

The role of circular economy in the decarbonization of the agrifood sector in Portugal

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Introduction

The agrifood sector in Portugal plays a vital role in the nation's economy but is also a significant contributor to greenhouse gas (GHG) emissions. The contribution of the food and beverage industry to GHG emissions represents 11% of total emissions from the manufacturing industry, and around 2% of total national GHG emissions. As global environmental concerns intensify, the decarbonization of this sector is essential to meet both national and international climate targets. Circular economy (CE) principles offer a transformative approach to reducing emissions by rethinking resource use, minimizing waste, and enhancing sustainability throughout the agrifood value chain. In Portugal, the integration of CE strategies in agriculture and food production presents an opportunity to not only reduce carbon footprints but also promote economic resilience, resource efficiency, and food security.

Objectives

This work is part of the "Roadmap for Decarbonization of the Agri-Food Sector" project, which aims to create a document that supports the sector's transition to a carbon-neutral and circular economy. This section of the roadmap focuses on characterizing the agrifood sector's landscape, specifically in terms of transforming raw materials into products, by-products, and residues, with an emphasis on the dairy, meat, and fruit/vegetable processing industries. Current practices related to the valorization of by-products were evaluated, and suggestions for improvement were provided to the companies.

Methodologies

An online questionnaire was developed and distributed to agrifood companies via innovation company clusters that are part of the project consortium. Simultaneously, several companies were visited, where semi-structured interviews were conducted. Whenever possible, companies also provided their integrated waste registry maps. In both the online and in-person data collection, information on raw material consumption and the generation of products and by-products was gathered.

Main findings

In the dairy industry, 41% of the surveyed companies primarily produce cheese, with other products including milk, milk powder, and butter. The production capacities of these companies vary significantly, ranging from less than 1,000 tonnes per year to over 40,000 tonnes per year. On average, 67% of raw materials in this sector are transformed into products, while the remainder becomes by-products and residues. Waste and by-product generation is mostly continuous throughout the year, with milk whey—mainly from cheese production—being the primary by-product. Larger companies tend to dry whey and sell it for human consumption, while smaller companies often forward it to animal feed without further processing. Other by-products include buttermilk and second cheese whey. The most reported waste products are sludges, followed by packaging materials such as plastic and cardboard. By-products like animal feed are the most common destination, though some whey, sludges, and urban waste still end up in landfills. Organic by-products and sludges are sometimes used for composting. In terms of packaging, companies equally report using tetra-pak, cardboard, and plastic (30% each), with 75% incorporating recycled material into their packaging. Additionally, 60% of surveyed companies have plans to reduce waste by 2030, focusing on valorising waste, improving packaging, and donating by-products and products nearing expiration.

In the meat industry, 43% of surveyed companies produce fresh meat, while other products include animal feed meals, meat preparations, and aged meat. The survey included both large companies (producing over 100,000 tonnes annually) and small companies (producing less than 300 tonnes), with an even 50/50 distribution. This sector shows a lower average raw material utilization, with only 34% converted into products. Category III by-products, such as animal skin, bones, non-bovine blood, fat, and other non-commercially used parts, were reported by 80% of companies, while 20% reported Category II by-products, which include digestive content and parts with medicine traces. Packaging is identified as the most waste-intensive phase, with 43% of companies reporting plastic as the main waste material. Around 25% of companies send waste to landfills, though most packaging waste is recycled. One company internally valorises by-products directing waste from

poultry production towards animal feed production. Waste production in this sector is continuous, and all companies plan to reduce it by 2030 through by-product valorisation and minimizing packaging waste. All companies use plastic for packaging, with 25-50% made from recycled materials.

In the fruit and vegetable processing sector, a broad range of product categories was reported, including aromas, concentrates, sauces, seasonings, olive oil, jams, fresh and dried fruits, and plant-based drinks. While 62% of the surveyed companies are small businesses with annual production below 6,000 tonnes, 25% have production levels between 6,000 and 30,000 tonnes, and 13% exceed 30,000 tonnes annually. This sector has the highest transformation rate, with an average of 92% of raw materials being converted into products, as many companies use by-products for the production of seasonings or jams, maximizing their valorisation. By-products reported include fruit and vegetable peels (29%), non-compliant produce (36%), and seeds and pits (14%). Waste production mostly consists of sludges, plastic, cardboard, and other packaging materials. Companies generally reuse by-products within their operations, though organic materials that cannot be reused are typically sent for animal feed or composting. One company reported sending non-consumable produce to landfills. Packaging materials are processed for recycling, and while 60% of companies use plastic for packaging, less than 25% of this is recycled plastic. Waste production in this sector is largely seasonal, peaking in October and November. Half of the surveyed companies have waste reduction plans for 2030, focusing on new product lines from by-products, packaging improvements, and biogas production from waste.

Improvement suggestions

In this work, we propose several measures to promote circular economy within the decarbonization roadmap, which could be applied to several companies. These include:

- Maximize the use of all parts of the food, transforming by-products into new products or ingredients, for example, for feed, fertilizers, biofuels or extraction of bioactive compounds;
- Use biodegradable or recyclable packaging, as well as optimize it to reduce volume and weight;
- Reduce the use of materials in packaging and products, favouring their durability and recycling;
- Implement water use reduction and efficiency technologies, such as water recirculation in cooling and washing systems, in addition to optimizing slaughter and processing processes;

- Monitor and record all water expenses (taking advantage, if possible, of digitalization technologies to identify critical points for potential improvements and reduction of water resource consumption);
- Optimize production processes to consume less raw materials;
- Establish partnerships with suppliers that adopt sustainable practices and reuse waste, creating a closed cycle;
- Establish partnerships with companies that extract bioactive compounds from by-products.

Significance of this study

This study holds significant importance as it provides a comprehensive assessment of waste generation, by-product valorisation, and resource efficiency in key sectors of Portugal's agrifood industry, including dairy, meat, and fruit/vegetable processing. By identifying the raw material utilization rates, the study highlights areas where sustainability practices are either lacking or could be improved, such as in the dairy sector's whey processing or the meat industry's high packaging waste. The findings underscore the need for a shift towards circular economy principles to enhance decarbonization efforts across the sector.

Crucially, the study goes beyond assessment by offering practical improvement suggestions tailored to each company. These recommendations, which were forwarded to the surveyed companies, focus on optimizing by-product valorisation, reducing waste, improving packaging materials, and enhancing sustainability practices. By supporting businesses in adopting more efficient, environmentally friendly processes, the study contributes to the sector's transition toward a carbon-neutral and circular economy, positioning it to better meet future sustainability targets.