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Introducing the Green Protein Footprint method as an understandable measure of the environmental cost of anchovy consumption

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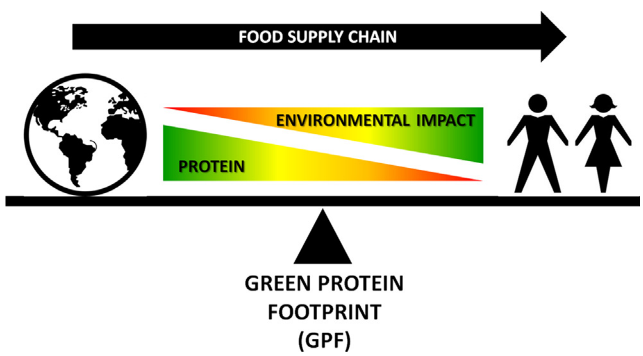
HIGHLIGHTS

- Food with high protein content and low environmental impact is a challenge.
- GPF assesses environmental impact and protein content under an LCA approach.
- The more elaborated food products (canned and salted anchovy), the higher GPF.
- Valorization of food losses in a circular economy framework improves the GPF.
- Packaging is the main hotspot of canned food products; plastic reduces its GPF.

GRAPHICAL ABSTRACT



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ABSTRACT

In a global framework of growing concern for food security and environmental protection, the selection of food products with higher protein content and lower environmental impact is a challenge. To assess the reliability of different strategies along the food supply chain, a measure of food cost through the environmental impact-protein content binomial is necessary. This study proposes a standardized method to calculate the Green Protein Footprint (GPF) index, a method that assesses both the environmental impact of a food product and its protein content provided to consumers. Life Cycle Assessment (LCA) was used to calculate the environmental impact of the selected food products, and a Life Cycle Protein Assessment (LCPA) was performed by accounting for the protein content along the supply chain. Although the GPF can be applied to all food chain products, this paper is focused on European anchovy-based products for indirect human consumption (fishmeal) and for direct human consumption (fresh, salted and canned anchovies). Moreover, the circular economy concept was applied considering the valorization of the anchovy residues generated during the canning process. These residues were used to produce fishmeal, which was employed in bass aquaculture. Hence, humans are finally consuming fish protein from the residues, closing the loop of the original product life cycle. More elaborated, multi-ingredient food products (salted and canned anchovy products), presented higher GPF values due to higher environmental impacts. Furthermore, the increase of food loss throughout their life cycle caused a decrease in the protein content. Regarding salted and canned products, the packaging was the main hotspot. The influence of the packaging

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was evaluated using the GPF, reaffirming that plastic was the best alternative. These results highlighted the importance of improving packaging materials in food products.

1. Introduction

The food system is already contributing to widespread environmental damage and compromising health and livelihoods of the global population (Iribarren et al., 2010a). In fact, of all economic activities, food industry has by far the largest impact on natural resource use as well as on the environment. This sector is responsible for 60% of global terrestrial loss and accounts for around 24% of global greenhouse gas emissions (Westhoek et al., 2016). Moreover, worldwide food waste is enhancing the pressure on the environment and causing a social concern linked to the enormous disparities in terms of food availability and consumption patterns across different countries. While approximately 1.3 billion metric tons of edible food is wasted per year throughout the global food supply chain, around 800 million people around the world are suffering from chronic undernourishment (FAO, 2014b).

Food wastes covers all the life cycle phases: from the sourcing stage, up to industrial manufacturing and processing, retail and household consumption. Nevertheless, the terms food waste (FW) and food loss (FL) have been used to define different types of losses generated along the food supply chain (FSC). FL describes the losses that occur in the production, post-harvest, processing and distribution stages of the FSC, whereas FW accounts the losses at retail and consumer stages (Parfitt et al., 2010). According to the Food and Agriculture Organization of the United Nations (FAO, 2014a), FL is “the amount of food intended for human consumption that, for any reason is not destined to its main purpose” along the FSC, considering FW as part of FL. In this sense, up to 42% of food is wasted in households, 39% losses occur in the manufacturing industry, 14% pertains to the food sector (ready-to-eat food, catering and restaurants), while 5% is lost along the distribution chain (Mirabella et al., 2014). Environmental impacts for the raw materials extraction and processing stages, as well as distribution and retailing, are found to be highly stable. However, consumer patterns are identified as highly variable depending on shopping, storage and cooking methods (Vázquez-Rowe et al., 2013). Regarding product selection, consumers may choose products that provide, for the same amount of protein, substantially different environmental impacts. Moreover, the selection of an adequate cooking method in the household may result in noteworthy environmental reductions (Vázquez-Rowe et al., 2014b).

Several European strategies are dealing to solve food system problems promoting sustainable food production and consumption patterns. From all these policies, the Food and Nutrition Security strategy is highlighted, due to its link with the increasingly interconnected challenges: natural resources scarcity, climate change and population growth; which affect the European and global food systems (European Commission, 2016). Other initiatives, such as the Bioeconomy Strategy for Europe (European Commission, 2012), the Roadmap to Resource Efficient Europe (European Commission, 2011a, 2011b) and the Blue Growth Strategy (Fig. 1) are promoting food waste reduction, the improvement of industrial symbiosis practices, the recovery of waste and by-products (European Commission, 2014), attaining a “zero waste” system based on cradle-to-cradle and circular economy concepts (Zaman, 2015; European Commission, 2015), and the use of sustainable practices for the management and exploitation of aquatic living (European Commission, 2011b). Nevertheless, food waste contributes not only to increasing global environmental pressure, but also involves the loss of the nutritional value (i.e, protein content) along the FSC. In fact, on the one hand, consumers may choose products that provide, for the same amount of protein, substantially different environmental impacts. On the other hand, the selection of an adequate cooking method in the household may result in environmental reductions (Vázquez-Rowe et al., 2014b; Self Nutrition Data, 2014).

Fish and seafood products are widely accepted to be an essential component of a balanced and healthy diet because they have a high “good fat” content and provide high quality proteins and many micronutrients such as vitamins and minerals (Carlucci et al., 2015). Fisheries constitute important sources of protein for human consumption, both in terms of direct human consumption (DHC), and indirect human consumption (IHC) (fishmeal, fish oil) (Avadí et al., 2017). In 2014, seafood accounted for about 17% of the global population's intake of animal protein and 6.7% of all protein consumed (Abdou et al., 2018). However, there is increasing concern about the negative impacts of animal protein production, from agriculture and from aquaculture or fisheries exploiting the whole range of aquatic ecosystems (Avadí et al., 2017). Moreover, approximately 30% of food loss in Europe is related to fishing (Vázquez-Rowe et al., 2011a), mainly in the form of discards or slipping, post-harvesting, and to the processing, distribution and consumption of fish and seafood (FAO, 2011). To reduce waste and enhance resource efficiency, circular economy promotes the valorization of waste to obtain new products. In recent studies, authors evaluated the environmental benefits of using waste from one sector as input for other feed/food sectors, i.e., the use of recycled food waste as enrichment for tilapia fingerlings production (Bake et al., 2009) and the use of food waste from cruise ships for its use in salmon aquaculture (Strazza et al., 2015).

Several authors have assessed the environmental impact of seafood products, such as canned sardines (Almeida et al., 2015) and tuna (Hospido et al., 2006; Avadí et al., 2015b), Peruvian *anchoveta* (Avadí et al., 2014), fresh sardines (Vázquez-Rowe et al., 2014b) and mussels (Iribarren et al., 2010b, 2010c). For the particular case of European anchovy (*Engraulis encrasicolus*), previous studies proposed the best available techniques for the canning sector (Laso et al., 2016a), analyzed the influence of product diversification (Laso et al., 2017b), evaluated purse seining fishery (Laso et al., 2017a) and identified waste management alternatives (Laso et al., 2016b). In particular, the latter evaluated the valorization of anchovy residues to produce fishmeal, fish oil and anchovy paste. In fact, it should be noted that considerable amounts of anchovy residues are generated in the production of canned and salted anchovies. These food losses represent a source of nutrients that could be used to produce feed for aquaculture, for instance, as practiced throughout the Peruvian anchovy value chain (Avadí et al., 2014). According to this, it is necessary to extend the application of the circular economy concept by means of an environmental and nutritional impact assessment of the production and consumption of European anchovy.

In this framework, the definition of a readily index that combines all the concepts covered by European environmental food policy is necessary in order to simplify the decision making process. We thus propose a methodology to calculate the novel Green Protein Footprint (GPF) index (Fig. 1), which assesses and compares both the environmental impact of a specific food product, as well as its protein content as provided to the consumer.

The environmental impact is evaluated with the internationally-standardized methodology, Life Cycle Assessment (LCA) (ISO, 2006). In parallel, the nutrient properties of the product are analyzed by means of the protein content along the life cycle chain.

2. Material and methods

Fig. 2 shows the methodological procedure proposed to obtain the GPF index. In the first place, the reference scenario and the different scenarios to be studied ae defined. The reference scenario is used to normalize the environmental impact per kilogram protein and represents