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Circular economy practices in the agri-food sector: an exploratory survey regarding Portuguese companies

Federica Scandurra[1,5], Roberta Salomone[1], Sandra Caeiro[2,3] and Ana Pinto de Moura[4]

[1] Department of Economics, University of Messina, Italy
[2] Center for Global Studies, Department of Science and Technology, Universidade Aberta, Lisbon, Portugal
[3] CENSE - Center for Environmental and Sustainability Research & CHANGE - Global Change and Sustainability Institute, NOVA School of Science and Technology, NOVA University of Lisbon, Lisbon, Portugal
[4] GreenUPorto—Sustainable Agrifood Production Research Centre/INOV4Agro, Department of Science and Technology, Universidade Aberta, Porto, Portugal

[5] federica.scandurra@unime.it

Abstract.

The circular economy is a paradigm able to reconnect the food system to the ecosystem, generating closed loops of inputs and resources. The agri-food sector has followed an intensive production and consumption model but now urges a change in roots to ensure sufficient resources for present and future generations.

However, the application and evaluation of CE in companies in the agri-food sector remain underexplored, but it is still a crucial step in pushing the sector's transition. Moreover, circularity is a huge opportunity for companies to increase their efficiency and competitiveness while respecting ecosystem boundaries. In this sense, Portugal represents an interesting context for exploring the potential of circularity, given the centrality of the agri-food sector in the country's economy and the interest shown in the topic, evidenced by several projects and initiatives launched to promote circularity in the sector. For this reason, this study aims to explore how circularity has been adopted and evaluated in the Portuguese agri-food sector. To this end, an online survey of a sample of Portuguese agri-food companies already involved in circularity was conducted from January to March 2023.

Considering a final sample of 31 companies, results indicate that: i) company size and the respondent's department have an impact on the level of detail of responses; ii) practices are largely associated with incrementally innovative (77 %), technological (50 %) or socio-organizational (37.5 %); iii) most evaluating companies adopt specific indicators (56 %), while a significant proportion does not evaluate circularity but already adopt evaluation tools related to CE.

The study aims to identify circular best practices for the industry to guide practitioners toward adopting circularity and offer insights for future academic contributions. This article aims to restore the sustainability of the food system and prevent food loss and waste along the food chain, in line with Sustainable Development Goals 2.4 and 12.3.

1. Introduction

The circular economy (CE) represents a promising paradigm for achieving sustainability in the agri-food sector (AFS) (Zhang et al., 2022), as the food system plays a central role in society because of its direct and indirect impact on human life. Whereby AFS is meant the system that "*…covers the journey of food (e.g., cereals, vegetables, fish, fruits, and livestock) from farm to table including when it is grown, harvested, processed, packaged, transported, distributed, traded, bought, prepared, eaten and disposed of. It also encompasses non-food products (e.g., forestry, animal rearing, use of feedstock, biomass to produce biofuels, and fibers) that also constitute livelihoods and all of the people as well as the activities, investments and choices that play a part in getting us these food and agricultural products*" (FAO, 2021, p. 3).

It is responsible for significant greenhouse gas emissions, soil depletion, and water pollution, but at the same time, it generates wealth and employment in rural and urban settings (Kumar et al., 2022).

The sector has traditionally followed a linear model of production and consumption based on the make-use-waste approach, which in the long run has proven unsustainable (De Bernardi et al., 2023). Worldwide, one-third of the food produced gets wasted, while hunger is rising. According to FAO projections, 670 million people will starve in 2030, the same target projected in 2015, before the introduction of the 2030 Agenda (FAO, 2022). The picture will additionally be compromised by the population increase projected for 2050, which will severely affect food loads (Martins, 2020.). The additional demand for food will exacerbate deforestation, reduce biodiversity, and water pollution (Silvestri et al., 2022). In this context, the CE offers a restorative and regenerative pathway for food production and consumption (Zhang et al., 2022). To enable this transition, organizations must integrate circularity into their operations. CE helps agri-food companies to improve process efficiency and increase market competitiveness while respecting the biosphere's limits (Martins, 2020). The potential of circularity in the AFS makes it a strategic tool for agri-food-driven countries.

Thus, interest in CE in the sector has increased in recent years, confirmed by the scientific literature on the subject (Esposito et al., (2020); De Bernardi et al., (2023)). A previous study (Scandurra et al., 2023) assessed the sector's maturity regarding circularity by analyzing case studies reported in the literature. This result stems from the prevalence of conventional practices in the literature, showing how circularity is not new in the food system but rather an element to rediscover. Relevant now is to understand if such maturity is also recognized by the companies of the sector and how they apply and measure circularity in their activities.

No economic sector has a standardized method for measuring the impacts of CE, but this is particularly the case for AFS (Poponi et al., 2022). Indeed, only a few studies in the literature focus on CE measurement in the AFS (e.g., Velasco-Muñoz et al., (2021), Silvestri et al., (2022), Poponi et al., (2022)). Besides identifying measurement tools for the industry, it is also critical to understand if and how companies use them.

In Europe, Portugal offers an attractive context for exploiting such potential. AFS is the backbone of the Portuguese economy. Its Atlantic and Mediterranean climate conditions result in a great variety of products. In particular, crop for 59.5% of the total production (18% of vegetables and horticulture, 20% of fruit and 10% of wine), and animal outputs for 38% (9.6% milk, 7.8% cattle and 7.1% of pigs (fi-compass, 2020) Today, agri-food production is one of the main drivers of the Portuguese manufacturing industry, representing 14.5% of total sales in 2016 (fi-compass, 2020). Agri-food production is mainly for the internal market, but exports are increasing, with the sector contributing 11.8% of Portuguese exports in 2018 (Martins, 2020.) Moreover, is one of the largest employers in Portugal, counting 294,000 workers and 135,000 companies (FIPA, 2019).

Portugal implemented the CE Action Plan in 2017 (Leading the transition: Action Plan for Circular Economy in Portugal 2017-2020) and since then has established several CE projects in the agri-food context. Relevant examples are the "Alentejo Circular" (2016-2018) focused on identifying circular practices in the olive, pork and wine production, excellences products of the Alentejo region, or the "REiNOVA Si" (2019-2021), a cross-border project that involved Portugal and Spain in mapping circular best practices among SMEs of the AFS or the CERTAGRI project (2018-2019), for introducing circular labels in agri-food products.
For this reason, the present study carried out an empirical analysis, exploring how CE is implemented and measured in a convenient sample of Portuguese agri-food companies.
This study presents the preliminary results of a more in-depth analysis involving semi-structured interviews with some sample companies. One part of the survey analysis, aimed at determining the main characteristics of the companies, the identification of practices and their evaluation, is described here. The complete study analysis will follow in future publications.

2. Methodology

The study relies on an online survey, designed with Microsoft Forms. The survey was delivered with email invitations and open from 26 January until 13 March 2023. It was written in English and then translated into Portuguese and tested by the research teams.
The survey was based on closed and open-end questions and articulated in:

- Section A, General information. The section enables to collect information regarding companies' localization, size, supply chain type and stage and the respondent's department into the company (5 multiple choice questions, of which 4 single and 1 multi select, and 1 classical open text question).
- Section B, Circular practices classification and assessment. The section identifies and evaluates the CE practices and processes in terms of the level of circularity, analyzed through the 4 R framework, that connects CE' principles to reduction, reuse, recycling, or recovering approaches; and the level and nature of innovativeness, as suggested in Scandurra et al.(2023), as well as the assessment of circularity and the tools/methods adopted (8 multiple choice questions, of which 5 single and 3 multi select, and 3 classical open text questions questions).

Data were exported and analyzed on Microsoft Excel. In this analysis, frequency tables, different graphical representations were used.
The study adopts a convenient sampling methodology to identify Portuguese Agri-food companies related to CE. This methodology makes it possible to include in the sample only those companies that meet the objective of the study, without considering the entire potential target population (Saunders et al. 2012). This enables the inclusion of private companies operating in the AFS: i) part of the Portugal Foods (https://www.portugalfoods.org/en/), a private nonprofit association that brings together various stakeholders in the Portuguese AFS, from companies to entities in the scientific ecosystem, ii) engaged in the circular Alentejo project (https://alentejocircular.uevora.pt/), a project developed in partnership between the Istituto Soldatura e Qualidade (ISQ) and the University of Évora, to raise awareness and mobilize economic actors in olive oil, wine and pig production in the Alentejo region (Portugal) to adopt the CE paradigm, promoting interest and awareness on the issue. The final sample consisted of 148 companies to be contacted.

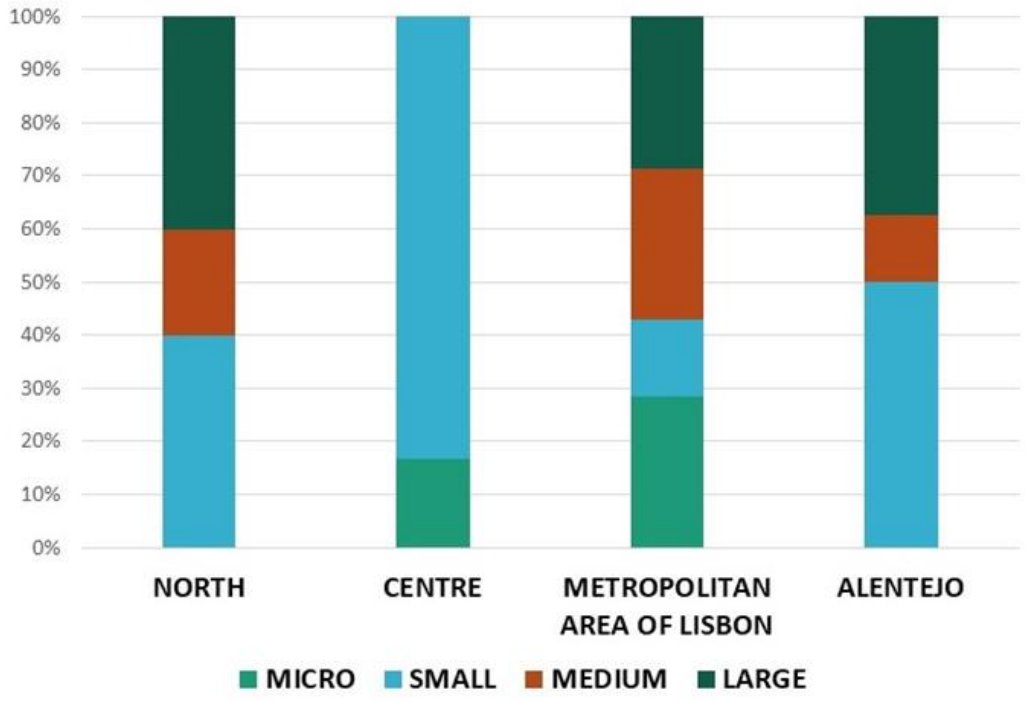
3. Results and Discussion

3.1. Sample characterization

From the survey task, 31 answers were obtained, with a response rate of 20%. According to the Portuguese official geographic localization (NUTS II), the responding companies were localized in northern Portugal (32%), Alentejo (26%), Centre (19%), and the Lisbon metropolitan area (23%). Companies were also classified according to the number of employees, as suggested by Eurostat: small and medium-sized enterprises (SMEs) (10-249 employees) account for 61% of our sample,

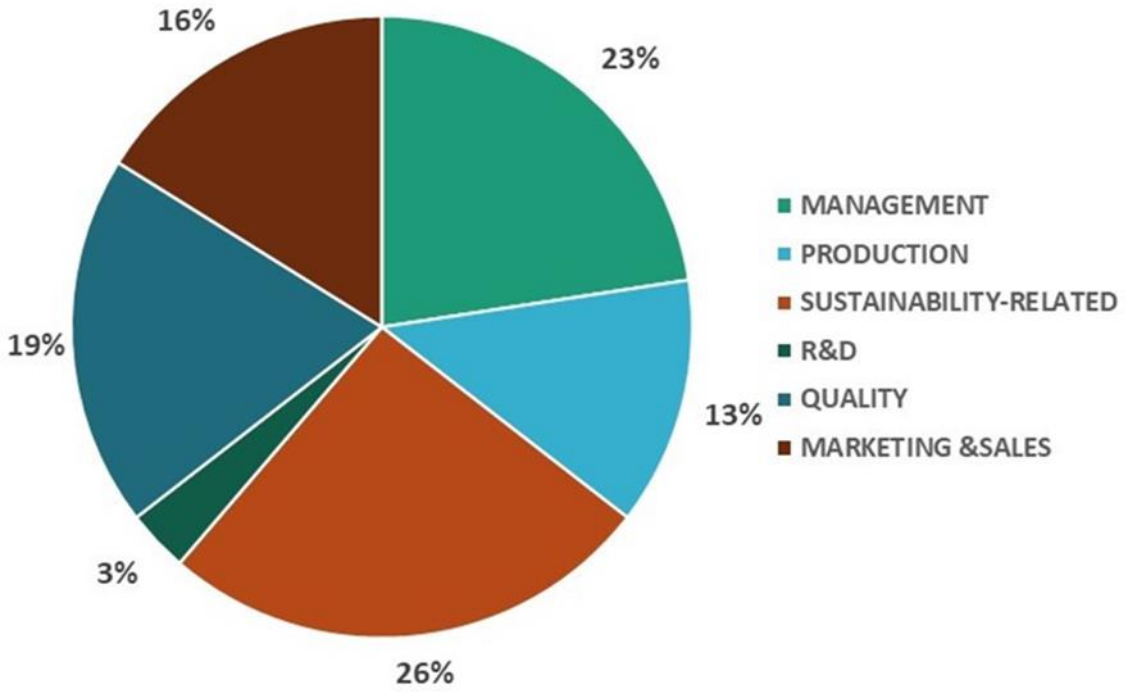
microenterprises (1-9 employees) characterize 10% of the sample, and large enterprises (250+ employees), corresponding 29% of our sample (Figure 1).

Figure 1. Companies of the sample classified per size and location (n=31).



Regarding the food supply chain companies' positions, around 75% of them are linked to processed food supply chains (e.g., olive oil and cheese), 19% to fresh food supply chains (e.g., almonds or meat), and 6% to processed foods used as raw materials for other production (e.g., plant extracts). As evidenced by figure 2, the survey gathered information from different departments: 26% of respondents work in sustainability-related departments, 23% in management, 19% in quality, 16% in marketing and sales, 13% in production, and 3% in research and development (R&D) departments.

Figure 2. Survey respondents classified according to corporate department (n=31).



3.2. CE adoption

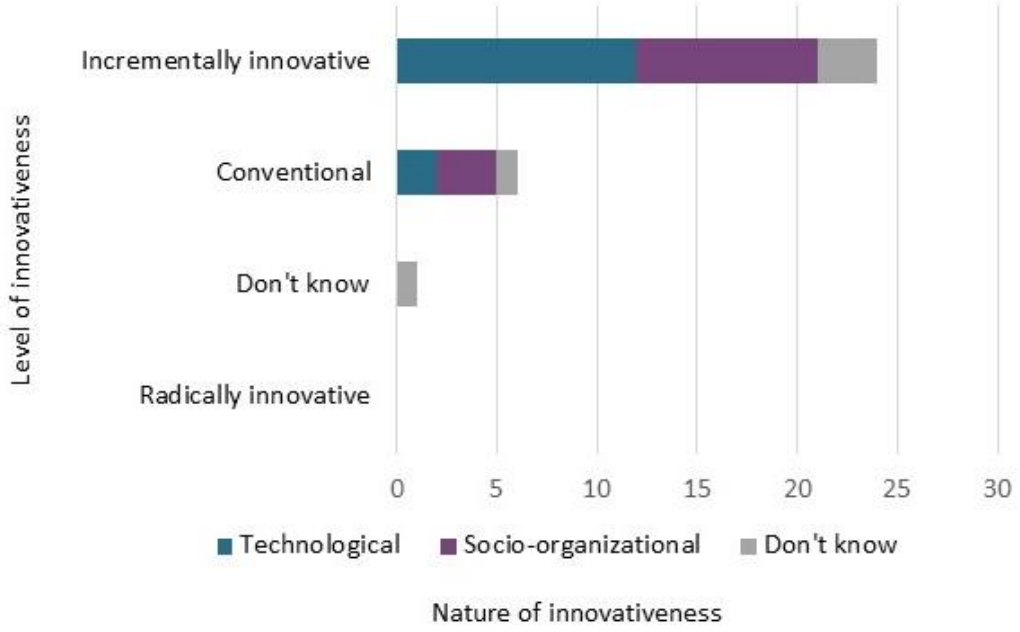
Results shows that circularity has been implemented by almost the entire sample (90%), although a residual fraction expressed interest in introducing it soon (10%). However, considering the stage of transition of the companies, namely their level of adoption of CE' principles, most companies have partially implemented circularity (77%), while only a limited fraction (10%) claim to have fully adopted CE in their activities.

Out of the description of circular practices implemented by the 31 companies it was possible to identify 54 practices. The level of detail provided, permitted the indication of 28 practices on their specific objective, while the remaining 26, which presented a general information, on their generic aim. Note that the number of practices does not correspond to the number of companies, as respondents may describe more than one practice.

Then, respondents had to define the company's practices implemented in terms of innovation. As shown in figure 3, 77% of the respondents identified their practices as incrementally innovative (e.g., nitrogen fixation by rhizobia leguminous plants), where 50% directed towards technological improvement, 37.5% towards socio-organizational improvement whilst remaining 12.5% were unable to determine this. Conventional practices (e.g., compost production) characterize 19% of the holdings, with greater emphasis on socio-organizational improvements (50%). 4% of the companies were unable to determine the level of innovativeness of their practices. Finally, none of the companies identified their practices as radically innovative.

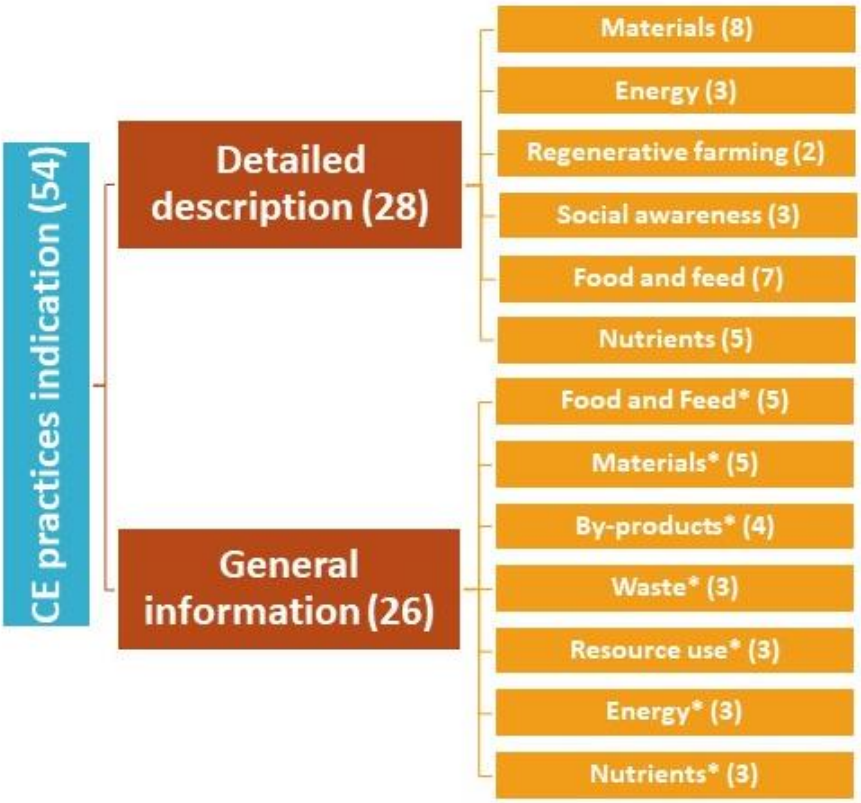
The level of circularity was measured from the 4 R framework: companies usually associate their activities with more than one R strategy, most relevant is the portion that associates all the Rs with its practices (23%). Considering the single Rs, the most common are re-use strategies, while the less present is reducing strategies. Nevertheless, overall reducing and re-using strategies are higher than recycling and recovering ones, determining the relatively high circularity of the companies' activities. Relating the R strategies to the level of innovativeness, both conventional and incrementally innovative practices adopt each of the 4Rs, with incrementally innovative ones more present for each strategy due to their high frequency.

Figure 3. Level and nature of the innovativeness of the company activities (n=31).



As pointed out by figure 4, the 28 detailed practices are oriented towards the production of materials for 29%, particularly in terms of packaging (e.g., improving eco-design by combining materials that are easy to separate or recycle together, or recycling plastic packaging in the company's facilities to be incorporated into the new plastic consumed internally). 25% to the production of food and feed, in particular, to the production of food for humans (e.g., donations or the use of cheese by-products to produce butter and cream cheese). 18% is directed towards nutrient generation, especially for fertilizer production (e.g., composting, leaving pruning in organic matter or self-fertilization of pastures). In addition, 11% of practices are targeted at improving the social awareness of stakeholders (e.g., training and monitoring of farmers' adoption of sustainability-related principles and techniques or the installation of storage sites for beverage packaging to increase recycling readiness). Energy production accounts for 11% of the sub-sample (e.g., the use of olive pits to heat boilers or steam condensed from boilers to heat cleaning water). Finally, regenerative farming techniques (e.g., free grazing of livestock) account for 7% of the practices. Of the 26 with only a general indication, 19% are directed towards obtaining food and feed by using by-products or surpluses from food production (e.g., fish and liquors). Another 19% use waste to generate or reduce materials. Around 15% of the companies surveyed aim to valorize by-products from processed products (e.g., olive oil and wine). Finally, the remaining 44% are focused on energy production, optimizing the use of resources (e.g., water), generating or rationalizing nutrients (e.g., reducing fertilizer use) and valorising various types of waste (e.g., recycling).

Figure 4. Circular practices classification per level of description and goal. In parentheses the number of practices per specific goal.



Where (*) indicates the generic aim of the practice for those that report only general information.
In parentheses the number of practices per individual category.

The strong presence of incremental practices seems at odds with Scandurra et al. (2023), who previously assessed the sector's maturity, given the significant number of conventional practices in the case studies presented in the literature. However, this divergence may be related to different perceptions of innovation among practitioners. In addition, the practice's indication allowed to identify some practices defined incrementally innovative but that are established techniques in the literature and therefore, should be classified as conventional (e.g., pruning as natural soil fertilizer, whey's valorization by reverse osmosis, or olive stones' use to heat boilers). To consider is also the role of the respondents within the company; for example, regarding the three mismatches mentioned above, the respondents belonged to the marketing and sales, management, and quality departments, thus not directly related to sustainability or CE, and this may affect their knowledge of the consistency of internal practices with circularity. Furthermore, some companies mentioned practices without an explicit link to circularity, especially concerning power generation through solar panels. Again, it is important to analyze this with the roles of the respondents; out of 5 companies that mentioned solar panels as their only or combined practice, 40% came from production, 20% from marketing, 20% from management and the last 20% from the quality department. The presence of many non-detailed practices is also relevant; when analyzing the origin of the respondents, 54% of the general practices are related to respondents from non-CE-related departments (e.g., production, marketing and sales, or quality), so it may have influenced the ranking process. This is also related to the size of the companies, given that only large companies (in the sample) have a department dedicated to sustainability-related topics. Thus, the presence of work teams on sustainability and environmental issues promotes a better understanding of CE and its principles.

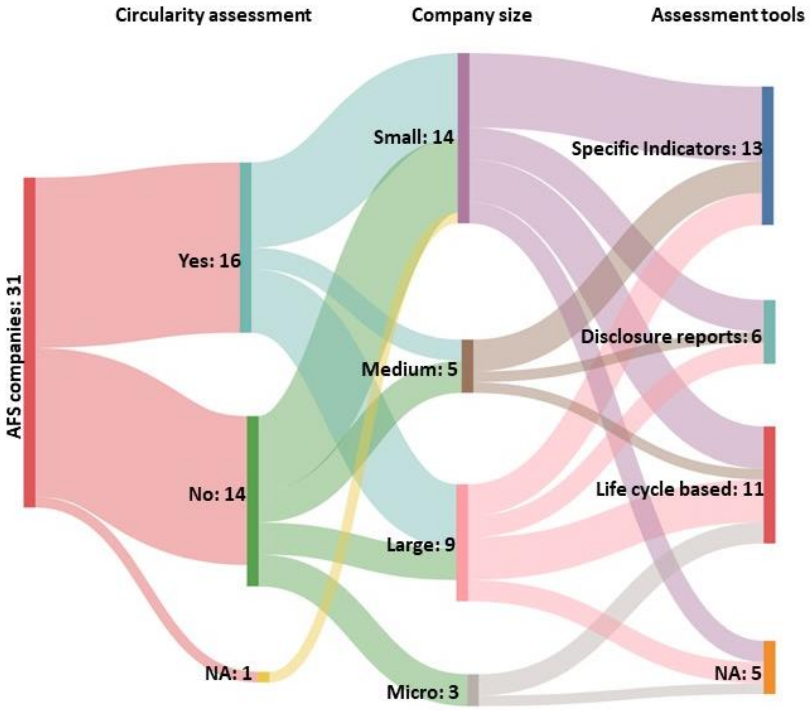
3.3. CE ASSESSMENT

The survey results showed that 52% of companies either fully or partially value circularity, 45% do not, and 3% do not know. In particular, about 67% of large companies and 58% of SMEs assess circularity, but none of the micro-enterprises. Note that the 31 companies in the sample reported 35 assessment tools since some companies adopt more than one tool in assessing circularity. Among the 16 evaluating companies, 55% adopt specific indicators, 25% life-cycle-based tools and 20% disclosure or communication reports (Figure 5).

Companies were also able to leave comments on their assessment of the CE. Notably, out of 11 associated with specific indicators, 64% did not explain the indicators used, while the remaining reported using indicators to monitor process efficiency, waste recovery, soil organic matter or CO_2 emissions. Considering the 5 Life cycle-based tools, two companies reported using carbon footprint analysis, one used Life-cycle assessment, and the remaining two gave no detailed answers. Among the disclosure reports, two companies indicated the sustainability report, one according to the Global Reporting Initiatives (GRI) standards, while the other two mention specific disclosure reports based on water and energy consumption, not specifying if for internal or external communication.

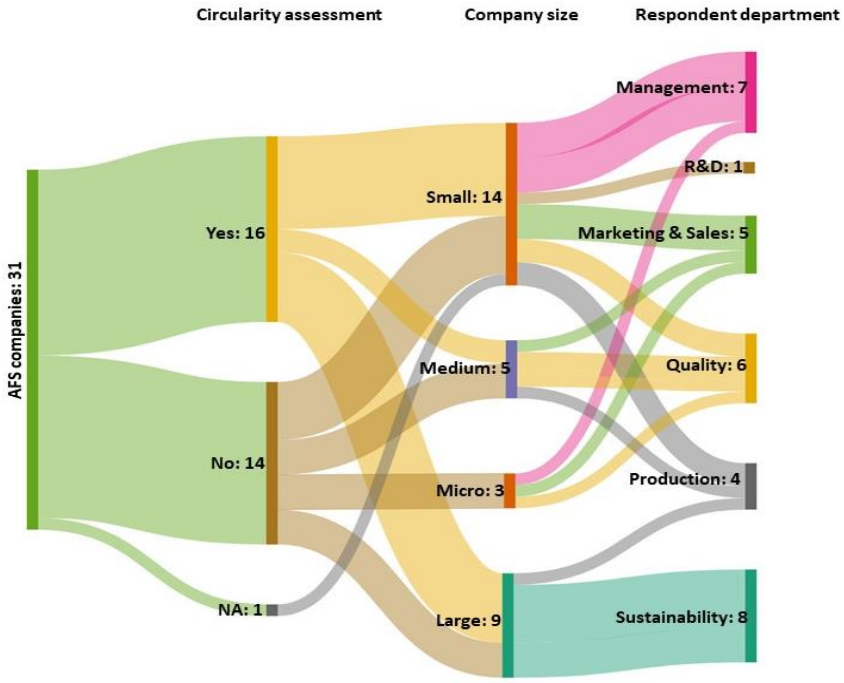
Interestingly, some companies that declare not assessing circularity have already adopted some of the proposed tools. Of the 14 that do not assess circularity, 67% adopt lifecycle-based tools, 22% specific indicators, and 11% disclosure reports; finally, the company that has no measurement information states that it submits a disclosure report; none of the companies mentioned added further details to their answers.

Figure 5. Circularity assessment related to company size and tools adoption (n= 31).



Hence, this suggests that companies have interpreted the question in a broader sense, so they adopted the proposed tools but have not yet measured circularity or that they have not a clear idea of circularity assessment tools. Linking the non-assessing companies to the responding departments, we found that only 21% of the respondents work in departments related to sustainability, with the remainder split between management (28%), marketing and sales (14%) and quality (14%). This figure is also related to company size, as 57% of the non-assessing companies are SMEs, 21% are micro companies, and 21% are large companies (Figure 6).

Figure 6. Assessment of circularity per size of the company and department of the respondent (n= 31).



4. Conclusion

The CE can be the turning point for the exploitation of food flows. The mapping of circular practices is of particular importance for AFS. The lack of standardized valorization schemes hampers the possibility of identifying strategies for the reusing or recycling of food products and residues. In addition, the classification process allows for raising awareness of circularity and its principles since, as evidenced by some practices that are not strictly circular but identified as such in the sample, there is still confusion in the sector. This concerns micro and small enterprises that do not have a sustainability department and yet are most of the Portuguese AFS companies. Therefore, the systematization of the collection practices allows operators to understand better the characteristics of the CE and to be able to replicate its example. The same goes for the innovativeness and the level of circularity assessed in the sample, as possible biases could be related to different visions between companies and academia. Most of the assessing companies adopt performance indicators covering a wide range of objectives, so there is no clear pattern for such indicators. In addition, a significant portion of the companies state that they do not measure circularity, but already adopt some circularity assessment tools. This may be due to a lack of knowledge of the available circularity assessment tools, as companies are just beginning to introduce circularity into their operations. Therefore, identifying industry-focused assessment tools is a crucial step to guiding companies towards efficient and cost-effective practices and communicating the value of their strategies to stakeholders. The study has some limitations related to the sample size; however, it presents a representative picture of the adoption and measurement of CE in Portuguese AFS companies. The critical issues evidenced in the survey analysis will be further investigated through interviews with some companies of the sample.

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