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Finding an economic and environmental balance in value chains based on circular economy thinking: An eco-efficiency methodology applied to the fish canning industry

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ABSTRACT

The production of food that is environmentally friendly and presents a high economic return is one of the current concerns for the food industry. Eco-efficiency links the environmental performance of a product to its economic value. In this context, this study combines Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) to propose a two-step eco-efficiency methodology assessment for the fish canning industry. An eco-label rating system based on a descriptive weighting of environmental (Global Warming Potential, Acidification Potential, Eutrophication Potential and the ReCiPe Single Score Endpoint) and economic (Value Added) indicators was applied to the canned anchovy. Secondly, LCA-LCC results were coupled to linear programming (LP) tools in order to define a composite eco-efficiency index. This approach enables translation into economic terms of the environmental damage caused when a given alternative is chosen. In particular, different origins for anchovy species (South American vs. Cantabrian) and related waste management alternatives (landfill, incineration and valorization) were evaluated under this cradle to gate approach. Results indicated that substantial differences can be observed depending on the origin of the fish. Anchovies landed in Cantabria show a higher value added score at the expense of larger environmental impacts, mainly due to fuel use intensity. Moreover, its environmental scores are lowered when fish residues are valorized into marketable products, while increasing the value added. This study demonstrates the environmental and economic benefits of applying circular economy. According to this, it is possible to introduce the cradle-to-cradle concept in the fish canned industry. The methodology proposed is intended to be useful to decision-makers in the anchovy canning sector and can be applied to other regions and industrial sectors.

1. Introduction

In recent years, the transition toward more efficient resource production and consumption patterns has been one of the main challenges for governmental authorities due to the potential threats for human well-being, the economy and the environment (Huysman et al., 2015). In this context, the European Commission (EC) launched the initiative “The Roadmap to Resource Efficient Europe” (EC, 2011) which proposes ways to increase resource productivity and to decouple economic growth from resource use and its environmental impact.

In particular, over the past century, worldwide marine fisheries have been increasingly vulnerable to overexploitation, detrimental fishing practices and environmental degradation (FAO, 2009), as well as intense fishing pressure which has led to a precipitous decline or collapse of several fish stocks (FAO, 2016). Moreover, the growth of world population translates into an increase in the consumption per capita of fish and seafood. In fact, it is estimated that 31.4% of fish stocks are being fished at a biologically unsustainable level (Bonanomi et al., 2017). Since seafood accounts for ca. 17% of the world's animal protein intake and is increasingly recognized as being an important part of global food security, a food versus feed debate exists. Controversy is ongoing with respect to what the best use of fish should be, i.e., for either direct human consumption (DHC) (Avadí et al., 2014) or indirect human consumption (IHC or feed fish) through the feeding of farmed

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animals (Fréon et al., 2014b). At a global scale, it is estimated that approximately a third of landed fish were used for animal feed in recent years. The ratio IHC/DHC depends on cultural and geographical aspects as well as the fish species. This is clear for anchovy species. In Peru, approximately 98% of total anchoveta (*Engraulis ringens*) landings are destined to the fishmeal and fish oil industry. This sector produced on average (2006–2015) 1183 million t/year of fishmeal and 230,000 t/year of fish oil (Fréon et al., 2017). In contrast, in Spain, almost 100% of captured anchovies (*Engraulis encrasicolus*) are destined to DHC, either as fresh anchovy (50%) or as elaborated products, such as salted or canned anchovies (50%) (Laso et al., 2016b).

One of the most recognized anchovy-processing sectors in Spain is located in the region of Cantabria (Northern Spain). Specifically, in 2014 the canning industry in Cantabria produced more than 14,000 t of canned anchovies, generating more than 100 million euros in economic revenue. Cantabrian anchovy constitutes a well-known gourmet product with important economic and food tourism implications. In order to survive in an increasingly competitive global market, Cantabrian canning sector anchovies must be able to design local strategies that contribute to their overall development. According to this, a diversification strategy and introduction in new green markets must be supported by a specific eco-efficiency study (García-Herrero et al., 2017). Eco-efficiency should deliver competitive goods and services from an economic perspective; however, this should be linked to a progressive reduction in environmental impacts throughout their life cycle (Lorenzo-Toja et al., 2016). Previous studies conducted by Laso et al. (2016a) evaluated the environmental impact of the whole anchovy life cycle (Laso et al., 2016b, 2017, 2018) and determined that a hotspot of anchovy canning industry was the generation of high amounts of anchovy waste (heads, spines, broken and rest of anchovies…) which must be managed (Laso et al., 2016a). The valorization of these residues rather than their disposal or incineration introduces in this sector the concept of circular economy. This approach aims to keep the value added (VA) in products for as long as possible and eliminate waste (European Commission, 2014).

Circular economy has usually been oriented towards material recycling (Hatayama et al., 2014), now increasing its use to food products. In this sense, this study proposes a circular economy approach to manage anchovy residues. Anchovy waste can be valorized into fishmeal, which can be used for aquaculture. Hence, humans are finally consuming fish species bred with feed from anchovy residues, closing the loop of the original product life cycle. Moreover, the use of anchovy residues from the canning process in order to produce fishmeal contributes to reducing overexploitation of the anchovy fishery and to promoting a more sustainable use of the marine resources.

However, it is necessary to go a step further, developing a method for the joint computation of environmental and economic indicators in order to attain eco-efficiency benchmarks of the anchovy canning sector. In this context, the ISO 14045 standard is expected to slowly start shifting the definition of eco-efficiency toward a life-cycle perspective. This approach requires that the environmental performance of a process or product should be directly related to its economic value (ISO 14045, 2012). For instance, the Life Cycle Assessment (LCA) method, standardized through the ISO 14040 and 14044 guidelines, was used to determine the environmental impacts linked to the anchovy life cycle (ISO, 2006a,b). On the other hand, Life Cycle Costing (LCC) was used to quantify the monetary value. LCC is a comprehensive decision-making tool for calculating the total cost, which is generated over the entire life cycle of products or processes (Yang et al., 2017). Several authors propose new methodologies to evaluate circular economy by means of a new value-based indicator. For instance, Di Maio et al. (2017) suggest measuring both resource efficiency and circular economy in terms of the market value of stressed resources and define circularity as the percentage of the value of stressed resources incorporated in a service or product that is returned after its end-of-life date. Huysman et al. (2015) develop an indicator to quantify the circular economy performance of different plastic waste treatment options. On the other hand, (Elia et al., 2017) propose a systematic approach to choosing the best fitting method to assess circular economy. However, this conventional definition of eco-efficiency assumes the absence of associated cost to environmental damage. As a novelty, our paper introduces linear programming (LP) to combine LCA and LCC methods to reach an eco-efficiency index (EEI) that attempts to quantify circular economy, beyond the usual theoretical and qualitative descriptions. The EEI aims at facilitating the decision-making process if polluting were penalized, exploring the lower and upper limits of the environmental damage penalty (EDP) that stakeholders would be willing to assume at the expense of producing more valuable products. On the other hand, the proposed method presents the advantage of rendering both VA and environmental impacts comparable in a one-dimensional representation. Hence, the paper introduces a methodological tool to evaluate the environmental and economic value of a product, contributing to the simplification of the decision-making process by an objective classification of different scenarios within the canning sector.

2. Material and methods

The environmental impacts were estimated using LCA according to the ISO 14040 and 14044 specifications (ISO, 2006a,b). The LCC methodology applied in this work was based on the approaches described by Hunkeler et al. (2007) and Swarr et al. (2011) and is congruent with the LCA methodology. Fig. 1 represents the procedure followed in this study, which includes the following five main steps: (i) identification of the different products/processes, (ii) goal and scope, (iii) extended life cycle inventory, (iv) environmental assessment and (v) economic assessment.

The proposed methodology combining LCA and LCC results allows identifying important relationships and trade-offs between the economic and environmental performance of the alternative scenarios, helping decision-making.

2.1. Identification of the different products to be analyzed

This study was conducted for the canning industry of the region of Cantabria (Northern Spain). The quality and prestige of canned anchovies are of particular relevance in this region. Nevertheless, this sector has experienced several economic and environmental downturns. On the one hand, in recent years, the stock level of the Cantabrian anchovy (*Engraulis encrasicolus*) has experienced critical situations. On the other hand, the costly distribution to new markets has hindered growth in the sector. As a result, canning plants were forced to import anchovies from other countries. Based on market demand and characteristics, anchovies may come from Cantabria (*Engraulis encrasicolus*), Argentina (*Engraulis anchoita*), Chile and/or Peru (*Engraulis ringens*). An additional issue of concern is that the canning process generates large amounts of anchovy residues, which must be managed in a sustainable way. Therefore, it is necessary to evaluate the eco-efficiency of the canning industry from different scenarios, taking into account anchovy importation from Argentina and Chile/Peru and the management of anchovy residues under a circular economy approach.

2.2. Goal and scope

The main objective of the present study is to propose a method to assess the eco-efficiency of canned anchovy products under a life cycle approach. To conduct this analysis, the reference unit (RU) defined was 1 kg of fresh anchovy captured in the fishing stage. This reference unit allows the assessment of the eco-efficiency process and facilitates the economic analysis. Moreover, it allows the eco-efficiency of the resource transformation to be assessed, that is, to determine the most sustainable use of fresh anchovy.