox 2005). Some negative sustainability aspects of acrylic fiber are unquestionable, such as their nonrenewability and low degradability. On the other hand, there are some advantages of acrylic fibers over cellulosic ones in terms of energy consumption (faster laundering and drying) and environmental aspects (less water consumption, no bleaching required). In addition, the cradle-to-gate analysis of the production chain from raw material to the end product indicated that acrylic was ahead of the other tested raw materials (elastane, nylon, and cotton) in terms of environmental impact (Van der Velden et al. 2014). Bearing this in mind, an attempt was made to introduce acrylic (PAN) yarn along with hemp component into knitted fabric during its manufacture. Hemp/PAN plain knitted fabric was produced by feeding one hemp and one PAN yarn with a blending ratio of 50% hemp/50% PAN, thanks to the same linear density (50 tex) of both yarns. The results indicated an increase of 35% in the compressibility of the hemp/PAN knitted fabric compared to the pure hemp counterpart but a decrease of about 23% compared to the pure PAN knit. However, the knitted fabrics were subjected to repeated wear cycles after which the hemp/PAN knit remained more compressible than the PAN knit. This resulted from the fact that a reduction of 11% in

the compressibility of the hemp/PAN knit was lower as compared to a decrease of 35% in the compressibility of the PAN knit after a period of usage of the items (Stankovic 2006). In the evaluation of the steady-state and transient thermal properties of the hemp and hemp/PAN knitted fabrics, it has been shown that heat transfer not seriously deteriorated by introducing the acrylic component into the knit. The thermal diffusivity indicating how rapidly a material can reach an equilibrium state was improved with the acrylic component, while the thermal absorptivity of the hemp/PAN knit was between the one-fiber type containing knits (pure hemp and pure PAN). After undergoing the trial period (wash and wear cycles), the geometry of these knits was changed, which in turn was affected by increased yarn aggregation in the knits after the wear trial test, influencing positively the thermal transfer properties of the hemp-based knitted fabrics (Novakovic et al. 2020a). In addition to thermal behavior, research on the liquid transfer properties of hemp-based knitted fabrics under various moisture content (0 to 30%) indicated that the liquid transfer ability of hemp knits could be improved by incorporating acrylic yarn, especially in the low moisture content range (up to 10%). Even more important, it was shown that the water transfer ability of the hemp/PAN knit was independent of the moisture content in it. The positive effect of blending hemp and acrylic fibers on the liquid transfer ability of the knits was also confirmed at their exploitation stage (Novakovic et al. 2020b).

In more recent research, the hemp-based denim fabrics were realized in the fabric manufacturing stage using pure cotton yarn as warp and pure hemp yarn as weft or two different types of weft yarns (cotton and hemp) in successive picks; thus, the composition of the fabrics was 72% cotton/28% hemp or 86% cotton/14% hemp, respectively (Saricam 2022). The FAST (Fabric Assurance by Simple Testing) parameters indicated the formability values for the tested denim fabrics within the acceptable range indicating their similarity in terms of production of garments from these fabrics. The hemp/cotton blended fabrics were characterized by higher bending rigidity and lower extensibility but higher compressibility and lower shear rigidity than those of pure cotton fabric. The air permeability and moisture management properties (water retention, wicking, drying time) of the blended fabrics were better than the cotton fabric. The thermal resistance values of the hemp/cotton fabrics were higher, and they gave a warmer feeling as compared to the cotton fabric. All denim fabrics were subjected to three different types of common industrial washing treatments (rinse wash, stonewash, and bleach wash), and the overall assessment revealed that the washing treatments improved the tactile properties of the fabrics compared to the untreated ones. In regard to thermal comfort, the washing treatments improved the air permeability, water retention, and drying properties of the hemp/cotton fabrics (Saricam 2022).

Regarding the results obtained in all the studies on the comfort aspects of hemp-based textiles, they probably cannot be explicitly extrapolated to other hemp textiles. However, they certainly contribute to the contemporary knowledge about the comfort aspects of hemp textiles and serve as the basis for further research on the comfort properties of hemp textiles for the aim of establishing production strategies and design guidelines for hemp textiles to the benefit of both textile producers and

consumers. On the other hand, the fact that in the online survey about hemp presented in Chap. 3, consumers' awareness about the positive aspects of the comfort of hemp clothing was rather low (only 30% positive answers from the total number of answers related to comfort) indicates the need for marketing campaigns to increase the consumer awareness in this regard.

3 Hemp Textiles from the Consumer Perspective

The aforementioned contemporary knowledge about the positive comfort aspects of hemp and its potential for the high-quality clothing sector resulted from a number of research which were based on objective testing and evaluation using standard testing procedures. These investigations offer quantitative and reproducible data that can be used to guide decision-makers in industry sectors such as industrial hemp companies, textile and clothing companies, and beyond. On the other hand, companies need knowledge about consumer preferences for various product attributes to respond to existing consumer demands. For clothing manufacturers, the compiled consumer feedback by wearers of particular clothing is a tool for product improvement to convince consumers to buy their product. However, there are no physical instruments for measuring a consumer's feeling or the level of satisfaction in terms of its preferences for sustainability attributes or comfort sensation while wearing a particular item of clothing. Bearing all these in mind, the subjective consumers' assessment of a range of knitted fabrics (including hemp-based ones) in terms of comfort properties will be presented.

The idea of the study was to combine the excellent hygienic properties of hemp fibers with the lightness and softness of acrylic fibers to compensate limitations of both fiber types and to produce knitted fabrics that can satisfy the thermal comfort criteria for the next-to-skin garment. The physical properties of hemp and acrylic fibers which can influence the comfort sensation of the garment are summarized in Table 1.

Single hemp and acrylic (PAN) yarns with the same linear density (50 tex) and twist (400 m^{-1}) were used for producing (by combining two of them) three variants of single jersey knitted fabrics differing in fiber content: 100% hemp, 100% (PAN,) and 50% hemp/50% PAN. Since the single jersey knitted fabrics were produced to have as much as possible the same structural characteristics (Table 2), they were

Table 1 Fiber characteristics (Sponner et al. 2005; Baltazar-y-Jimenez and Bismarck 2007; Cox 2005)

Parameter, unit	Hemp	Acrylic
Fiber density, g/cm^3	1.48–1.5	1.18–1.2
Moisture absorption, %	30	5
Moisture regain, %	12.5	2.5
Touch	Cold, smooth, and stiff	Warm and soft

Table 2 Characteristics of the single jersey knitted fabrics from which the garments were produced

Parameter, unit	Hemp	Hemp/PAN	PAN
Stitch density, cm^{-2}	84.3	73.2	71.8
Thickness, mm	0.957	1.022	1.092
Areal density, g/m^2	415	376	378

considered to differ mainly in their fiber content. The objectively tested compressibility and thermal comfort properties of the knitted fabrics have been already commented in the previous subheading.

Comfort sensory evaluation was carried out by the wear trial tests which involved human participants. In the tests, the items were not only worn but also maintained. Instead of using a climatically controlled chamber with tightly controlled wear study as has been often realized (Xu et al. 2020; Zhao et al. 2022; Sedilla and Maeda 2022), a field study was chosen which enabled collecting data during the real-life use of garments (McQueen et al. 2014; Suganti et al. 2017). As a consequence, various dynamic wear situations were included in the study. Bearing in mind the fact that the torso is the most thermal-sensitive part of the human body (Li et al. 2005), three kinds of undershirts (sleeveless shirts) were produced from the aforementioned knitted fabrics and tested in the field study.

Ten healthy volunteers (five males and five females) with ages ranging between 35 and 40 participated in the field trial. Among women, the follicular and luteal phases were distributed randomly. The procedure was fully explained to the participants, and they provided their voluntary and informed consent. However, they were uninformed about the specific details of the knitted fabrics to avoid bias in subjective responses and to allow them to focus on the perceived sensations without being influenced by other factors. The wear trial tests were conducted during the early autumn months (northern hemisphere) to minimize the effects of heat indoor-outdoor acclimatization. The undershirts were washed before the trials started in order to minimize the shrinkage effect. During each trial, the volunteer was required to wear one of the undershirts for 5 days (at least 5 h a day in continuity) in his real-life situations. Volunteers filled out a questionnaire after every hour while wearing the experimental garment. This way, for the same garment, the same participant answered the questionnaire five times during the day. The following week the same participant was wearing another undershirt, and during the third week, he (she) was wearing the third one following the same procedure. Each volunteer evaluated each of the three undershirts. The undershirts were washed between each wear trial test in water (40 °C) with household (commercially available) detergent Perwoll (Henkel GmbH, Austria), line-dried, and ironed with an electric iron (<150 °C). The care procedure was the same for all items and always performed by the same person to avoid any subjective influence. The experimental garments were randomly distributed among the participants during the wear trial tests.

The questionnaire was designed to record the ratings of thermal comfort and thermal sensation triggered by a garment for each hour during the wear trial test.

Table 3 The scales of subjective ratings in the questionnaire

Thermal comfort						
3 Very comfortable	2 Comfortable	1 Slightly comfortable	0 Neutral	−1 Slightly uncomfortable	−2 Uncomfortable	−3 Very uncomfortable

Thermal sensation								
1 Very cold	2 Cold	3 Cool	4 Slightly cool	5 Neutral	6 Slightly warm	7 Warm	8 Hot	9 Very hot

The participants used previously established subjective scales (Gagge et al. 1967) to rate their thermal comfort and thermal sensation while wearing the clothing items. The subjective scales used in this field study are listed in Table 3. The participants were also asked to record their physical activity. Optional lines for additional comments from the participants in the wear trial tests were provided in the questionnaire.

The data are presented as the averaged observations of ten participants in the wear trial tests. The statistical significance between means was assessed using analysis of variance (ANOVA). When significant effects were found, Tukey's post hoc analyses were performed. In all analyses, the probability value $p < 0.05$ was used to establish significant differences meaning that 95% confidence intervals were used to investigate the main effects and interactions of the variables.

A comparison of temporal changes in the average scores of the thermal comfort among tested undershirts is shown in Fig. 2. Before comparing the undershirts, it should be noted that the perceived thermal comfort of all the items was independent of the time progression of the trial test, as confirmed by ANOVA statistics ($p = 0.99$, $p = 0.82$, and $p = 0.98$ for hemp, hemp/PAN, and PAN, respectively). Therefore, it seemed reasonable to calculate the overall rating as the average of a total of 250 thermal comfort ratings obtained for each undershirt during the wear trial tests (Table 4). As can be seen in Fig. 2, the thermal comfort ratings for the pure hemp and PAN undershirts ranged from "slightly uncomfortable" to "neutral", whereas the hemp/PAN undershirt was mainly rated as "neutral," which gave it an advantage over the other two items. This was also confirmed by the calculated overall ratings for the items given in Table 4. Although ANOVA statistics indicated a significant difference among the items in the thermal comfort perceptions, Tukey's test indicated that actually, the hemp/PAN undershirt was that stood out from the hemp ($p = 0.001 < 0.0167$) and PAN ($p = 0.000 < 0.0167$) items, whereas these two behaved similarly ($p = 0.035 > 0.0167$).

A broader picture of the perception of thermal comfort can be obtained based on the distribution of a total of 250 ratings for each undershirt given in Fig. 3. As can be seen, the hemp undershirt was most often rated as "neutral" (0), followed by "slightly uncomfortable" (−1), and "slightly comfortable" (1). The hemp/PAN undershirt was rated as slightly uncomfortable almost as often as the hemp one (61 vs. 63, in absolute values), but the "neutral" and "slightly comfortable" ratings represented nearly 71% of all ratings, as compared to 61.6% "neutral" and "slightly comfortable" ratings for the hemp undershirt. In most cases, the participants rated

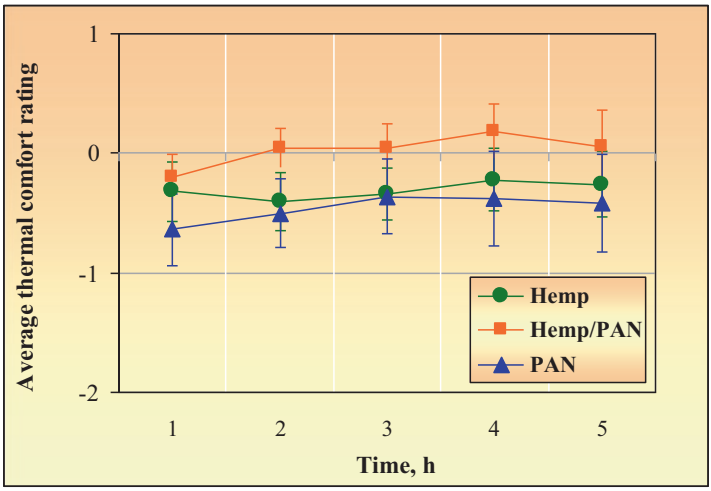

Fig. 2 Temporal changes in thermal comfort ratings for three undershirts

Table 4 Overall average values of the thermal comfort and thermal sensation ratings

Rating scales	Hemp	Hemp/PAN	PAN	p (α = 0.05)
Thermal comfort comfort	−0.3	0.02*	−0.5	0.000
Thermal sensation	5.4*	5.9	6.2	0.000

*Statistically significant difference (Tukey's post hoc test)

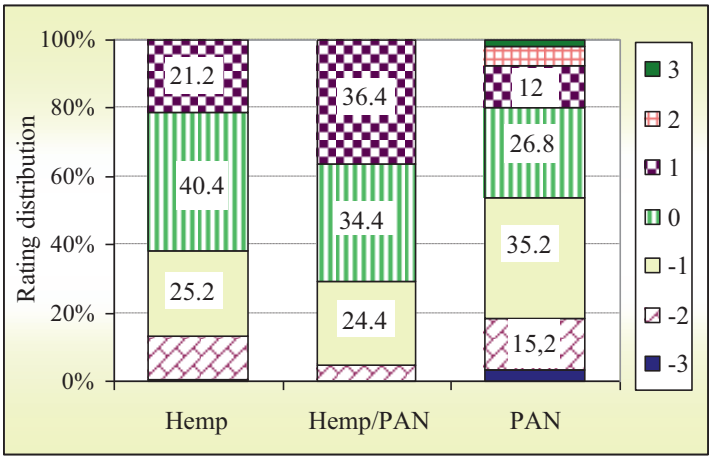

Fig. 3 Distribution of thermal comfort ratings of three undershirts

the pure PAN undershirt as "slightly uncomfortable" (35% of all ratings), followed by "neutral," "uncomfortable," and "slightly comfortable" ratings (Fig. 3).

A comparison of temporal changes in the average scores of the thermal sensation among three undershirts is shown in Fig. 4. It can be noted that temporal changes in

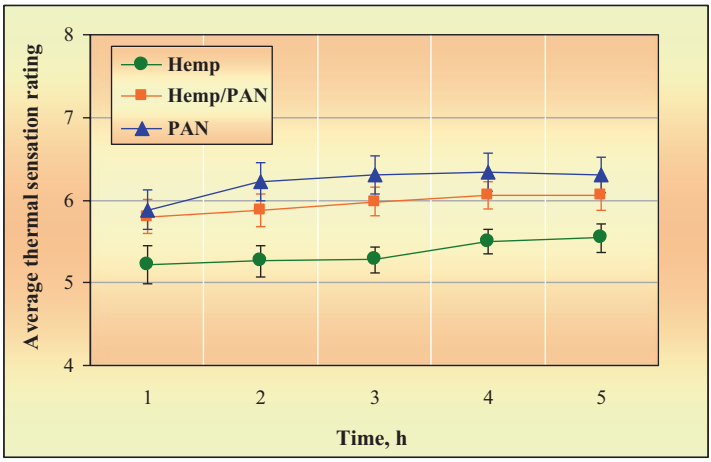

Fig. 4 Temporal changes in thermal sensation ratings for three undershirts

thermal sensation were minimal for all tested undershirts, which was confirmed by ANOVA statistics since the calculated p-values (0.631 for hemp, 0.813 hemp/PAN, and 0.615 for PAN) were higher than α(0.05). Bearing in mind that the underwear is expected to maintain the neutral thermal sensation of a person, the hemp undershirt appears to be the closest to the ideal one with its average grade of 5.4 (Table 4) meaning the quite neutral thermal sensation (Table 3). The hemp/PAN and PAN undershirts were mainly perceived as "slightly warm" (5.9 and 6.2, respectively). The subjective ratings of the thermal sensation were found to be significantly different among the undershirts (by ANOVA). However, the post hoc test indicated that the hemp undershirt differed from the other two who behaved similarly ($p = 0.034 > 0.0167$). This is also illustrated by the distribution of the thermal sensation ratings of the undershirts presented in Fig. 5. For the hemp undershirt, "neutral" and "slightly warm" thermal sensations represented about 85% of all ratings, whereas, for the PAN undershirt, about 65% of the ratings were "neutral" and "slightly warm" sensations. For the hemp/PAN undershirt, 78.4% of the total ratings included "neutral" and "slightly warm" with the overall rating being almost an average of other items' ratings (Table 4).

The results obtained in this field study are in accordance with the general opinion according to which textile fibers of high moisture regain provide cooler sensation. Indeed, it has been shown by the objective evaluation of the knitted fabrics from which the undershirts were made that the hemp knit was characterized by the highest thermal absorptivity (the higher the thermal absorptivity the more intense the feeling of coolness) followed by hemp/PAN and PAN knitted fabrics. In addition, the hemp knitted fabric exhibited the highest heat transfer ability according to objective measurements (Novakovic et al. 2020a). Therefore, it seems reasonable to believe that the "neutral" perception of the hemp undershirt in a thermal sense is not a coincidence. In addition to the warm and hydrophobic nature of acrylic fibers, the thermal absorptivity and thermal conductivity of the PAN knit, which were the

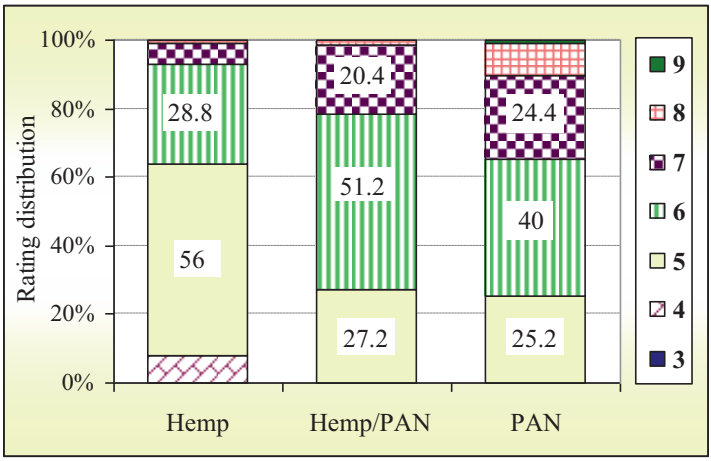

Fig. 5 Distribution of thermal sensation ratings of three undershirts

lowest among the three knits (Novakovic et al. 2020a), must have resulted in the "warmest" thermal sensation of the PAN undershirt. Given the above, the subjective perception of the hemp/PAN undershirt was expectedly between the other two knits in regard to the thermal sensation.

In an attempt to find out the relationship between the thermal sensation and comfort perception, the correlation coefficients between the obtained thermal sensation and comfort ratings were calculated (0.83, 0.86, and 0.95 for hemp, hemp/PAN, and PAN knits, respectively), indicating the quite high correlation between thermal and thermal comfort sensations. A "neutral" thermal sensation meaning the absence of either warmth or cold sensations has been already connected with "pleasantness" or "comfort" but only in the absence of thermoregulatory processes in the human body such as sweating, vasoconstriction, and vasodilatation (Gagge et al. 1967). Transient comfort phenomena which involve the simultaneous transport of heat and moisture through fabrics may add to dampness, buffering, or chilling effects when wearing a garment (Dent 2001). This stimulates the thermophysiological activity of the human body, and the garment is perceived as uncomfortable. The effects are more pronounced in hygroscopic fiber fabrics, which can be a reason for the fact that the "slightly warm" hemp/PAN undershirt is more comfortable than the "neutral" hemp one (Table 4).

This real-life human perception analysis approach to collecting human sensation values provided information on thermal comfort and thermal sensation in terms of normal human experience. Environmental conditions and physical activity levels were random in every wear trial test. Therefore, collected human responses resulted from a mixture of opinion and experience, along with combined changes in environmental conditions and metabolic stress. In an attempt to analyze the subjective human perception of tested undershirts in terms of thermal and comfort sensations under various physical activity levels, the responses connected with the specific activities were extracted from a total of 250 ratings. Figure 6 illustrates the

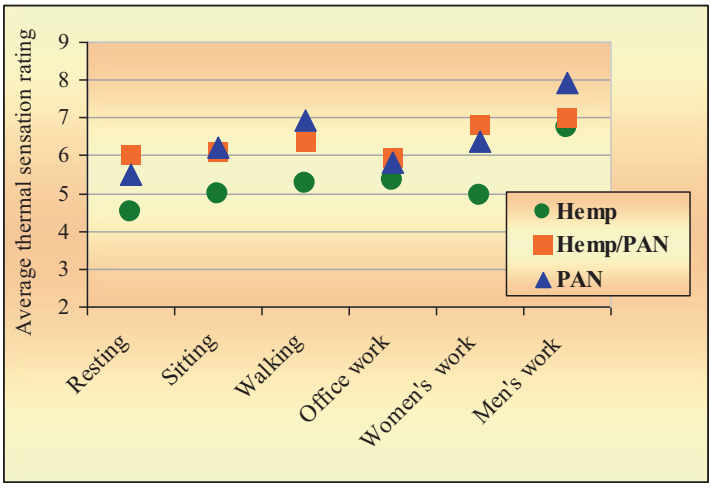

Fig. 6 Thermal sensation ratings for three undershirts under various activity levels

subjective thermal sensation responses for various activity levels. In Fig. 6, women's activity means housework, while men's activity means great physical effort such as gardening or sack handling. The ratings of thermal sensation of the hemp undershirt changed from "slightly cool" during resting time through "neutral" during moderate activity to "slightly warm" during high physical activity. This made the hemp undershirt superior in comparison to the other two items. The PAN undershirt was rated as "slightly warm" or "warm" depending on the activity level. The highest heat transfer ability and thermal absorptivity of the hemp knitted fabric in comparison to the other knits, as evidenced in the previous objective measurements (Novakovic et al. 2020a), are responsible for the "coldest" feeling of the hemp knit during resting or sitting positions. At moderate physical effort when sweat may occur, quite high moisture absorption ability of hemp (Table 1) contributes to the pleasant neutral thermal sensation by removing the sweat from the local microclimate. Bearing in mind the thermal diffusivity of the knitted fabrics from which the undershirts were produced (Novakovic et al. 2020a), indicating how rapidly a material will adjust its temperature to that of the surroundings, the highest thermal diffusivity of the hemp knit can account for the difference in the thermal sensation ratings of the undershirts during high physical activities. Besides, the hemp knit exhibited the highest liquid transfer ability in the transient (non-balanced) conditions (Novakovic et al. 2020b). The thermal sensation ratings for the hemp/PAN undershirt were similar to those of the PAN undershirt except at the highest physical activity level where the feeling of discomfort appeared to be alleviated, thanks to the hydrophilic nature of hemp fiber. Although the subjective ratings of the thermal sensation depending on the physical activity level were found to be significantly different among the undershirts, Tukey's test indicated the hemp one that actually differed from others.

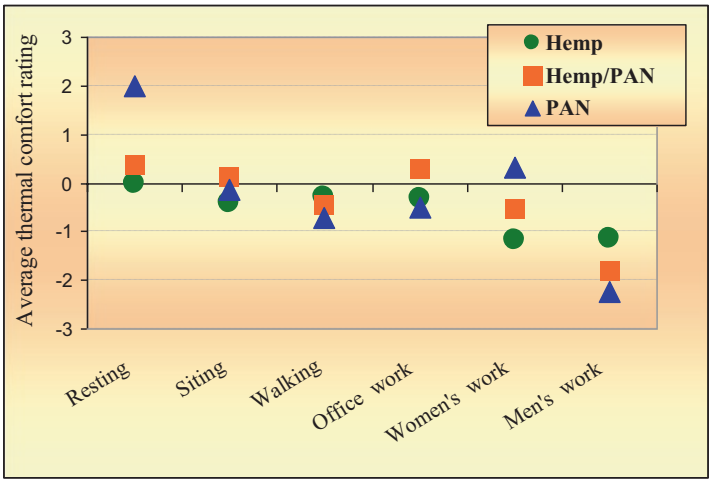

Fig. 7 Thermal comfort ratings for three undershirts under various activity levels

Figure 7 illustrates the subjective thermal comfort responses for various activity levels. According to the results, there were no differences in the thermal comfort sensations among the undershirts with respect to the physical activity level, which was confirmed by ANOVA statistics ($p = 0.835 > \alpha(0.05)$). A worsening of thermal comfort during high physical activities was registered by all participants for all undershirts. Being composed of hydrophobic acrylic fibers, PAN undershirt cannot manage fast enough with a higher amount of liquid sweat buildup on the skin surface during high physical activity (Novakovic et al. 2020b). The metabolic heat released from the body during high physical activity should be transferred through the garment to maintain the thermal balance. Being porous with low moisture regain (Table 1), acrylic fibers are characterized by low thermal conductivity (good thermal insulator) due to which the PAN undershirt feels "warmer" during high physical activity of the body. Indeed, the participants explained the worse ratings of the PAN undershirt during high physical activities mainly by the excess sweat and warmness. A worsening of the thermal comfort of the hemp undershirt during high physical activity can be attributed to the transient effects such as buffering, chilling, etc., which cause the reaction of the thermophysiological mechanisms in the human body. The participants perceived a worsening of the thermal comfort of the hemp undershirt as the clinginess and sticky surface of the knit.

These wear trial tests provided valuable insight into the effect of fiber properties on the comfort and thermal sensation perceived by the working population. The results indicated that the hydrophilic (or hydrophobic) nature of hemp and acrylic fibers, along with the thermal and moisture management properties of the knitted fabrics from which the garments were produced, were of great importance for the thermal sensation and comfort perception. Consumers expressed a preference for the hemp undershirt in terms of thermal sensation, while the hemp/PAN undershirt was perceived as the best choice with respect to thermal comfort. A worsening of

the thermal and comfort sensations was perceived by consumers while wearing the garments during increased physical activity. The hemp undershirt appeared to be at an advantage in terms of thermal and comfort sensations during great physical efforts.

The obtained results can be useful for engineers and decision-makers in textile companies to develop new hemp-based products which will be competitive in the global clothing market. Garment shopping is always based on the personal experience and preferences of the consumer, but informing a larger number of consumers (other than those participating in the study) about the outcomes of this and similar studies will contribute to increased consumers' awareness about all positive aspects of using hemp textiles (sustainability, comfort). This may result in more thoughtful decision-making during purchase and increased demand for hemp-based textiles.

In general, the method of the real-life sensory evaluation of a garment by consumers in the wear trial tests seems to be an effective tool for developing and marketing new textile products.

Acknowledgments This work was supported by the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia (Contract No. 451-03-47/2023-01/200135). The author would like to thank all the participants in the wear trial tests for their voluntary contribution.

References

Asad, R. A. M., Yu, W., Zheng, Y.-h., & He, Y. (2015). Characterization of prickle tactile discomfort properties of different textile single fibers using an axial fiber-compression-bending analyzer (FICBA). *Textile Research Journal, 85*(5), 512–523. https://doi.org/10.1177/0040517514548753

Baltazar-y-Jimenez, A., & Bismarck, A. (2007). Wetting behaviour, moisture up-take and electrokinetic properties of lignocellulosic fibres. *Cellulose, 14*, 115–127. https://doi.org/10.1007/s10570-006-9092-x

Bertaux, E., Lewandowski, M., & Derler, S. (2007). Relationship between friction and tactile properties for woven and knitted fabrics. *Textile Research Journal, 77*(6), 387–396.

Cierpucha, W., Kozłowski, R., Mankowski, J., Wasko, J., & Mankowski, T. (2004). Applicability of flax and hemp as raw materials for production of cotton-like fibres and blended yarns in Poland. *Fibres & Textiles in Eastern Europe, 12*, 13–18.

Cil, M. G., Nergis, U. B., & Candan, C. (2009). An experimental study of some comfort-related properties of cotton-acrylic knitted fabrics. *Textile Research Journal, 79*(10), 917–923. https://doi.org/10.1177/0040517508099919

Cox, R. (2005). Acrylic fibres. In J. E. Mc Intyre (Ed.), *Synthetic fibres: Nylon, polyester, acrylic, polyolefin* (pp. 167–234). Woodhead Publishing Ltd..

Czekalski, J., Kozakiewicz, D., Michalak, M., & Stasiak, M. (2000). Ecological blended yarns: Hemp – PAN. *Fibres & Textiles in Eastern Europe, 8*(3), 22–23.

Dent, R. W. (2001). Transient comfort phenomena due to sweating. *Textile Research Journal, 71*(9), 796–806.

Gagge, A. P., Stolwijk, A. J., & Hardy, J. D. (1967). Comfort and thermal sensations and associated physiological responses of various ambient temperatures. *Environmental Research, 1*(1), 1–20.

Hamburger, W. J. (1948). Mechanics of elastic performance of textile materials: I. Development of an elastic performance coefficient in tension. *Textile Research Journal, 18*(2), 102–113.

Hardy, H. B., Ballou, J. W., & Wetmore, O. C. (1953). The prediction of equilibrium thermal comfort from physical data on fabrics. *Textile Research Journal, 23*(1), 1–10.

Hwang, M. S., & Ji, D. S. (2012). The effect of yarn number and liquid ammonia treatment on the physical properties of hemp woven fabrics. *Fibers and Polymers, 13*, 1335–1340. https://doi.org/10.1007/s12221-012-1335-x

Ji, D. S., & Lee, J. J. (2016). Mechanical properties and hand evaluation of hemp woven fabrics treated with liquid ammonia. *Fibers and Polymers, 17*, 143–150. https://doi.org/10.1007/s12221-016-5597-6

Jinqiu, Z., & Jianchun, Z. (2010). Effect of refined processing on the physical and chemical properties of hemp bast fibers. *Textile Research Journal, 80*(8), 744–753. https://doi.org/10.1177/0040517509342317

Kim, H. A., & Kim, S. J. (2018). Hand and wear comfort of knitted fabrics made of hemp/tencel yarns applicable to garment. *Fibers and Polymers, 19*(7), 1539–1547. https://doi.org/10.1007/s12221-018-8275-z

Kocic, A., Popovic, D., Stankovic, S., & Poparic, G. (2016). Influence of yarn folding on UV protection of hemp knitted fabrics. *Hemijska industrija, 70*(3), 319–327. https://doi.org/10.2298/HEMIND141126036K

Kumar, R. (2017). Low stress mechanical properties & total hand values of silk acrylic knitted fabrics. *Periodic Research, 6*(2), 1–6.

Lee, J. J., & Ji, D. S. (2017). Evaluation of liquid moisture management properties on hemp woven fabrics treated with liquid ammonia. *Textile Research Journal, 87*(14), 1752–1764. https://doi.org/10.1177/0040517516659370

Li, J., Wang, Y., Zhang, W., & Barker, L. R. (2005). Cold sensitivity differences between body sections under clothing. *Textile Research Journal, 75*(3), 208–212. https://doi.org/10.1177/00405175050750030

Li, J., Feng, J., Zhang, H., & Yhang, J. (2010). Wear properties of hemp, ramie and linen fabrics after liquid ammonia/crosslinking treatment. *Fibres and Textiles in Eastern Europe, 18*(5), 81–85.

Liu, H., You, L., Jin, H., & Yu, W. (2013). Influence of alkali treatment on the structure and properties of hemp fibers. *Fibers and Polymers, 14*(3), 389–395.

McQueen, R. H., Harynuk, J. J., Wismer, W. V., Keelan, M., Xu, Y., & de la Mata, A. P. (2014). Axillary odour build-up in knit fabrics following multiple use cycles. *Journal of Clothing Science and Technology, 26*(4), 274–290. https://doi.org/10.1108/IJCST-05-2013-0064

Novakovic, M., Putic, L., Bizjak, M., & Stankovic, S. (2015). Moisture management properties of plain knitted fabrics made of natural and regenerated cellulose fibres. *Hemijska Industrija, 69*(2), 193–200. https://doi.org/10.2298/HEMIND140201034N

Novakovic, M., Popovic, D., Mladenovic, N., Poparic, G., & Stankovic, S. (2020a). Development of comfortable and eco-friendly cellulose based textiles with improved sustainability. *Journal of Cleaner Production, 267*, 122154. https://doi.org/10.1016/j.clepro.2020.122154

Novakovic, M., Milanovic, J., Grujic, D., & Stankovic, S. (2020b). Liquid transfer properties of textile fabrics as a function of moisture content. *Hemijska Industrija, 74*(2), 119–132. https://doi.org/10.2298/HEMIND190925008N

Ozturk, M. K., Nergis, B., & Candan, C. (2011). A study of wicking properties of cotton-acrylic yarns and knitted fabrics. *Textile Research Journal, 81*(3), 324–328. https://doi.org/10.1177/0040517510386111

Pavlovic, S., Stankovic, S., Popovic, D., & Poparic, G. (2014). Transient thermal response of textile fabrics made of natural and regenerated cellulose fibres. *Polymer Testing, 37*, 97–102. https://doi.org/10.1016/j.polymertesting.2013.12.010

Pejic, B., Kostc, M., Skundric, P., & Praskalo, J. (2008). The effect of hemicellulose and lignin removal on water uptake behaviour of hemp fibers. *Bioresource Technology, 99*(15), 7152–7159.

Saricam, C. (2022). The comfort properties of hemp and flax blended denim fabrics with common industrial washing treatments. *Textile Research Journal, 92*(17–18), 3164–3178. https://doi.org/10.1177/00405175211054216

Sedilla, K., & Maeda, T. (2022). Autonomic thermoregulatory responses and subjective thermal perceptions upon the initiation of thermal behavior among resting humans in hot and humid environment. *Journal of Physiological Anthropology, 41*, 35. https://doi.org/10.1186/s40101-022-00308-x

Slater, K. (1985). *Human comfort*. Charles C. Thomas.

Sponner, J., Toth, L., Cziger, S., & Franck, R. R. (2005). Hemp. In R. R. Franck (Ed.), *Bast and other plant fibres* (pp. 176–206). Woodhead Publishing Ltd..

Stankovic, S. (2006). Compressional behavior of knitted fabrics exposed to repeated wash and wear cycles. *Hemijska industrija, 62*(5–6), 129–137.

Stankovic, S. (2008a). Compression hysteresis of fibrous systems. *Polymer Engineering and Science, 48*(4), 676–682. https://doi.org/10.1002/pen.20994

Stankovic, S. (2008b). Static lateral compression of hemp/filament hybrid yarn knitted fabrics. *Fibers and Polymers, 9*(2), 187–193. https://doi.org/10.1007/s12221-008-0030-4

Stankovic, S. (2009). *Influence of agro-cellulose fibre based yarn structure on subsequent textile transformation and end-use properties*. Dissertation, University of Belgrade. https://doi.org/10.2298/bg20090409stankovic.

Stankovic, S., & Bizjak, M. (2014). Effect of yarn folding on comfort properties of hemp knitted fabrics. *Clothing and Textiles Research Journal, 32*, 202–214. https://doi.org/10.1177/0887302X14537114

Stankovic, S., Asanovic, K., & Pejic, B. (2006). Karakteristike kvasenja pletenina na bazi konoplje namenjenih za medicinske svrhe (Liquid wetting properties of hemp based knitted fabrics for hospital uses). *Tekstilna Industrija, 54*(10–12), 24–29.

Stankovic, S., Popovic, D., & Poparic, G. (2008). Thermal properties of textile fabrics made of natural and regenerated cellulose fibres. *Polymer Testing, 27*, 41–48. https://doi.org/10.1016/j.polymertesting.2007.08.003

Stankovic, S., Novakovic, M., Popovic, D., Poparic, G., & Bizjak, M. (2019). Novel engineering approach to optimization of thermal comfort properties of hemp containing textiles. *Journal of the Textile Institute, 110*(9), 1271–1279. https://doi.org/10.1080/00405000.2018.1557367

Stankovic, S., Pavlovic, S., Bizjak, M., Popovic, D., & Poparic, G. (2022). Thermal design method for optimization of dry heat transfer through hemp-based knitted fabrics. *Journal of Natural Fibers, 19*(15), 12155–12167. https://doi.org/10.1080/15440478.2022.2052393

Suganti, T., Senthilkumar, P., & Dipika, V. (2017). Thermal comfort properties of a bi-layer knitted fabrics structure for volleyball sportswear. *Fibres and Textiles in Eastern Europe, 25*(1), 75–80. https://doi.org/10.5604/12303666.1227885

Van der Velden, N. M., Patel, M. K., & Vogtlander, J. G. (2014). LCA benchmarking study on textiles made of cotton, polyester, nylon, acryl or elastane. *International Journal of Life Cycle Assessment, 19*, 331–356. https://doi.org/10.1007/s11367-013-0626-9

Viscusi, D., Pantani, R., & Gorrasi, G. (2021). Transport properties of water vapor through hemp fibers modified with a sustainable process: Effect of surface morphology on the thermodynamic and kinetic phenomena. *Applied Surface Science, 541*, 148433. https://doi.org/10.1016/j.apsusc.2020.148433

Xu, J., Liu, H., Wang, Y., & Li, J. (2020). Investigation on thermal comfort of the uniform for workers in tropical monsoon climates. *Journal of Clothing Science and Technology, 32*(6), 849–868. https://doi.org/10.1108/IJCST-07-2019-0104

Zhang, G., & Zhang, L. M. (2010). Improving the dyeing properties and softness of hemp fabric using chitosan and epoxy modified silicone oil. *Journal of the Textile Institute, 101*(9), 849–857. https://doi.org/10.1080/00405000902935015

Zhang, J., Zhang, H., & Zhang, J. (2014). Evaluation of liquid ammonia treatment on surface characteristics of hemp fiber. *Cellulose, 21*, 569–579.

Zhao, M., Wang, F., Gao, C., Wang, Z., & Li, J. (2022). The effect of flow rate of a short sleeve air ventilation garment on torso thermal comfort in a moderate environment. *Fibers and Polymers, 23*(2), 546–553. https://doi.org/10.1007/s12221-021-0545-5

Index

S. S. Muthu (ed.), *Consumer Awareness and Textile Sustainability*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-3-031-43879-0