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Food losses, shelf life extension and environmental impact of a packaged cheesecake: A life cycle assessment

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ABSTRACT

Packaging is associated with a high environmental impact. This is also the case in the food industry despite packaging being necessary for maintaining food quality, safety assurance and preventing food waste. The aim of the present study was to identify improvements in food packaging solutions able to minimize environmental externalities while maximizing the economic sustainability. To this end, the life cycle assessment (LCA) methodology was applied to evaluate the environmental performance of new packaging solutions. The environmental impact of packaging and food losses and the balance between the two were examined in relation to a cheesecake that is normally packaged in low density polyethylene film and has a limited shelf life due to microbial growth. A shelf life extension was sought via application of the well-established modified atmosphere packaging (MAP) technique. Samples for MAP (N_2/CO_2: 70/30) were placed inside multilayer gas barrier trays, which were then wrapped with a multilayer gas and water barrier film (i.e. AerPack packaging); control batches were packaged in gas barrier recycled polyethylene terephthalate (XrPet) trays and wrapped with a XrPet film. Samples were then stored at 20 °C and inspected at regular intervals for chemical-physical, microbiological and sensory parameters. Results show that the new packaging solution could considerably extend the shelf life of cheesecakes, thereby reducing food waste and decreasing the overall environmental impact. Moreover, the new packaging allows one to minimize transport costs and to generate economies of scale in manufacturing.

1. Introduction

According to the European Commission (2010), food waste in the EU accounts for around 89 million tons of waste per year and, if the current trends persist, this figure is expected to increase to 126 million tons by 2020. In fact, the food/drink manufacturing and retail/wholesale supply chain produces the largest share of EU food waste (58%), followed in second place by household waste (44%). In addition to ethical and economic concerns, food waste has negative consequences on natural resources. In fact, as pointed out by Manfredi, Fantin, Vignali, and Gavara (2015), food waste is socially and ethically unacceptable because of the persistent high number of malnourished people and also because of the number of consequences on the environment such as emissions into air, water and soil in the phases of production and supply chain. Moreover, as noted by WRAP (2009) in the case of the United Kingdom, reducing the considerable amount of household food and drink waste would save households money, while reducing the environmental impact.

Thus, each step of the entire food chain (farmers, food manufacturers, retailers, consumers) has the capacity to play a significant role in preventing and reducing food waste. However, it is worth noticing that most of the loss in retail occurs in relation to baked goods, meat, seafood and ready-to-eat foods due to their high level of perishability (Gunders, 2012). As highlighted by Gunders (2012), several drivers influence in-store retail losses, such as expectations of aesthetic perfection and expired "sell by" or "best before" dates. In fact, market research has shown that many customers select their preferred stores based on the quality of perishable goods; thus retailers are highly motivated to display products of the perfect shape, size, and colour. Furthermore, products are generally discarded just before they reach their sell by or best before dates.

In this context, packaging is well-known to play an active role in preventing food waste by preserving food quality and, in turn, guaranteeing safety, even though it is itself associated with a high environmental impact that may even be higher than that associated with the production/loss of some food products. However, quantifying environmental impact is difficult, also due to differences in local practices regarding waste treatment, thus the available evidence is rather sparse and inconclusive. The Directive 94/62/EC, nevertheless, has imposed to EU countries, targets for the recycling rates of

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packaging waste, but the complex situation where the industry is responsible for an activity that is carried out by local authority poses potential conflicts (Ferreira da Cruz, Ferreira, Cabral, Simoes, & Cunha Marques, 2014). These problems concern the recycling system structure, the account for the cost of managing packaging waste, and the environmental impacts from conservation of raw materials and diversion of waste from landfills (Ferreira da Cruz, Simoes, & Cunha Marques, 2014). WRAP (2011) emphasizes the role of the food industry in food waste prevention that can act by influencing behaviour and facilitating behaviour change through the way the industry packages and presents products to the consumer.

Innovations in packaging could represent a tool for increasing the global sustainability of food production and reducing food loss and waste achieved through extending shelf life – defined as the time span during which the quality of the food product is satisfactory.

The present study aims to contribute to the literature by identifying potential packaging improvements that in addition to extending the product shelf life also minimize environmental externalities and thereby maximize the economic outcome and thus incentivize their application. As far as we are aware, no previous study has analyzed these issues from the perspective of the food industry. A cheesecake was chosen as the food model as it has a short shelf life that is mainly limited by mould growth. This product is normally packaged in cardboard trays wrapped with Low Density Polyethylene (LDPE) film and shows a maximum mould-free shelf life of 1 week. To extend the shelf life, a Modified Atmosphere Packaging (MAP) approach was applied and sensory, textural and other chemical-physical parameters were assessed, being the primary factors affecting the shelf life of a food product. The results will enable decision-makers to understand the performance, economic and environmental trade-offs that need to be made between the alternative packaging systems in order to make the most appropriate packaging choices in a sustainable perspective.

The paper is organized as follows: after this Introduction, a short literature review on the LCA of food packaging and its importance for the limitation of food waste is presented in the Section 2. The description of the methodological approach adopted is provided in the Section 3. Section 4 contains the results and their discussion while concluding remarks are presented in Section 5.

2. LCA of food packaging and its importance for the limitation of food waste

The Life Cycle Assessment (LCA) approach allows one to account for the environmental aspects (European Commission, 2012). This methodology is mainly applied to industrial products and processes, and it is the subject of increasing interest due to for its application in evaluating the environmental impacts of products, processes or activities. Indeed, it is often employed for assessing the equilibrium between technological innovation and environmental protection (Siracusa, Ingrao, Lo Giudice, Mbohwa, & Dalla Rosa, 2014; Manfredi et al., 2015). As far as food packaging and LCA are concerned, a number of studies have applied this methodology over recent years (Williams & Wikström, 2011; Siracusa et al., 2014; Silvenius et al., 2014; Wikström, Williams, Verghese, & Clune, 2014; Manfredi et al., 2015; Zhang, Hortal, Dobon, Bermudez, & Lara-Lledo, 2015). One strand of research analyses the relationship between the environmental impacts of food waste and packaging alternatives. For instance, Williams and Wikström (2011) examined the environmental impact of packaging and food losses and the balance between the two for 5 different food items (cheese, bread, milk, ketchup and beef). Their results show that packaging that reduces food waste can provide an important tool for reducing the total environmental impact; even if the impact associated with the packaging itself is greater than the impact associated with the food loss. As highlighted by the authors, this is particularly relevant in the case of cheese and bread. To investigate these findings further, Wikström et al. (2014) analyzed the consequences of omitting food waste from the LCA of packaging systems. The paper shows the packaging attributes that influence food waste; the goal being to demonstrate how packaging attributes may affect consumer behaviour and food waste, and thus influence the outcome of a LCA study on packaging. Additionally, the authors highlight that a reduction in food waste may often incentivize a packaging format with a higher climate impact. Silvenius et al. (2014) examined the environmental impacts of food waste and how packaging choices can even constitute a factor that causes food waste. The paper presents the results of three LCA case studies of packaged food products (ham, dark bread and yogurt drink) with different assumptions about the packaging sizes and alternative materials. According to their results, packaging solutions that minimize waste generation in households as well as in the distribution and retail processes will minimize the environmental impacts of the entire product-packaging chain.

Furthermore, Manfredi et al. (2015) apply LCA to compare the environmental performance of a traditional packaging system with the performance of packaging coated with an active layer for fresh milk packaged in Tetra Top® beverage containers. The final aim is to study the influence of the packaging on the amount of milk waste. The findings show that there is a reduction in milk waste by employing the second solution and a consequent reduction of environmental impacts due to milk saving. Similarly, with the aim to assess the overall environmental performance of the food and packaging system considering the effect of food loss reduction by using active packaging Zhang et al. (2015) perform a LCA to evaluate an essential oil component-enabled packaging for fresh beef. Their findings show that the active packaging solutions could reduce beef losses at the retail of the EU market.

In a recent study, Conte, Cappelletti, Nicoletti, Russo, and Del Nobile (2015) employed LCA to evaluate a new packaging design concept and their aim was to provide an eco-indicator able to measure the environmental effect of packaging alternatives. Their study focused on an Italian cheese product and considered shelf life and food loss probability. The findings highlighted that in order to minimize environmental implications, it is fundamental that the capacity of packaging to reduce food loss is considered, in addition to the impact of the packaging production and disposal phases.

This thought is in line also with the study of Manfredi et al. (2015) that demonstrates the importance of including food waste in the analysis of packaging systems by employing LCA. As they pointed out, it is a central issue the evaluation of the relationship between packaging design and food waste for the environmental sustainability of packaging solutions. In fact, a preliminary LCA analysis on the food and its shelf life connected with the packaging allows one to assess several aspects of product environmental impacts and has the potential to help evaluations to minimize the food waste.

It is also important to note that from the retailer's point of view, the package should protect the product and deliver it undamaged to the final consumer. Therefore, its role must also be considered from an environmental perspective when comparing different packaging solutions, especially for highly perishable products with a short shelf life. Albrecht et al. (2013) show the preferable environmental performance for three transport packaging systems, but especially indicate the necessary relevance to merging economic and social aspects into a LCA. Merging economic aspects will be one of the study goals. LCA is particularly relevant in this kind of analysis since it involves a simplified procedure that allows one to identify particular characteristics but also key issues associated with a product in order to improve its sustainability. In fact, as reported in Ferreira, Cabral, da Cruz, Simões, and Marques (2016) LCA can serve several purposes that, however, have in common the assessment of the environmental dimension.