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Research article

The circular economy model in the agri-food sector: A new strategy for the regional development

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Abstract: It is undeniable that the agri-food system is one of the greatest waste-producing sectors, with the inevitable generation of a certain quantity of scraps due to processing at an industrial level. Circular economy may offer a valid solution to overcome this problem, but the application of the model requires the availability of reliable data about quality and quantity of waste, which are currently missing. For this purpose, the objective of this paper is to address the issue of waste generation in the agri-food industry using a survey questionnaire. In-depth interviews were conducted with the owners or the technicians of selected case studies from the Marche region agri-food sector. Then, mass balance was applied based on primary data collected during the interviews. Moreover, to explore the potentiality of the circular model for the development of a regional agri-food sector, barriers, opportunities and services were also investigated. Results identified the vegetable and olive oil transformation as the most impacting in terms of quantities of waste produced. Food business operators currently find it difficult to give a proper definition of circular economy and envision the implementation of the model soon. However, they are also very enthusiastic and positive in finding alternative solutions to recover the waste. A great support could be provided by establishing a regional database for waste qualification and quantification. This work could be useful for policy makers, helping to understand the hurdles that agribusiness entrepreneurs shall face in this economic transition.

Keywords: circular economy; agri-food supply chain; food loss and waste; by-product; sustainability; mass balance; case study; questionnaire; barriers; opportunities

1. Introduction

The agri-food sector has always been one of the major waste generators, particularly when considering the transformation and processing of raw material at industrial level [1–5]. This production implies environmental, economic and social impacts, affecting the sustainability of the agri-food manufacturing supply chains [6]. Wasting resources contributes to additional consumption of water and energy, generating greenhouse gas emissions and impacting global climate change [7–9]. Waste production imposes an economic loss for producers, where they are not able to transform their investment in raw materials and facilities into a profit [10]. From the social perspective, wasting resources means less safe food available, contributing to world hunger [11,12].

The best strategy against food wastage is prevention. Whenever possible, the food industry should put in place systems, methods and technologies aiming to avoid its production since the beginning of the supply chain [13,14]. Innovative processing and packaging technologies could support the basic requirements of food processing, namely food safety, without compromising the taste, and giving a nod to the reduction of wastage [15]. But managing commodities to produce added value products entails the removal of inedible parts in different quantities according to the starting input. As reported by Food and Agriculture Organizatio (FAO) [16], the highest level of loss is registered for roots, tubers and oil crops (25%), followed by the fruits and vegetables group (20–25%), meat and animal products (10–15%) and cereals and pulses (below 10%). When prevention is not applicable, the European Waste Framework Directive defines a series of other measurements, known as waste hierarchy, that could be adapted and applied in any context, including agri-food. Papargyropoulou et al. [17] adapted the waste hierarchy to the context of the food supply chain, classifying the waste management activities from the most (prevention) to the less (disposal) preferable option. In between, reuse, recycle and recovery recall the 3Rs' principle at the base of circular economy (CE) [18]. CE has been disclosed as a model that aims to make a better use of resources. The shift from a traditional take-make-use-dispose model to the application of circular principles offers relevant opportunities to businesses for reducing their impacts, considering waste as a secondary resource [19–21]. The implementation of circular economy principles may affect the 3Ps (planet-people-profit) of sustainability. It reduces the pressure on natural resources, by reusing discarded products and contributes to lower the greenhouse gas emissions. It entails productive activities developed with respect to society and the environment, to promote decent working conditions and a fair social development. Finally, it promotes fair remuneration and job-creation perspectives, based on the reuse and valorisation of waste [22–24].

The European Union, with the Green Deal and Farm to Fork strategies, is placing CE in the centre of the future industrial green growth [25–29]. Besides the fact that CE has emerged as a potential winning solution in the agri-food industry, a lot still needs to be done concerning the regulatory framework and the technical aspects [30].

One controversial aspect posed by the regulations is properly the definition of what is a food waste. While in literature we generally debate between *food loss* and *food waste*, according to the production step of the supply chain in which they are generated, from the consolidated version of the Waste Framework Directive [31] the problem is more substantial, and *food waste* can be defined as it is or it can be also included in the group of *bio waste*. Not to be underestimated, there are the concept of *by-product* and the *end-of-waste* criteria. In both cases, for different reasons, we are not dealing with waste, but with substances that could be further re-used [32]. This creates problems to the

entrepreneurs that, according to the status of their waste, should manage them differently, with different risks and costs. For this study, in light of circular thinking, we will refer to by-products when dealing with food waste and to waste when considering all the other resources used (like packaging).

In addition, one of the main problems is that quantification of food by-products and waste is characterised by conflicting results, mainly due to different methods and practices. Inconsistencies could be caused by the influence of the water content on the total weight, the divergence between the terms (loss, waste, by-product), the seasonality of certain productions and the approaches during processing, sale and consumption of food [33–35]. What could be highlighted by the current available studies is that, in most cases, the used data is retrieved from databases (FAO, Eurostat), reports and food balance sheets [35–38]. It is difficult to find high quality data by-products and waste deriving from direct measurement and analysis. On these premises, to contribute to the research field of CE in the agri-food sector, this study aims to answer the following research questions:

- RQ1: Which type and how much by-product and waste are produced during the processing of raw materials into food products?
- RQ2: Which are the barriers and opportunities in implementing the CE in a regional agri-food sector?
- RQ3: Which services are needed to facilitate the adoption of a circular model?

Since the availability of reliable qualitative and quantitative data about food loss and waste is scarce, the originality of the paper lies in the fact that we tried to collect as much as possible primary data with an ad hoc questionnaire during interviews in selected case studies from the Marche (Central Italy) agri-food sector. According to that data, a mass balance was built for the production process of each case. Furthermore, interviewees were asked about their knowledge concerning CE, the barriers and opportunities they perceive in embracing such a model and the services they need to facilitate its adoption. This research was done as part of a project funded by the Marche regional government and dedicated to the implementation of the circular economy model in the agri-food sector. For this reason, we believe that this study could have potential implications in the establishment of an innovative sustainable food industry, based on the complete exploitation of resources and with less impacts, bringing economic advantages for the regional development. The rest of the paper is organised as follows. Section 2 presents an overview of the Marche Region agri-food sector. Section 3 describes the methodology employed in the analysis. Sections 4 and 5 show and discuss the main results. Finally, Section 6 concludes the paper.

2. The Marche region agri-food sector

The agri-food industry plays a key role in the Italian manufacturing sector, accounting for almost 16% of the production value, with the food and beverage compartment representing 15% of the total number or manufacturing companies. Sicily (13%), Lombardy (10%) and Campania (10%) are the regions with the highest numbers of company, while Marche represents 3% of the sector [39]. The Marche region is in central-eastern Italy, overlooking the Adriatic Sea. The economy of the region is characterised by small and medium enterprises (SMEs), often family-oriented and deriving from long-lasting tradition, highly specialised and distributed equally throughout the territory, but mainly concentrated on the coast and in the valleys. One of the pillars of the Marche's economy is the agri-food compartment, representing about 10% of the regional manufacturing sector and generating employment for about 14,000 employees. According to the data provided by the regional Statistical Information System (SIS) and following the ISTAT classification by ATECO codes, in the second

quarter (April-June) of 2021 there were more than 26,000 companies belonging to ATECO A01 (agricultural crops and animal production, hunting and related services), A03 (fishing and aquaculture), C10 (food industry) and C11(beverage industry). The ATECO code is an alphanumeric combination that identifies an economic activity (*ATività ECOnomica*). The letters identify the economic macro-sector while the numbers (from two to six digits) represent, with different degrees of detail, the specific articulations and subcategories of the sectors themselves. In detail, the proper agricultural activities account for 91% of the total agri-food, fisheries and aquaculture represent 2.5%, the food manufacturing corresponds to 6% of the total and the beverage industry accounts for only 0.5%.

Considering the five provinces of the region, the largest number of farms is concentrated in the province of Macerata (6,999 companies). In regards to fisheries and aquaculture, the province of Pesaro-Urbino ranks first (172 companies). In the manufacturing sector, the province with the largest number of food and beverage enterprises is Ancona (369 and 38 companies respectively) (Figure 1).

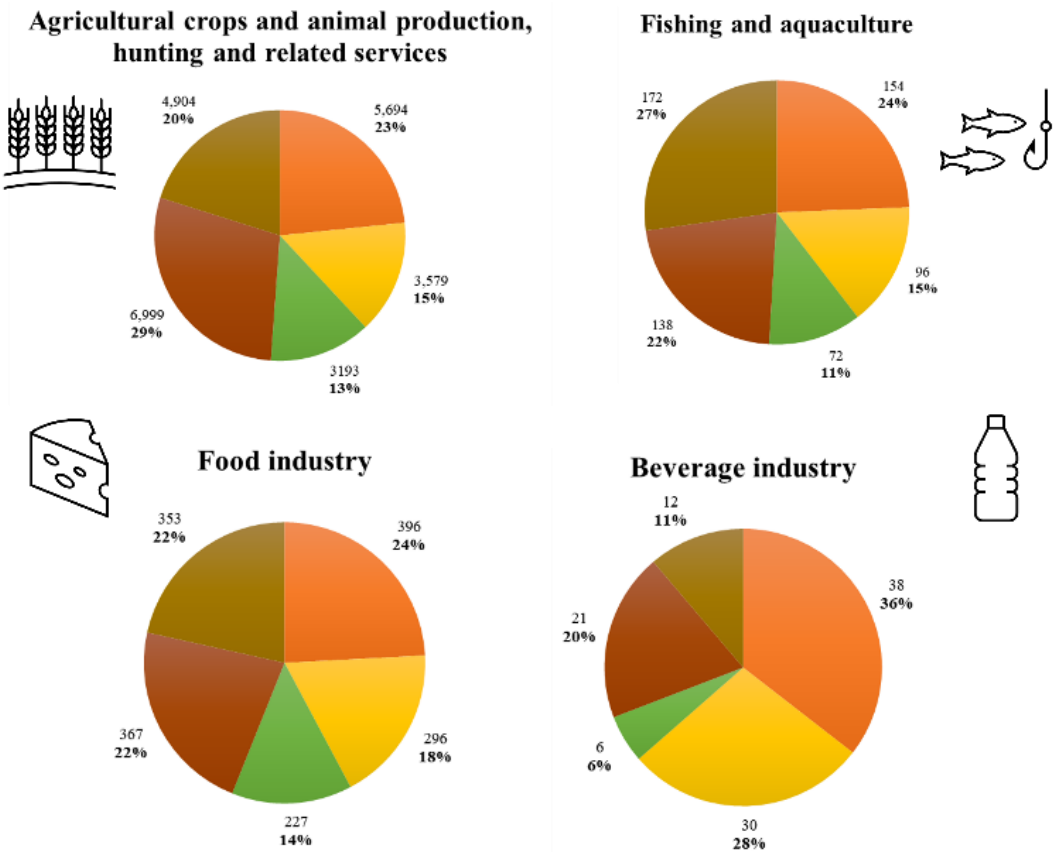

Figure 1. Subdivision of the agri-food sector by province (AN: Ancona; AP: Ascoli Piceno; FM: Fermo; MC: Macerata; PU: Pesaro-Urbino). Source: Author elaboration from SIS data for the second trimester (April–June) of 2021.

Considering the food industry solely, there are 1,639 companies involved in the food manufacturing in the Marche region. Most of the companies (24%) are in the province of Ancona, followed by Macerata and Pesaro-Urbino (22%). By contrast, the beverage industry counts 107 companies, mostly located in the province of Ancona (36%) and Ascoli Piceno (28%). Figure 2 shows the contribution of each different supply to the total of the food (Figure 2a) and beverage (Figure 2b) industry.

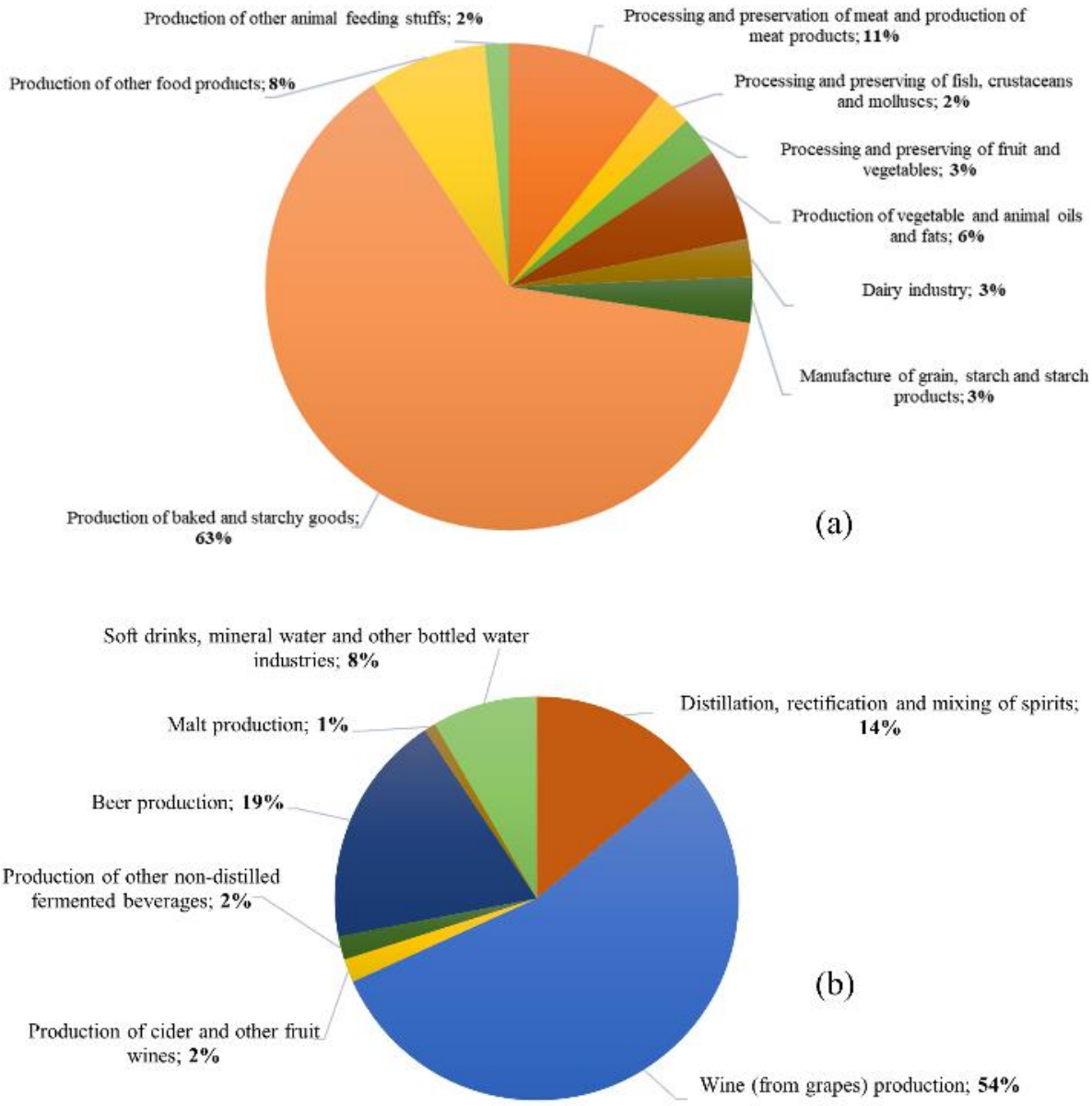

Figure 2. The food and beverage industry of the Marche region in the second quarter of 2021. a) The percentage contribution of each sub-sector to the totality of the food industry. b) The percentage contribution of each sub-sector to the totality of the beverage industry. Source: Author elaboration from SIS data for the second trimester (April–June) of 2021.

Considering the different activities, the Marche food sector is characterised by the prevalent presence of baked and starchy products (63%), including pasta. In fact, there are 316 pasta makers spread in the territory, producing both dry and fresh pasta. The Marche's pasta has a long tradition linked to the territory, with the use of mainly local or Italian wheat. In addition to durum wheat semolina pasta, fresh egg pasta is one of the most important specialties. As proof of this, the *Maccheroncini di Campofilone* pasta have been recently recognised with the PGI (protected geographical indication) quality mark. Moreover, the strong vocation of the Marche territory to organic agriculture, also proven by the presence of an organic district, guarantees an additional element of

competitiveness on the market. Since most of the pasta making is still done according to traditional methods and in small batches, it is essential to introduce elements of innovation to make this reality resilient. Considering the importance of the sector for the regional economy, two companies, one producing fresh egg pasta and one producing dry pasta, were included in the study.

Even though it represents just the 3% of the total, the processing of fruit and vegetables is a backbone of the Marche food industry. In fact, since 2004, a producer organisation (PO) was created with the aim of ensuring the protection of agricultural producers. Today, it is an established company in Italy for the processing of frozen vegetables and the first for the cultivation, processing and marketing of peas. It is undeniable that fruits and vegetables are one of the highest food waste groups, many of these residues having the potential to be reused for different purposes [40]. For these reasons, the frozen vegetable processing companies belonging to the PO, were included in the study.

The olive oil production is an excellence of the Marche territory, representing 6% of the food transformation industry. With two quality labels, one PDO (protected designation of origin) and a PGI, the quality and typicality of the Marche oil are the result of the combination of various factors including the variety used (mainly Frantoio and Leccino), the climate, the agronomic techniques and the tradition of the mills, which allows the coexistence of cutting-edge production with more traditional plants. The recovery of the olive pomace for the extraction of the residual oil or for energy purposes represents an excellent example of circular practice [41]. Indeed, one of the most important extra virgin olive oil (EVOO) producers in the region was included in the analysis.

From Figure 3a, it is notable that 8% of the food industry is dedicated to the production of the so-called other food products, like chocolate, ready-to-eat meals and coffee. The analysis of the statistical data highlighted that several coffee roasteries are spread on the territory. From the literature, it emerges that the coffee industry is facing a range of sustainability issues, including waste production, that could be managed by implementing a circular economy system in several ways [42–45]. One of the main roasteries of the Marche region took part to the survey.

Finally, as can be seen in Figure 3b, the production of wine from grapes represents more than 50% of the regional beverage industry. In fact, wine production and wine tourism represent important elements of the Marche economy, especially after the Covid-19 pandemic. In wine production, since ancient times, wine lees and pomace were used to obtain spirits, representing a perfect example of circularity. However, wine making produces tons of by-products with a high added value, potentially recoverable for several applications like dietary supplements and cosmetics [46–49]. Therefore, to include a case from beverage production, a winery was involved in the study.

3. Materials and methods

For the analysis, we decided to proceed with the multiple case studies approach [50], as several units were selected and tested for their by-products and waste production and propensity towards the circular economy model. The use of case studies could be criticised for the lack of scientific rigour and reliability, without addressing the issue of generalisability. However, the application of a multiple case study approach allowed to investigate and compare several realities in the regional agri-food sector, providing a holistic view of a real context environment. Indeed, the use of multiple cases can allow the generalisation, as the results can lead to a replication in a similar context [51].

A sampling methodology was established based on the research interest and the objectives of the regional project.

- The case companies should belong to different supply chains from the Marche's agri-food sector.
- The case companies should belong to the most relevant sectors of the Marche's agri-food according to the statistical analysis presented in the above section.
- The case companies should have a solid brand reputation.
- The case companies should run a mature and profitable business that is able to support investment for the circular transition.
- The case companies produce by-products with a potential circular use.

Based on the above criteria, we have decided to proceed with the following supply chains as they were identified by the statistical analysis of the Marche's agri-food sector as the most relevant.

- Processing and preservation of fruit and vegetables (frozen vegetables company).
- Production of oils and fats from vegetable and animal origin (extra-virgin olive oil producer).
- Production of baked and starchy products (fresh egg stuffed pasta and dry pasta).
- Production of other food products (coffee).
- Wine production.

Data collection was carried out by questionnaire and direct interviews with entrepreneurs and technicians of the different companies from April 2022 to March 2023. In each selected case study, at least two people were interviewed, generally the owner and the technician in charge of the production processes. Whenever possible, the interviews were performed face-to-face. Otherwise, telephone calls or online meetings were arranged, in accordance with the current Covid-19 regulations. The questionnaire was structured in three parts:

Part A: General information of the company. In this first part, information was collected to define the profile and structure of the selected case study.

Part B: Analysis of by-products/waste generation. To understand the amount of by-products and waste obtained in each of the selected case studies, considering the operative processing step, it was chosen to apply the methodology of the mass balance. The mass balance represents an important milestone on the pathway to circular economy. It has been designed to trace the flow of materials through a complex value chain. At its most basic, this method estimates waste by subtracting the outputs from the inputs, with the difference being considered the quantity of waste produced. In the Commission Delegated Decision (EU) 2019/1597, it is reported that, when direct measurement is not available, mass balance should be used [52]. The reason for finding out data on by-products and waste using the methodology of the mass balance is that numbers on inputs and outputs are generally of a higher quality and precision compared to data on waste generation. While entrepreneurs are strongly inclined to register all the quantities of raw materials and final products (for inventory and economic purposes), frequently they are not inclined to measure how much waste they produce. So, data on waste could be potentially provided by national institutions using different waste definitions, classifications and measurement systems, making the accounting process fragmented and disaggregated [53].

In detail, interviewees were asked to illustrate the flow chart of their production line(s), the typologies and quantities (tons/year) of inputs (ingredients and packaging) and outputs (final produces, waste and by-products) at the beginning and at the end of the processing (Figure 3). As regards waste and by-products, the current destination and the costs of disposal/management were also asked.

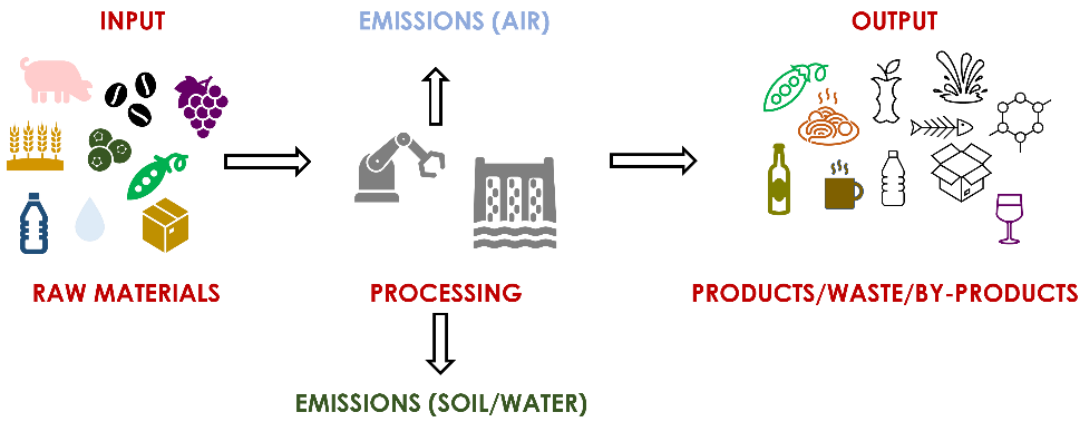

Figure 3. Schematic representation of the mass balance. In our study, emissions to air, soil and water were not considered. Source: Authors

Part C: Circular economy. The last part of the questionnaire was devoted to the investigation of the current knowledge about CE by the different interviewees, the barriers, and the opportunities to the implementation of the model, as well as the services that they are seeking for facilitating the transition. They were asked to provide their personal definition of circular economy and their thoughts about alternative solutions to reuse their waste. Barriers and opportunities were evaluated using a 5-point level of agreement Likert scale (1 completely disagree, 2 disagree, 3 undecided, 4 agree, 5 completely agree), while the services were ranked according to a 5-point level of importance Likert scale (1 not important at all, 2 not important, 3 important, 4 very important, 5 extremely important). To conclude, interviewees were asked about their perception on the involvement and propensity of the Italian and European government in spreading and encouraging the transition from a linear to a circular model.

Three researcher authors with experience in qualitative research and on the topic of agri-food supply chains and CE have independently analysed the data collected. All the individual analyses converged into the results [54]. At the end, it was not possible to perform statistical data treatment because the number of valid responses was less than necessary to carry out a robust quantitative analysis. As reported by Berardi et al. [55], qualitative methodologies, as the case study method, have been widely used in studies addressing the theme of circular economy in agri-food supply chain.

4. Results

4.1. Description of the case studies

The frozen vegetables company included in the analysis was founded in 2007 and is located in the northern-costal part of the region. The raw material comes from the producers' cooperative, constituted by over 600 member farms for more than 6,700 hectares of surface. The company transforms mainly peas (representing 42% of the total production) and leafy vegetables (26%), intended both for the national (large-organised distribution, catering and industrial purposes) and international market (15% of the production, primarily USA and Northern Europe). The company is also the owner of a biogas plant.

The fresh stuffed egg pasta plant was established in 1955 as a small family-run pasta shop, but in

1973 became a bigger reality. Still, it can be defined as a small family-run artisan company, with 17 persons employed. It is in the central part of the region, near the Apennines. The main products are cannelloni pasta stuffed with ricotta cheese and pork meat. The products are distributed only on the national market, specifically in Central Italy, through large-organised distribution, catering and retailing.

The dry pasta company represents an excellence of the region, localised in the southern-costal part of Marche. The first wheat fields and plant were established in 1938. Currently, the activity continues with a focus on the territory, bringing innovation and sustainable production. All the semolina used for the pasta making comes from the fields, managed in organic production, surrounding the company, The durum wheat is then milled in a local facility. The pasta is produced in several formats (long and short dry pasta), sold in the national market (direct selling, Ho.Re.Ca. channels and delicatessen shops) and exported worldwide for a 30% of the production (mainly USA and Japan). The plant employs about 15 people.

The roastery is in the northern part of the region, on the border with Emilia Romagna. Its history dates to the XIX century, where the founder was dedicated to the commercialisation of different exotic food products, including coffee. The industrialisation of the system was performed in the 1950s, when the first productive plant was established. The raw material comes from different part of the world (Africa, South America, India and Oceania). Inside the plant, raw material is stocked, analysed, roasted and eventually grinded. The number of employees is 70. The final products are destined only for the national markets and for restaurants and bars affiliated to the brand.

The farm producing EVOO extends for about 60 hectares in the northern-west part of Marche and 7,600 olive trees occupy more than one third of the total surface (20 hectares). The production is fully organic and it is characterised by the presence of several cultivars (Frantoio, Leccino, Raggiola, Ascolana Tenera, Rosciola and Picholine). The production of oil takes place in two phases. Then, monovarietal, blend and aromatic oils are placed on the national market.

Last, the winery included in the study was founded in 1934. The farm has a total of 70 hectares, distributed in several municipalities in the southern-costal part of the region. The new generations are strongly investing in sustainable solutions, with regards to water saving systems. The winery produces PDO and PGI wines, sold on the national market through large-organised distribution, direct selling and Ho.Re.Ca. channels. There are 10 permanent workers, to whom are added the seasonal workers during the harvest period of the grapes.

4.2. Analysis of waste/by-products generation

With the numerical data provided (tons/year) during the interviews, it was possible to build a simplified mass balance of the processing stage in each supply chain from the delivery of the raw materials until the packaging of the finished products. For olive oil and wine production, the pruning residues were also identified as a waste. Table 1 shows the results of the second part of the questionnaire. For each supply, the typology of waste/by-product, the quantity produced and the current management system are reported. The quantity is expressed as percentage to provide a general index of how much is commonly wasted in each sector. The respondents were not able to provide a clear distinction between what they intend as waste and by-product. In their imaginary, they would like to classify all of them as by-products, to facilitate the recovery and reuse. For the sake of the work, we classify all food residue as by-products, while waste is packaging, wastewaters and pruning residues.

Table 1. Results from the mass balance analysis and current destination of the waste/by-products. Source: Authors

Food processing	Waste/By-product	Quantity (%)	Management
Frozen vegetables	Vegetable by-products	16	Biogas
	Wastewater	94	Landfill
	Packaging waste	5	Separated collection
Fresh stuffed egg pasta	Pasta by-products	10	Manuring; animal feed; charity
	Meat by-products	20	Manuring; animal feed
	Packaging waste	5	Separate collection
Dry pasta	Pasta by-products ("*curve*")	10	Knead again; animal feed (pigs); charity
	Packaging waste	2	Separate collection
Coffee	Husks (silverskins)	0.7	Bio-waste collection
	Packaging waste	2	Separate collection
	Jute bags	100	Landfill
Extra virgin olive oil	Olive pomace (wet)	84	Biogas
	Olive pit	3	Pellet
	Packaging waste	5	Separate collection
	Pruning residues and leaves	-*	Reuse in the field
	Wastewater	-*	Sewer
Wine	Wine lees	4	Distillery (spirits production)
	Grape pomace	11	Distillery (spirits production)
	Pruning residues	-*	Reuse in the vineyard
	Grape stalks	4	Reuse in the vineyard
	Packaging waste	-*	Landfill

* Identified as waste, but the interviewees were not able to quantify them.

As can be seen from the table, vegetables and EVOO produce the highest amount of waste. On the contrary, roasting coffee results in the least losses. For packaging, wastewaters and pruning residues, the interviewees recognised them as wasted resource, but they were not always able to provide the amount.

- Frozen vegetables: The vegetable by-products mainly consist of non-edible discarded parts removed during the first phases of the process (peels, seeds, pods, external leaves and stalks), and unsuitable products for further transformation (not standardised or damaged). The wastewaters come from the washing phase and from the cleaning of facilities and machineries. Plastic and paper waste are due largely to inefficiencies during the packaging process.
- Fresh stuffed egg pasta: The main by-products originate from the meat processing. In fact, the company receives the pork half-carcasses from which obtains the meat used in the filling. The cutting of the meat produces non-edible products like bones, blood, nerves and fat. The pasta by-products result from technological inefficiency, errors in cutting the dough and problems during packaging. Plastic and paper waste are due largely to inefficiencies during the packaging process.
- Dry pasta: During the production, the main by-products derive from technological inefficiency of the system (*waste cone*) and processing waste (*curve*). Incorrect packaging causes problems

during weighing, generating paper waste.

- Coffee: The most substantial weight losses are due to cleaning process (3% of contaminants and foreign bodies) and proper roasting (26% of water removal). Indeed, silverskins, in weight, represents barely 1% of the waste. Plastic and paper waste are due largely to inefficiencies during the packaging process. Jute bags represent the main problem for this supply chain, as 100% of the received sacks is discarded in landfill.
- EVOO: The average annual yield for the oil extraction is 13%, leading to a considerable quantity of by-products, mainly wet pomace and pits. The packaging waste mainly consists of broken glass bottles because of wrong packaging procedures. Wastewaters deriving from the cleaning of the facilities and machineries are currently not recovered. The leaves from the cleaning of the olives and the pruning residues are not quantified by the company, but they are employed as natural soil conditioners in the olive groves.
- Wine: From the fermentation process, the main by-products are pomace and lees, currently destined to spirits production. The stalks, removed prior to the crushing of the berries, are used in the field along with the pruning residues. The packaging waste mainly consists of broken glass bottles because of wrong packaging procedures.

From the discussion about the current destination, it emerged that some of them already put in place what we can call good circular practices. Certain methods are somehow mandatory. Ee refer to the wine production where, by law, producers and processors of wine grapes are obliged to deliver the resulting by-products to a distillery [56]. Others, like the use of biomass for biogas generation, manuring and animal feeding are good starting point to favour the transition from a traditional to a circular model. In the pasta making, the donation to charity organisation is an opportunity not fully exploited yet as it is mainly occasional. For the dry pasta, an important aspect is the reuse of the dough and the possibility to even sell the *curve* as a special pasta size, converting an unavoidable by-product into an opportunity. Some of the residues, like the leaves, are useful resources for the agronomic practices. The same is for olive pomace, authorised by the Law 11 November 1996 n. 574 [57] and the Ministerial Decree 6 July 2005 [58] for the agronomic use, by ensuring the proper distribution and incorporation of the substances on the soil to avoid consequences to water supply, harming living resources and the ecological system. The acceptability limit for spreading is 50 cubic metres per hectare for by-products from conventional cycle mills and 80 cubic metres per hectare of surface area for water and pomace from continuous cycle mills. Since it is produced in large quantities, the olive oil entrepreneur prefers to avoid the use in the field by directly sending the pomace to a biogas digestor.

The problematic aspect concerns the packaging, generally destined to separate collection or landfill, and the wastewater (used for cleaning the raw material or the facilities) that is not currently recovered in any of the supply chain, but rather destined to the landfill or the sewer.

Considering the monetary value spent to currently give rid of the waste, not all the interviewees were able or prone to provide actual numbers. From the data obtained, the costs range between hundreds (pasta) and thousands (vegetables and coffee) euros. The entrepreneur who is currently spending less than the others has been able to get a 15% discount on taxes for partially recovering his waste. For the EVOO producer, managing the pomace as they are currently doing represents a great opportunity to contain the costs, as the biogas plant organises and performs the collection of the biomass from the plant for free.

4.3. Circular economy: definitions, barriers, opportunities, and services

In the last section of the questionnaire, interviewees were asked to provide their personal definition of CE, as well as to express their knowledge about and willingness to adopt alternative use of their waste and by-products. To visually present the circular economy definitions provided by entrepreneurs, a word cloud was made (Figure 4).

Figure 4. Most recurring words in the CE definitions given by the interviewees. Source: Authors

Word clouds are an easy and quick way to perform a preliminary qualitative analysis of data through text size and colour, where a term mentioned more often will be included in a larger font [59]. All the interviewees found difficulties in providing a definition of CE as "*the concept by itself is rather simple, but it is somehow difficult to explain*". Most of them have attributed the model to a sustainable use of resources and to the recovery and valorisation of waste. The ones which are not only food business operators, but also agricultural entrepreneurs, stated that "*circularity is something at the base of the Marche region agriculture, as in the past it was not possible to waste any resource*". What was curious was that one producer (fresh stuffed egg pasta) stated "*I have always done in this way, without calling it circular economy. I simply do what is beneficial for my business in all senses*". The same producer was also the only one not available to try alternative solutions for his waste, as "*I think I am already doing as much as possible for my company. I do not know, and I am not interested in any alternative way to improve what I am already doing*". All the others were enthusiastic in searching for novelties to be brought to their process, even the ones already implementing circular practices. The most discussed topic was the water recovery, particularly for the frozen vegetable and EVOO companies. The frozen vegetables plant is now thinking in investing in modern and high-efficient refrigerators able to recover the wastewaters and use them to freeze the product. Another fundamental aspect was the energy production, considering the current global uncertainty regarding fossil fuel supplies and prices.

Regarding the barriers in implementing the circular economy model, all the interviewees agreed that the public administration and the bureaucracy are a hindrance slowing down the process and

making it more difficult. In this regard, the current legislative framework is not supportive, being unclear and creating even more confusion. Whilst not considering the profitability of a circular system to be limited, five out of six respondents said that at this time operation costs would not be sustainable by their companies. Furthermore, they all agreed that currently there is no monetary support by the regional and national government or, if there is, it is not delivered to all. In addition, trained figures who can guide the transition process are still missing on the job market. Finally, none of the interviewees was able to see how the final consumer could perceive the added value of a circular chain.

Although it is not easy, the respondents identified several opportunities in shaping the regional agri-food with a circular approach. Apart from recovery and valorisation of waste and by-products, leading to added-value creation, they all agreed that the implementation of a CE model would contribute to job creation and diversification of the income, improve the sustainability of the process and widen the market of interest.

The shift from a linear, traditional system to an innovative circular one is not a single man job but requires the effort and collaboration amongst different actors. For this reason, the most important service for all was a networking system, able to make in contact different companies in the agri-food sector favouring the industrial symbiosis, where the waste of one becomes the resource of another and partnerships with company specialised in waste reuse. To facilitate recovery, reuse and redistribution of resources, the implementation of a logistics platform for waste collection and disposal and the creation of an online database for waste quantification and qualification at regional level were considered essential. One of the respondents was particularly steadfast in underling the necessity of training the personnel, as well as exploiting dedicated consultancy with experts, like academics, technician and trade associations. In summary, Table 2 presents the main barriers, opportunities and services emerged from the interviews.

Table 2. Main barriers, opportunities and services for the implementation of CE in the Marche agri-food sector. Source: Authors

Barriers	Opportunities	Services
Public administration and bureaucracy	Recovery and valorisation of waste	Networking
Unclear policy framework	Job creation	Logistic platform for waste collection and disposal
Costs of investment	Income diversification	Online database for waste qualification and quantification
Absence of economic support	Improved sustainability	Training
Absence of trained figures	Creation of new markets	Dedicated consultancy

Last, each interviewee expressed an opinion about the current involvement of the Italian and European governance in promoting the CE model. While two out of the six respondents were not aware of which are the commitments and initiatives in force, the others conveyed a quite cynical consideration on their operate. It was a diffused viewpoint that "*the Italian government and the European Union are somehow promoting the shift to the circular economy. However, for now, everything seems so vague. I am not able to see any concrete action in doing so. Probably, they should spend less money in advertising it and try to invest in something real*" and "*We, as companies, are really guiding the transition. If we want something to be done, maybe it is better to do it by ourselves*".

5. Discussion

The results of our analysis confirmed that, as for most of the regional entrepreneurial fabric, also the agri-food is characterised by the presence of SMEs, with a limited number of employees and a turnover of less than 5 million euros. The only exception of the analysis is represented by the company producing frozen vegetables, which is one of the excellence business realities in the region. For such small companies, particularly after the Covid-19 pandemic, it is essential to find innovative solutions to overcome crisis moments and become resilient on the globalised market. The implementation of a circular economy model could open tangible economic opportunities, improve raw materials supply to industry by recovering the waste, create jobs and bring on the transition for a green technologies sector.

As can be seen by the data in Table 1, the quantity of by-products measured within the analysis is in line with previous studies [16,60–63]. When processing raw materials to obtain final food products, a certain amount of waste and by-products is inevitable. As the waste hierarchy imposes that, when possible, waste should always be prevented, in the industrial processing the attention should be focused on limit and reduce, whenever possible, the discarded quantities and to find a viable solution to manage the waste in a sustainable manner. However, food business operators should be informed of which are the possibilities to reuse the by-products, according to their quantity, quality and origin, from remanufacturing them to donation for charity [64]. All the respondents are aware that every kilogram of waste produced is a loss in terms of productivity and profitability. Up to now, the solutions taken had to be a way to get rid of the waste without any additional cost [55]. In this sense, energy production represents a winning solution, also with the support of the European and Italian policies (Renewable Energy Directive and Italian Ministerial Decrees). But, considering the recent sustainability strategies and the need to change our productive system, entrepreneurs are becoming convinced that investing in synergies and technologies for the recovery of by-products can actually represent an added value. The waste hierarchy considers energy production as one of the least favourite options, just before landfilling [17]. However, the current geo-political situation, climate change and the necessity to shift to renewable and sustainable energy sources define the urgent need for steadily available biomass in large quantities. As more than one third of the food produced globally is wasted [65], the feedstock for bioenergy and biofuel is available in sufficient quantity. Seasonality may represent one of the main hurdles to overcome for products like vegetables, olive oil and wine, where the production campaign is limited to a specific timeframe of the year. That obstacle poses the entrepreneurs into the advantageous position to create long-lasting relationships with other actors from different supply chain [66]. These symbiosis and cooperation are at the base of a successful circular model [67]. In a small production reality, like that of the Marche region, the solitary entrepreneurial mentality must be overcome. The Covid-19 pandemic has presented new challenges of a social and economic nature. There is a need to create a system that is more resilient, green, digital and versatile, to adapt even to unexpected situations [68]. Collaboration between industries would represent a win-win situation [69]. In this regard, the creation of a regional database for the qualification and quantification of agri-food by-products and waste would be of great support. The platform would foster not only the exchange of material, but also alternative business ideas that encourage and promote the spread of the circular model. From the interviews, it emerged that companies increasingly require support that does not make them feel alone in their action of renewal, facilitating a process that, although theoretically simple, seems for now insurmountable.

Agribusiness entrepreneurs should be aware that there are other solutions to valorise waste and

by-products [40,70]. When considering the alternatives, the feasibility of the project at industrial scale is a primary concern. Innovative use of by-products must be tested on a small scale, but to be successful they should be carried out methodically on a pilot scale, evaluating the techno-economic feasibility for the market's demand [71].

From the definitions provided by the interviewees it resulted that, even if they found difficulties into explaining their idea of the model, they are conscious of what they want from CE and the word cloud highlights that the concept is within their words. They are confident that CE could be the future to ensure a fair and sustainable sector. Nonetheless, the highlighted barriers confirm that still a lot shall be done, particularly for the institutional, technical and economic sides. The administrative system is not currently prepared to face the challenges of the transition, having to rely on a fragmented regulatory framework often hindering the recovery and valorisation of by-products. For SMEs one key barrier was found to be the lack of technical knowledge and skills, limiting the implementation and adoption of new practices and innovative circular business models. The financial barriers should not be underestimated, considering the costs of shifting from the linear, traditional, well-established way of doing business to something that is theoretically simple but far from being practically spread, especially for SMEs [72–74]. The regional government, supported by the Italian and European authorities, should focus mainly on these aspects to favour the diffusion and application of CE in the agri-food sector. A strong position towards regional policies to facilitate the reuse of by-products, the organisation of courses and workshops for the workers at all levels (from manual labourers to managers) and the award, with economic support, to all those forward-looking and pioneering entrepreneurs are amongst the initiatives that could boost the interest of the companies. For a business, sustainability has always been determined solely by the economic aspect. It is for the government to encourage a mentality shift, where an activity can be sustainable in all the three dimensions, economically, environmentally and socially. In this context, circular economy seems to be a promising positive contribute, because waste recovery could bring cost saving and creation of new market, which provide additional economic and social benefits in terms of job creation, welfare and living standards. In addition, the transition towards CE approaches is a strategic way to ensure environmental protection by eliminating agri-food losses and waste, reducing greenhouse gas emissions and preserving the ecosystem [24,74–76]. Acting like this is also a way to show entrepreneurs that the public authorities are proposing tangible solutions and actions to cancel the misleading perception of proposing a lot but doing nothing, sensed during the interviews.

The interviewed SMEs were also able to catch prospects from the challenges. Recovering the waste represents an opportunity: even though CE requires additional costs at the beginning, it is seen not only as an economic investment, but in general as an investment in the future of the company, for a sustainable development for future generations. CE will be beneficial for the market, fostering the utilisation of the so-called secondary raw materials and so reducing the price of the virgin, non-renewable ones. But circular economy is not just waste recovery, it is a holistic approach that entails all the aspects of the production, such as water reuse and saving, lower emissions and energy dispersions, consumer engagement and information, fostering a whole new sustainable system. CE implies a complex vision of sustainable development that should include all the actors of the supply chain, the society and politics, maximising the ethical and economic value [77–79]. Research institutes, like universities, represent a need and a chance for companies to build solid linkages helping and guiding them in the transition.

6. Conclusions

This paper presented a questionnaire survey to investigate the production of by-products and waste in the production phase of selected agri-food supply chains and the approach of entrepreneurs and experts towards the circular economy by identifying barriers, opportunities and services for the implementation of the model in the Marche region. Our findings suggest that CE finds great interest in the regional context under study. The precise quantification of food by-products and waste represents the first essential preliminary step towards circular economy. The mass balance allowed to understand the extend of by-products generation in the production process, by collecting quantitative and qualitative primary data about inputs and outputs of each considered supply chain. The availability of more precise, detailed and consistent data allows managers to achieve greater efficiency in the production process, leading to reduced utilisation of natural resources.

This work, born from the collaboration with the Marche region in a project dedicated to the diffusion of the circular economy model in the agri-food sector, could be useful for policy makers to understand which are the hurdles that agribusiness entrepreneurs shall face in this economic transition. Furthermore, respondents were explicit into asking for specific services to face the challenges of the modern markets. This study could serve as a base to highlight to entrepreneurs the importance of having a consistent system to measure the quantity of wasted resources to improve the sustainability of their productions. To develop innovative circular business models, managers and technicians should be aware of the possible solutions which can be adopted to recover and valorise their waste. In a context like the one of the Marche, characterised by the presence of SMEs often family-run, it is important to overcome the perplexities and resistances of a managerial conservatism. The results of this study could be useful to better plan and improve the waste management in the agri-food sector and contribute to introduce ad hoc policies to support the economic transition. In detail, policies should consider the diversities of the different characteristics of the supply chains (fruit and vegetables, wine, olive oil, etc.), while considering the possible solutions to valorise the by-products (energy production, functional food, animal feed, etc.) in a sustainable way.

The study has some limitations. First, the number of case studies examined is limited. In the future, it would be desirable to consider more supply chains not included in this analysis and other regional context to have a complete picture of the agri-food sector in the Marche region and make the study more generalisable with results from other Italian territories.

Furthermore, we did not include secondary data coming from reports or databases. A triangulation of multiple data sources would improve the reliability of the findings using different samples from multiple data sources.

Moreover, despite being present as data, the analysis did not focus on packaging and wastewater. The recovery of materials such as plastic, paper and glass is essential in a circular economy perspective. An emblematic case is represented by jute sacks for the delivery of coffee. They are entirely disposed of as waste. However, they could be valued in alternative ways, such as handcrafting. Wastewater represents a controversial aspect in waste management, as they represent a high valuable, limited source, but pollutant for the environment, so it cannot be treated lightly. Finally, in the mass balance, emissions to air, water and soil were not considered. They are an important parameter for the assessment of the sustainability of a production process. Through a multidisciplinary approach, it would be interesting to understand which and how many substances are emitted and to hypothesise solutions for their reduction or compensation.

Another important aspect is the consumer. Circular economy is a model of production and consumption and it could not be effectively implemented if the consumer is not ready to be involved in this process. Further studies should investigate the consumer perception of circular economy, as well as the propensity to buy and pay for a product obtained with food by-products. As respondent were not able to estimate the perceived added value of a circular model for the consumers, it would be of great benefit to assess if they are ready to become part of the renewal. In this sense, the companies, with the support of the regional government, could guide them into the transition without waiting for things to happen, becoming the drivers of the change. The consumer could be engaged in the circular process without be directly involved in the industrial process of food transformation. The collaboration between companies and the regional government may promote initiatives and workshops to spread the circular thinking, starting from the new generations in schools, fostering the sustainable economic transition.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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