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ORIGINAL PAPER

# Going in Circles: Key Aspects for Circular Economy Contributions to Agro-industrial Cooperatives

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**Abstract**
The global agribusiness context faces at the same time challenges of feeding a growing global population that is used to safe and nutritious food, opportunities based on innovation, high technology and efficiency in the agri-food production systems from field to table. Given the context, this article aims to present the main key aspects of the circular economy to agro-industrial cooperatives. These contributions were named key aspects, such as circular and symbiotic practices, competitive advantages, innovation, cooperation and barriers and opportunities. The field presents a problem that few literature in fact discusses circular economy approaches in the context of agro-industrial cooperatives. As a methodological procedure, a literature review was carried out in three databases to obtain relevant documents and thus analyse and discuss some characteristics based on circular economy practices applied in agro-industrial cooperatives. As a result, a diagnosis of the current scenario that agro sector organizations are facing in terms of the main rural activities and sustainable practices that relate to the circular economy; measures taken to generate competitive advantage; innovation behaviour; and how linear and circular business models are being applied in the agroindustry. A framework is presented to show potential routes strategies for closing the cycle in an agro-industrial cooperative. The opportunities are based on the implementation of high technology in the field, the use of bioenergy and the development of new circular business models throughout the agro-value chain. The study has contributions to rural properties and managers of cooperatives in terms of waste reduction, innovation generation and increases in activities and processes based on circular economy.

**Keywords** Circular economy · Circularity · Farm · Cooperation · Agro-industrial business

## Introduction

The global agribusiness scenario faces at the same time challenges and opportunities in the agrifood systems from field to the table. The main challenges are feeding an estimated population of 8.5 and 9.7 billion people in 2030 and 2050, respectively [1], with

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safe, nutritious and affordable food; also reduce impacts from climate change and resource exhaustion [2]. In order to achieve this goal, opportunities have been developed in the sector based on innovation [3], digitalization [4], climate-smart agriculture [5], smart specialisation policies [6], big data [7] and robust technologies for data analysis in order to achieve higher, sustainable and efficient production.

In this sense, agribusiness gathers and moves various activities of production and by-products related to agriculture and livestock based on cleaner production. The agroindustry inserts itself in this system aiming to perform the collecting, transforming and processing of raw material from various segments of the field. However, for agro-industrial systems to gain strength, innovation and be sustainable, cooperatives are essential.

Agro-industrial cooperatives are forms of association where several rural properties have similar objectives of efficiency and cooperation. In the agri-food supply chain, several processing and manufacturing companies are organized in cooperatives, and workers who are members of this system have cooperative assets [8], including absolute preference for environmental protection and social development [9]. In addition, agricultural cooperatives have been playing an important economic role in providing market access to smallholder farmers around the world [10] and contribute to the eradication of poverty in rural areas [11]. For development to actually take place, appropriate approaches must be used to contribute to increasing business productivity and efficiency.

The current "discarding" linear model ("extract-produce-consume-dispose") is not sustainable [12]; with this in mind, the circular economy can be characterized as an interesting practice of avoiding raw material inputs from outside the system, reusing what remains within the system, and act to prevent environmental concerns. Circular economy is a still emerging approach [13] that has recently gained strength in politics, business and academia [14], and switching from a linear to a circular economy in the agri-food field requires innovative business models [15].

With a focus on sustainability and sustainable development [16], circular economy is a strategy to narrow material and/or energy flows within a system. With expectance that global resource extraction is about to grow to 82 billion tons in 2020 [12], concrete measures need to be taken to minimize such a situation in all productive sectors. In agro-industrial cooperatives, circular economy finds valuable resources in animal and agricultural waste for reuse, creation of new business models and mainly value generation. A circular interaction through different industrial dimensions with the agro sector allows opportunities for innovation with the transformation of waste into usable products [17]. Transforming agricultural waste can create revenue opportunities (such as the sale of biogas or electricity), environmental opportunities (such as the production of biofertilizer) and social opportunities (such as generating employment and income in a new job, e.g. operator of a biodigester).

Although there is a lot of literature from the agro point of view in several segments, such as agricultural waste ([18, 19]), biogas ([20, 21]), fertilizer ([22, 23]), strategic and economic performance ([24–26]), organizational models for cooperatives ([10, 27]), external incentives [28], social responsibility and reputation in cooperatives [29], food safety [30] and entrepreneurship in agricultural cooperatives [31], few materials are available on sustainable practices involving circular economy applied in agro-industrial cooperatives.

Agro-industrial cooperations in a circular economy context are documented in the relevant literature. Meso level (symbiosis) cooperations between agricultural businesses internally and externally (towards industries) mostly happen through circular practices, such as "reduce" (e.g. less fertilizers by valorising organic waste), "recover" (e.g. energy from agricultural waste), promote sustainability and are also documented in the relevant

literature. However, theoretical frameworks for the exploration of circular incentives in these fields seem to be little explored.

Nonetheless, researchers on this topic have recently begun to produce papers and publications of high impact in terms of circular economy practiced in agro-industrial cooperatives, such as Pierie et al. [32]; Bluemling and Wang [33]; Yazan et al. [18, 34]; Silva et al. [17]; Sudarić et al. [35]; and Donner et al. [15]. However, none of the studies found reported a literature review listing the key aspects between cooperation and circularity practices. In this context, this study seeks to cover this research gap and was based on three research questions/research problems: (i) What are the main insights of the documents found in the body of literature on circular economy to agro-industrial cooperatives? (ii) What does the literature expose about competitive advantage, innovation, cooperation, and barriers and opportunities for agro-industrial cooperatives? (iii) What are future issues to be explored in this field? Consequently, this article aims to present the main key aspects of the circular economy to agro-industrial cooperatives. The novelty of this study is to discuss the contributions named key aspects, such as circular and symbiotic practices, competitive advantages, innovation, cooperation and barriers and opportunities. This discussion is based on a framework designed to show potential routes strategies for closing the cycle in an agro-industrial cooperative.

The results of the work have a practical contribution and meet needs of the cooperatives managers within the agri-food chain in terms of understanding: (i) the current scenario of circular economy practices applied in the sector; (ii) opportunities to leverage gains for the sector through competitive advantage, innovation and cycle closure; and (iii) visualize potential routes of materials, energy and waste based on the developed framework. The theoretical contribution of this work is summarized in the opportunity for scientific development in favour of increasing the competitiveness, sustainability and cleaner production of rural properties and agro-industrial cooperatives. In addition, insights on production systems, waste management, bioenergy generation and efficient energy use in agro-industrial cooperatives are reported.

The work contributes to the discussion supported by Sustainable Development Goals (SDGs), promoted by the UN [36]. Some goals are as follows: eliminating hunger, achieving food security and promoting more sustainable agriculture (Goal 2); promoting access to sustainable and modern energy in the agricultural environment (Goal 7), encouraged by the use of biogas; support sustained, inclusive and sustainable economic growth (Goal 8) in rural and agro-industrial environments, enhancing generation of jobs, income and decent work; strengthen patterns of sustainable production and consumption (Goal 12) by promoting circular economy and circular business models; and combating climate change (Goal 13) by reducing agricultural waste, making use of clean energy and fuel and closing the cycle of materials and energy (reuse).

This article is structured in the following way. The first section sought to present the initial considerations on the theme, the research gap, the objective of the work and the theoretical and practical contributions. The second section shows the steps adopted to perform this review and the criteria evaluated in the documents found in the literature. The third section presents the backgrounds on circular economy and agro-industrial cooperative. The fourth section presents a framework and discusses the key issues to be considered in this topic, such as industrial symbiosis, competitive advantage, innovation, cooperation and barriers and opportunities. Lastly, the final section reports on the conclusion and recommendations for future issues.

## Methodology

The investigation carried out in the presented article was generated from a theoretical research and followed some steps.

(i) The first step of the methodology was defining keywords and combinations, such as Agribusiness, Cooperative, Circular economy, Bioeconomy, Symbiosis. Searches were carried out in the databases Web of Science, ScienceDirect and Scopus, without temporal limitation, searching for articles in the English language, documents of the category revision and full articles. All duplicate documents were excluded (76 documents). All authors of the study worked on this stage.

(ii) Next, all the titles of the documents that returned through the databases and relevant articles that were part of the scope of this study were selected for full reading and analysis. In addition to this search in three databases, another strategy used to find documents was to sought in reference lists of previously selected articles (technique known as cross referencing).

The previous studies that are most related to the focus of this work (number of seven documents) were Pierie et al. [32]; Bluemling and Wang [33]; Yazan et al. [18, 34]; Silva et al. [17]; Sudarić et al. [35]; and Donner et al. [15]. Even so, other documents (more than 25 documents) surrounding the theme of circular economy to agro-industrial cooperatives were discussed.

The second stage of the methodology was the definition of key issues analysed in articles found in the literature, such as (i) industrial symbiosis; (ii) measures taken to generate competitive advantage; (iii) the behaviour of innovation; (iv) cooperations approaches; (v) obstacles faced; and (vi) current and future opportunities. These characteristics are presented and discussed in the "Key Aspects in Circular Economy Approaches to Agro-industrial Cooperatives" section. Furthermore, the online tool (draw.io) served to build a framework with potential routes and cycle closing opportunities in agro-industrial cooperatives (see Figs. 1 and 2).

## Background

### Circular Economy

Any and all productive systems can be understood as part of a cyclical and natural model, where inputs and outputs of processes have interactions and exchanges with the natural environment. Concerns about sustainability issues are growing [37], and the identification of circularity between systems and environment allows identifying opportunities for improvement in the three spheres of sustainability (environmental, economic and social). The paradigm shift of a linear model (take-make-use-dispose) to a circular model in production systems progresses to production and sustainable consumption, intervening in modes of raw material extraction systems, processing, production, distribution, use, destination and final disposal.

The concept of circular economy has become one of the most recent proposals to promote economic growth, while considering the scarcity of raw materials and energy, as well as being a new model for expanding businesses [38]. In this sense, circular economy allows innovations in business models acting with sustainability. In terms of principles, circular economy is characterized as restorative and regenerative, facing challenges regarding the use of resources of organizations. The approach promotes sustainable growth through income generation, jobs and reducing environmental impacts. Therefore, the goal of circular economy is to keep products, components and materials at their highest level of utility and value [12]. In this context, this approach allows to increase competitive characteristics of organizations from the same region through collaborations and restructuring of business models.

The linear economy has played an essential role in economic development in recent decades [39]. The industrial sector represented important advances in manufacturing production. However, traditional models of linear savings on the use and disposal of waste and by-products are no longer viable [40]. From the point of view of raw material extraction and final disposal of waste, linear economy does not usually present good advantages. These issues are becoming increasingly worrisome and discussed in the current context in academia, government agency and productive sector.

The transformations needed to achieve resource efficiency are based on technical, social and organizational innovations throughout the value chain that connect production and consumption [41]. The connectivity of the stages of the productive life cycle with innovations in areas considered strategic allows economic gains, social advances and improvement of environmental performance among members of this symbiosis.

The problem of waste in agricultural production affects directly producers, cooperatives, industries, government and consumers. Many waste and losses problems are due to linear business systems, where there is lack of some collaborative closed circles that could generate reuse of insums, business and products, collaboration and cooperatives, as well as generation of jobs and income in the sector. To Berbel and Posadillo [42], there is a need to establish incentives and drivers to take advantage of environmental services in agriculture to protect watersheds and biodiversity and to ensure food production using sustainable technologies, and these changes will then need to find ways to reduce losses and waste of agroindustry products.

Given this context, circular economy can generate several benefits for agro-industrial cooperatives if it acts in order to take advantage of waste and other processes losses in a symbiotic way, in win–win relationships, through different producers and companies involved in agroindustry. According to EMF [43], six actions can be employed to mobilize a shift to a circular economic system. These actions are presented by a framework known as ReSOLVE: Regenerate, Share, Optimize, Loop, Virtualise and Exchange. Other solutions linked to circular economy, such as life cycle perspectives, ecodesign, green innovations and sustainable manufacturing, can be developed in strategic sectors of agro-industrial cooperatives to promote sustainability, competitiveness and innovation.

## Agro-industrial Cooperatives

Agro-industrial cooperatives have changed considerably in recent decades, with the reformulation of traditional structure and adoption of non-traditional models in response to changes in their competitive and institutional environments [44]. A cooperative is an example of a formal institution with the aim of generating greater market power, having specific information, such as production and harvesting methods of cooperative members [45]. There are currently more than 1.2 million cooperatives in the agroindustry throughout the world [46], and the capacity to increase production of economies and promote local, regional and national development is an important role for cooperatives.

In many developing countries, agricultural cooperatives are a means to improve agricultural performance of small farms, mainly through services that improve the adoption of new technologies, sustainable practices and production marketing [22], for example, in a new technology for drying grains, processing milk or generating renewable energy. Cooperatives offer members opportunities to purchase goods, have market-related information cheaper, gain bargaining power in a specific market and locate a susceptible market [45]. This reflects the alignment and type of management of agricultural cooperatives. Solid organizations with good market strategies and visions focused on environmental and economic aspects of sustainability tend to show competitive advantage and be innovative.

Food supply chains have evolved a lot over the past four decades, such as the nature of products, shelf-life conditions, consumer behaviour and the food supply organizations systems [47]. In this context, one of the most cited studies in this field seems to be Cook [48] who explored agricultural cooperatives in the USA, showing sharp growth since the 1980s. However, our countryside ancestors were already meeting in agricultural cooperatives with the aim of developing production methods and bargaining for products and spices. And today, this has become an immense, competitive and extremely important business, as it is an essential item for human survival—food.

Therefore, at the current scenario of feeding 7.8 billion people [49], taking care of agricultural supply chain management to combat food waste [50], balance the volatility of the price of grains and food [51], produce nutritious and healthy food [36], manage agricultural waste and climate change-causing emissions [52], and at the same time, acting with robust practices and techniques to leverage economic and environmental gains are an uncertain scenario, and many variables are at stake.

In the field of cooperatives, the literature presents studies in various activities, such as livestock, agriculture, livestock-agriculture and agribusiness interactions with other industries. There is consensus that application of circular economy concepts and symbiotic models in livestock reduce potential environmental impacts. About perspectives of livestock, Awasthi et al. [3] analysed manure management practices in China; Ribeiro et al. [20] investigates the potential bio-gas generator using chicken manure for the generation of clean energy; and Pierie et al. [32] sought to optimize the anaerobic bio-digestion system through sustainability indicators.

Agriculture composes a wide range of analyses that aggregate the circular economy with positive results, such as corn cultivation [53], manioc [54] and leaf vegetables [55]. However, Yazan et al. [18] states that through cooperation between farmers and livestock farmers, it is possible to make the sale of biomass more profitable due to the higher added

value of the raw material. In this context, studies are being developed aiming at the application of the circular economy in livestock and agriculture in order to generate competitive advantages and cycle closure.

Besides the interaction between animal producers and farmers to value the substrate and continuous supply of biomass, there is also interaction of agroindustry with other industries through symbiotic models that foresees to take advantage of waste from the agricultural sector to be sold as raw material for other industries [15, 17].

These studies are all with respect to sustainable aspects of agriculture, nothing particularly for cooperatives. Thus, there are many more investigations on these topics. Therefore, the next session presents the main key aspects in circular economy approaches to agro-industrial cooperatives.

## Key Aspects in Circular Economy Approaches to Agro-industrial Cooperatives

European countries seem to be more inclined to meet government demands in promoting circular economy [56], and studies found in the literature on this subject show exactly that, for example, Pierie et al. [32], Bluemling and Wang [33], and Yazan et al. [18, 34] in Netherlands; Sudarić et al. [35] in Croatia; and Donner et al. [15] in France. However, recent scientific research and public regulations towards the circular economy have been developed around the world in this theme. This may indicate greater agro-industrial development and sustainable practices in these regions.

Therefore, a framework was developed to present potential routes of materials, energy and waste based on circular practices for agro-industrial cooperatives. Figure 1 shows three rural properties (with various agricultural activities/processes) inserted in an agro-industrial cooperative. The different symbols, colours and flows are generic.

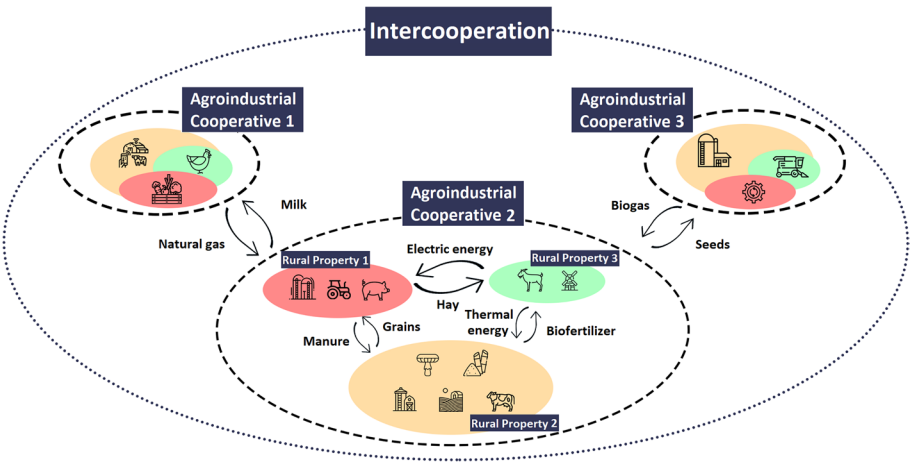


**Fig. 1** Potential material, energy and waste flows based on agro-industrial cooperatives circular practices

Materials such as grains (e.g. rural property 2) can move to another property to enter the drying process (e.g. rural property 1); mushrooms can be transported to a processing process on another property; pigs are sent to slaughters; milk collected on the farm (e.g. agro-industrial cooperative 2) can go to the processing plant (e.g. agro-industrial cooperative 1). This can be characterized as a business model that can be named "agro2agro". Figure 2 can exemplify this.

In terms of energy, rural property can produce thermal and electrical (bio)energy and can be distributed to the property itself, to neighbours and to the agro-industrial cooperative, for instance. In the case of agricultural waste, pig and bovine manure may serve as a raw material for a biodigester located on another property, for example; and the biofertilizer (produced in the biodigester) returns for use in the crop.

In this aspect, the exchange of information, material, energy and waste can be characterized by a term named "agro2agro". Farms located in a nearby region (or installed within an agro-industrial cooperative) can carry out these exchanges, so the entire system can benefit. Therefore, Fig. 2 exhibits an "agro2agro" relationship in terms of circular economy.

The relationship between cooperatives can extend itself through exchanges of knowledge, technology and experience. Each rural property can have production challenges. These challenges can be overcome by knowledge management and technology transfer. In addition, the exchange of new experiences can generate innovation and improvement in the production system of the farms. In fact, "agro2agro" relationship can create value to elevate farms to a technological level, generating innovation and competitive advantage.

Relationships of material exchanges, energy and waste do not happen suddenly. Rather, this flow is gradually established, as technical knowledge is needed, must be economically viable and promote cooperation among managers [56]. Investment in new flows is slow, as a biological evolution and that to make such changes, means making a radical change within the organization [57]. Therefore, closing the cycle in terms of materials and energy within the agro-industrial system is not simple. In this sense, key aspects emerge when it comes to exchanging material, energy and waste, such as (i) circular and symbiotic practices; (ii) measures taken to generate competitive advantage; (iii) the behaviour

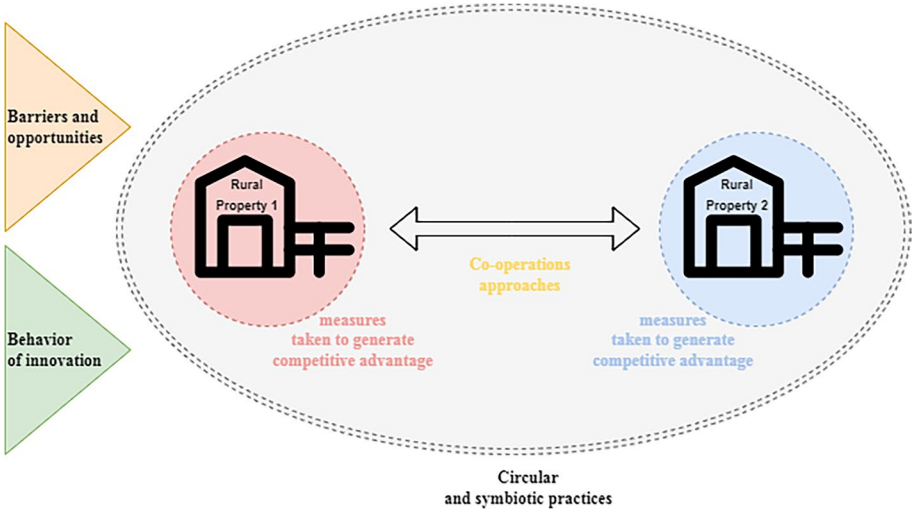


**Fig. 2** "Agro2agro" relationship based on circular economy initiatives

of innovation; (iv) cooperations approaches; and (v) barriers and opportunities in the field. These aspects are discussed thereafter.

Therefore, this section sought to present the practical contribution of the study based on potential routes of materials, energy and waste based on the developed framework. The next sections seek to present the opportunities to leverage gains for the sector through competitive advantage, innovation and cycle closure.

## Circular and Symbiotic Practices

To manage operations from the perspective of sustainability, it is important to have a connection between operations management [58]. It is possible to succeed by applying concepts of industrial symbiosis [59]; in this context, it shows that industrial symbiosis allows the creation of an industrial waste recycling network through collaborations between agro-industrial cooperatives, forming an intercooperation relationship (see Fig. 1). However, to apply an industrial symbiosis, barriers between farm compromises need to be overcome. According to Golev et al. [60] by overcoming these barriers, investment in sustainable development can become viable business.

To Mulrowet al. [61] the anchor company has a larger scale of production and by-products consumption, being important to attract other interested companies in order to integrate the network. This way, the entry of companies into the industrial symbiosis network favours development of benefits, such as the increase in waste exchanged between them over the long term [62]. In this context, industrial symbiosis allows to leverage industrial cooperation and favours the development of new business, job creation and reduction of environmental impacts of production processes [63].

In this perspective, to assist implementation of industrial symbiosis, the most current technique in the literature is circular economics [64]. And circular models integrated with industrial symbiosis favour implementation of circular processes in industries [40]. However, to apply circular processes, it is necessary to change businesses models and behaviour of the entire production chain and should include in this process the consumer [39].

In agribusiness by recirculating organic waste, industrial symbiosis benefits from the use of nutrients [65], and important chemical elements for planting are returned to the land through biofertilizers bringing as benefit reduction of chemical fertilizers usage and a better yield of crops [66]. In addition to benefits such as biofertilizers, agro-industrial waste can also be used for renewable energy generation [20]. On this theme, the organization of those involved in symbiosis in the form of a cooperative favours approximation of the waste generator (such as cattle producers) and waste consumers (such as farmers who demand biofertilizers).

The cooperative business also favours for bioeconomy practices since it is possible to continuously have the substrates [19]. Considering that the bioeconomy includes the production and utilization of goods and services based on biological resources, Sudarić et al. [35] presents a conceptual structure that favours the bond between cooperatives, enhancing a bioeconomy and rural development as well as to identify the characteristics and challenges of the cooperatives in Osijek-Baranja County and to propose measures for cooperative operations in the context of social economy.

### Measures Taken to Generate Competitive Advantages

In the 1990s, research was directed to industrial ecology and industrial symbiosis favouring the creation of competitive advantages, since companies are connected through exchange of goods [39]. And currently, research on this topic is still recurrent in several sectors. The interaction between companies requires friendly and trusting relationships to generate collectively beneficial competitive advantages [56, 58].

In this field, Romero and Carmen [67] approach a mathematical model that identifies the degree of competitive advantage obtained, so an indicator was developed in order to evaluate the relationship of industrial symbiosis between organizations. Also, Awasthi et al. [3] investigate the application of industrial symbiosis through integration between manure producers and farmers; this way, collaborations can generate competitive advantages due to the generation of value in a product that would previously be discarded in the environment, in addition to generating bioenergy and biofertilizers to be used in agriculture. In this subject, exchanges of material, energy and waste in cooperatives can enable production of renewable energy through anaerobic biodigesters [32], seen as the supply of by-products is more regular in cooperative models [19].

Although the use of organic waste happens more easily when there are clear economic incentives [68], competitive advantages in agro-industrial cooperatives can occur taking into account approaches beyond the economic aspect, such as compliance with environmental measures and legislation. Varela-Candamio et al. [69] focus on the participation of rural women in the agricultural food system, through a better understanding of their multiple role in food supply and demand with emphasis on obtaining competitive advantage; and Rotolo et al. [53] reinforce the achievement of competitive advantages for regional and national sustainable development through long-term policy decisions, as well as support to local organizations, in order to recycle products within the region and/or add value to local production.

Every organization aims to reduce costs, and alongside this, to improve their environmental performance, with this concern about natural resources has increased, as there is a limitation in nature. Therefore, establishing waste streams and by-products has a singular goal—to generate added value. The ideal is to generate the lowest possible cost and socio-environmental impact [59].

Building cooperatively managed producer networks are means of dealing with an industrialized structure [70]. That's why, farmers' cooperatives continue to be a promising approach to the development of second-generation biofuels [70] and for upstream and downstream production of the pork chain [71].

As a matter of fact, research on bioenergy in the agro sector is gaining increasing representation, and the theme seems to be recent. In light of this, Montoro et al. [23] investigate the mixture of sweet potato with dairy cattle manure in order to improve production efficiency of biogas, biomethane, biofertilizer and electricity; Yazan et al. [34] address the supply of biomass to biogas producers in order to produce renewable energy; and Ribeiro et al. [20] investigate the use of poultry farm waste for biogas generation and its conversion into electricity.

However, besides to bioenergy production practices, other sustainable practices can be seen, as in the study by Petit et al. [71], which addressed a prospects of farmer welfare, employee welfare, production enhancement and climate change; and Bluemling and Wang [33] who analyze conditions to close the nutrient cycle contained in cattle manure in order to reduce the pollutant load resulting from intensive cattle breeding. In fact, through

the circular economy, it is possible to make the bioenergy production system economically viable in a cooperative system [32], adding value to products and gaining competitive advantages for the agrobusiness. This can be seen in a generic way in Fig. 1. Exchanges of materials, energy and residues within the farm (rural property 1, 2 and 3), between farms, in the agro-industrial cooperative (1, 2 and 3) and in inter-cooperation can add value to the agrobusiness, make internal flows and generate competitive advantage.

## The Behaviour of Innovation

Switching from traditional models of linear economies to a circular economy [72] requires changes from eco-innovations to sustainable engineering solutions [40]. Recently, in a post-oil society, Europe has created an innovative, competitive and sustainable vision, dissociating economic growth from resource depletion and environmental impacts, presenting excellent actions in the development of innovation and advanced bio-based technologies throughout different sectors in recent decades [66]. This is led by practices aimed at research and development, the commitment of all stakeholders and concrete actions.

Innovation needs to be tied to sustainable development in the agro-industrial cooperative environment. In this way, improving knowledge networks can help in the adoption of innovation in the bioeconomy [21]. Bioeconomy addresses the use of renewable biological resources and their conversion into food, bio-based products and biofuels through innovative technologies in the agro food processing and industrial biotechnology sector [66] and industries that practice eco-innovation are more likely to develop cooperation in order to develop research, product innovation and information management [73]. With the advancement of technologies in the field (such as agricultural machinery), the agro-industrial sector (as more efficient machines for the processing of food), development of biofuels (such as biomethane, biodiesel and bioethanol), in the development of clean energy (from biogas) and others, innovation is part of this sector.

In the study by Montoro et al. [23], the use of cassava in co-digestion can be characterized as an innovation in technological process of anaerobic digestion and can enhance sustainability of dairy farms in a manner consistent with a circular economy. In addition, Gava et al. [21] helped to understand the interaction between biogas users and stakeholders in the Agricultural Knowledge and Innovations Systems (AKIS) in Mediterranean Europe.

The innovation approach in the field is related to the advancement of high technology, called agroindustry 4.0, on topics such as digitalization [4], climate-smart agriculture [5], big data [7] and others. Moreover, the factors that led biogas to enter an innovation status in the agro-industrial sector are fraught with numerous environmental and economic advantages. The potential routes shown in Fig. 1 in terms of biogas may act in replacement of electricity from the grid to electricity from the biogas generator engine; replacement of diesel and gasoline to biomethane; replacement of chemical fertilizer to biofertilizer; replacement of conventional gas to biogas; and other applications.

## Cooperation Approaches

The purpose of a cooperative is unique, co-operating to economic growth. In many developing countries, agricultural cooperatives are an important economic vehicle for small hold farmers [22]. The structure of this management is presented in a wide range of services and

production, being specifically attractive to landowners and agricultural producers [9], as shown in Fig. 1.

The idea of creating a group of rural producers to generate an agro-industrial cooperative refers to the thought that alone it is very difficult technically and expensive to compile all parts of the food production chain. Linking steps in the field, processing, capitalizing and selling to a single producer often become unfeasible. In this way, the union of a specific production sector (cereals, wine, fruits and others) make up an agro-industrial cooperative, seeking to establish long-term strategies to meet the interests of members in a lasting manner [15].

Industrial symbiosis can leverage gains through industry cooperation [63]. Exchange of materials, energy and waste between farms establishes a link of partnership, cooperation and strengthening. This strengthening occurs not only in the properties, but in the local and regional community of a cooperative, with generation of employment, income and opportunities for the arrival of new farmers.

In the literature, the work of Yazan et al. [34] showed cooperation between animal breeders and biogas producers that aims to generate economic benefits for both actors. The economic benefits can be the reduction in the cost of electricity, adding value to the destination of agricultural residues, reduction in fertilizer costs and other examples. Both for the producer who allocates manure (an environmental liability) and for the farmer receiving manure (for the production of biogas and electricity) gains are cooperation and can make up new business models based on industrial symbiosis. In contrast, competitive advantage occurs when the exchange is beneficial for both sides (but also for a third party—the environment), and this is agreed through the cooperation.

## Barriers and Opportunities in the Field

Speculation about the timing of the "oil spike", volatile gasoline prices and stronger consensus on global climate change [70] are discussions based on various sectors and society. However, this can also represent opportunities for organizations, including agro-industrial cooperatives.

Countries with intensive livestock farming face problems with the disposal of nutrients in animal manure [65], and while this can be seen as a limitation, it can become a path. Animal manure cannot be thought of as a residue, but as a material that contains nutrients (such as nitrogen, phosphorus and potassium), and also as a material that can add value (such as bio-based fertilizer and anaerobic digestion for biogas production). Undoubtedly, one of the main challenges of organizations for this millennium is in reducing the carbon footprint, and this includes the agro-industrial sector (in industrial processes), agriculture and livestock (in stages in the field) and in the decentralization of electricity generation from non-renewable sources in some countries (with opportunities to generate renewable energy).

The bridge between linear and circular is represented by innovative and disruptive business models and brings a number of practical challenges for companies [74, 75]. A linear economy flows like a river, a circular flow like a lake [76]. In recent years the agri sector is prone to look for business models that include the production and marketing of products following the bioeconomy [69]. Much has been said about generating electricity from clean sources and reducing greenhouse gases in the rural environment; however, alternative paths are needed for sustainable development in fact, such as circular economy practices [77].

The challenge of implementing innovative strategies should enable the development of e-agriculture in terms of avoiding delays that could increase the discrepancy between rural and urban [78]. The future of the rural territories of the European Union is conditioned by rapid changes in social and economic developments, and also by larger urbanized areas [69]. The occupation of land use is part of agriculture; however, making shorter value chains or local food productions are practical practices that began a while ago [79] and tend to continue with the creation of new innovative and circular business models in the agro environment. Despite barriers of entry of large companies into the food market, the sector is considered emerging, and new business opportunities for small entrepreneurs may arise [69].

Circular economy is more than just circularity. The economic benefits can also be interesting when the material, energy and waste cycle is closed. Through the exchange of materials, rural properties and agro-industrial cooperatives can benefit economically, since the purchase/sale takes place within the limits of the agro-industrial cooperative, and not outside this system. Acting in the economic and environmental sectors, it can make agriculture more sustainable.

In fact, agribusiness can be circular. The use of agricultural waste is of particular interest in the context of the circular economy [77], optimizing the use of resources and minimizing the generation of waste [80]. Nonetheless, many challenges are still addressed and need to be overcome, such as emissions, water footprint and phosphorus. The potential for climate change mitigation through reducing emissions of non-$CO_2$ greenhouse gases in agriculture has been discussed for many years [81]; however, for the agriculture sector to perform reduced greenhouse gases emission, climate-smart activities and improved food security are impetus for a more sustainable agricultural future [82].

On the one hand, agriculture is one of the main causes of water consumption and degradation [83]; on the other hand, water footprint is an option for monitoring green water, blue water and grey water in agricultural use. Finally, another challenge is the question of phosphors. Phosphorus is an essential and non-substitutable component of living organisms [84]. A more sustainable option than mineral fertilizer (e.g. nitrogen, phosphorus, potassium) may be the biofertilizer. Seeking to close the phosphorus cycles and reduce the use, the biodigester to produce biofertilizer can be a good alternative. The most common practice is stipulated around the production of bioenergy, making use of agricultural and livestock waste. The biodigester can be seen as a promising technology in agro-industrial cooperatives with the objective of taking advantage of waste and generating added value through products such as biogas, biofertilizer, biomethane and electricity [85, 86].

The current situation may be considered unstable and unsustainable due to rising ecological reasons from the destructive nature based on fossil fuels of agriculture practiced in some parts of the world [87]. Therefore, developing business models that integrate all economic actors along the value chain [66] presents opportunities for the current economic scenario, and overcoming these challenges requires research and innovation in agriculture sector, to achieve radical switches in lifestyle and resource use [88]. Therefore, this section sought to present the barriers and opportunities in the field and sought to answer the practical contribution of the current scenario of circular economy practices applied in the sector.

## Conclusion and Future Issue Recommendations

This research aimed to present the main key aspects of the circular economy to agro-industrial cooperatives named as key issues such as competitive advantage, innovation, cooperation, barriers, opportunities and future issues. The main findings are that circular economy when applied in agro-industrial cooperatives has benefits in the management of activities and processes and as an opportunity to close cycles in terms of material, energy and waste flow. Therefore, this research can establish some specific conclusions:

- Competitive advantage: The concept of industrial symbiosis and circular economy has been part of agro-industrial cooperatives that have a culture of producing and preserving the environment, making production processes more sustainable, with initiatives to generate competitive advantage.
- Innovation: The cooperatives that applied these concepts seem to be more likely to develop cooperation, with initiatives to innovation. The concept of cooperatives is a very important in terms of innovative ways of value chain management, cluster formation and closed loop supply chains.
- Cooperation: Potential route strategies that add value to the product exist in the cooperative environment that refer to the scientific value of the article and the applicability of the results, such as it is not trivial to identify these routes. In contrast, acting as a cooperation can become easier and faster in rural properties to achieve specific sales and development goals compared to those that work in isolation.
- Barriers: Legislation and bureaucratic issues can intervene in cooperation and initiative among owners to close the partnerships and the cycle, such as the purchase of agricultural waste and sale of electricity.
- Opportunities: Agro-industrial cooperatives have a very particular way of dealing with issues of facilitation and governance, because of the way in which cooperatives are organized. The way in which agro-clusters deal with these issues is something that is interesting for many more sectors that want to work with the circular economy concept; then, also here the agroindustry can not only learn from economy concept, but the agroindustry can also be an inspiration to other types of industry.

In this sense, the results of the study have a practical contribution within the "agro-2agro" chain in terms of understanding: (i) the current scenario of circular economy practices applied in the sector; (ii) opportunities to leverage gains for the sector through competitive advantage, innovation and cycle closure; and (iii) visualize potential routes of materials, energy and waste based on the developed framework.

Furthermore, in the agro-industrial environment, the profile of stakeholders can involve the farm community, customers, suppliers, investors, society and the government. The results of farms generated from the circular economy perspective can be presented to stakeholders via some aspects, such as sustainability reports, market positioning, compliance with SDG targets, competitive advantages and others.

This study is not without limitations. The criteria for the determination of keywords selected for the search in the literature, search engines, the analysis of the characteristics of the articles found and the content analysis can make up the limitations of this study. On the other hand, the work sought to cover a long-time frame in the body of literature, with research in relevant databases, high impact in the scientific

field and composed of peer review documents, showing the robustness and quality of the articles found.

The work, therefore, seeks to promote the use of technologies in the field, use of renewable energies, management and reuse of agricultural waste and the direction for the use of new circular business models. Insights in terms of increased competitiveness, innovation and cooperation are also provided. It can be affirmed in the contextualization of the problem of this research that within a set of solutions proposed for the achievement of the development of agro-industrial cooperatives, it is possible to notice that there is a need for approximation between cooperatives and academia, in order to enable greater potential for research, development and innovation.

Finally, three recommendations for a strong scientific approach, related to some SDG [36] for agro-industrial cooperatives in search of sustainable development tend to be emphasized: (i) decentralize and diversify renewable energy sources through the use of biogas, biomass, wind and solar power plants, with the objective of mitigating aspects of climate change; (ii) economic growth, sustainable and inclusive, with the creation of new circular business models of high performance added to high technology index, and can contribute to the generation of employment and income; and (iii) improve the supply chain in search of reducing food waste, while seeking efficient production techniques to provide safer, nutritious and affordable food.

Future issues from the development of circular economy practices for agro-industrial cooperatives have generated some recommendations:

- Idea of an agricultural nexus: the role of agro-industry in the regional transition to a circular economy may be analysed in terms of how the feedstock, the fertilization, the water and the waste can all be integrated into a water-industry-agriculture nexus.
- Strengthen the development of new circular business models throughout the agro-value chain.
- To sensitize to all stakeholders upstream and downstream of the agro-industrial cooperative about the importance of developing practices aimed at circular economy.
- Enhance support of public agencies in development of local and regional cooperatives with subsidies.
- Promote arrival of new owners in cooperatives in order to expand cooperation and generate new development opportunities in terms of technology, bioenergy and sustainable processes.

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BSR: conceptualization; methodology; formal analysis; investigation; writing, original draft preparation; visualization.

RHGJ: conceptualization; methodology; formal analysis; investigation; writing, original draft preparation; visualization.

CMP: conceptualization; writing, review and editing; supervision.

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