Packaging shelf-life and potential food waste can influence the environmental impact of food products: the case of red beef

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Food packaging has been seen for a long time as an additional environmental cost within a packaged food life cycle. Packaging manufacturing and waste are widely believed to have a significant impact on the overall environmental performance of packaged food items. (Gallucci et al., 2021; Sazdovski et al., 2021). Recent scientific studies, on the other hand, have shown that food packaging has a favorable impact on the overall environmental profile of food packaging systems. This is attributable to the intrinsic qualities of packaging materials and solutions, such as those that might avoid and minimize food waste probability (Verghese et al., 2015; Wikström et al., 2018). For these reasons, packaging effective eco-design is a point of major concern in actual strategies towards environmental sustainability of food-packaging systems (Pauer et al., 2019). A well eco-designed system should balance waste reduction, both in terms of packaging and food, and preservative performance efficiency (Coffigniez et al., 2021; Verghese et al., 2015). Wohner et al. (2019) and Gutierrez et al. (2017) studied the role of shelf-life in reducing potential food waste and, consequently, the overall environmental impacts of the food-packaging system. Numerous food packaging materials, solutions, and systems are currently available on the market and characterized by different material compositions, properties, and characteristics that lead to different expected shelf-lives and eventually different potential food waste reductions (Gogliettino et al., 2020; Sumrin et al., 2021). In this scenario, the search for the best eco-designed solution is hard to achieve.
Among different food categories, animal-based products such as beef meat have a greater scope of improvement in terms of overall environmental impacts thanks to the use of innovative eco-designed packaging systems. This is because their environmental load is generally higher than the one of the packaging itself (Springmann et al., 2018). As a consequence, the potential reduction of beef waste, thanks to an extended shelf-life, ends in an overall improvement of the environmental profile of these food-packaging systems. The Life Cycle Assessment (LCA) approach is frequently used in the packaging industry with the goal of detecting environmental hotspots and identifying more environmentally friendly alternatives through comparative analysis(Molina-Besch et al., 2019; Vendries et al., 2020; Wohner et al., 2019). Even if a great amount of research is currently focusing on the environmental assessment of food-packaging systems, considering both direct and indirect effects of packaging solutions, knowledge and methodological approach gaps still occur. In this context, this study aimed at demonstrating this theory, by proposing an alternative LCA approach evaluating and comparing packaging performances in terms of expected shelf-lives and related potential food waste of beef.
A comparative environmental analysis of three different packaging solutions for sliced beef was carried out through LCA with a "cradle-to-grave" approach for both packaging and beef life cycles. The study compared Modified Atmosphere Packaging (MAP; gas mixture; 8 days of shelf-life) and Vacuum Skin (VS; under vacuum; 21 days of shelf-life) systems as innovative solutions, against

Overwrap packaging system (OW; in air; 2.5 days of shelf-life), identified as the conventional solution. The study was carried out following the requirements of ISO 14040:2021 and ISO 14044:2021 standards. The functional unit was defined as one unit of packaging containing 500 g of sliced beef in relation to the expected shelf life for each packaging system.
To account for the differences in performance given by the three packaging solutions, the study used a technique for evaluating shelf-life ratio and related potential food loss. The performance of the three packaging methods was calculated using the shelf-life ratio (SLR). As a consequence, the worst-case scenario, OW, was deemed to have the highest chance of food waste. Furthermore, literature was used to determine the percentages of food waste at retail (3.90%) and household (14.5%). (Mena et al., 2014; Caldeira et al., 2019). The amount of potential food waste was then determined at both the retail and household level.
Environmental impacts were analysed using SimaPro v 9.1.1.1. (PRé Sustainability, Amersfoort, The Netherlands) software and the database Ecoinvent v 3.6., Agrifootprint 5.0, and World Food LCA Database Version 3.5 and following cut-off allocation criteria.
Considering only the packaging life cycle, the environmental impacts of the three different packaging solutions are highly dependent on their average weights, dimension, and material compositions. From characterization results, the bottom part was identified as the main hotspot with an average responsibility of 59.7% (maximum of 68.4% in MAP and minimum of 46.6% in OW). The second hotspot was represented by the top lid (13.2%, with a maximum value of 19% in OW and a minimum of 3.9% in MAP), followed by packaging disposal (11.1%, with a maximum value of 13.8% in OW and 9.8% in VS and MAP), adsorbent pad (11%) and packaging creation process (5.0%). According to environmental impact results comparison, the OW system showed the best environmental profile mainly due to its lighter mass and composition. However, when the impact of possible food waste was taken into account, the packaging system with the longest shelf life (identified in the VS system) was shown to be the best choice in terms of environmental impact. In contrast to the previous situation, the OW system has the biggest environmental effect in practically every category studied (10 out of 11). The production and the end-of-life scenario of the wasted beef seemed to be the main responsible for the higher environmental impacts if compared to the other steps of the entire food-packaging life cycles. In this regard, the average influence of beef waste on all the impact categories is 76% for MAP, 89% for OW, and 67% for VS system.
As proven by Wikström et al. (2016), the high environmental responsibility of beef underlines the necessity to include food waste as an extra variable when designing packaging solutions in the framework of eco-design. Nevertheless, depending on the type of food product and packaging systems, the major conclusions drawn for this study could not be generally applied to all food-packaging systems (Williams & Wikström, 2010). Future eco-design approaches should consider the potential food waste reduction, as a direct consequence of improved shelf-life along with the environmental profiles of production and disposal of packaging materials. Moreover, harmonization among the scientific community should be reached to consider these aspects in LCA studies for food packaging.

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