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Life Cycle Assessment for eco-design of product–package systems in the food industry—The case of legumes

A. Del Borghi, C. Strazza, F. Magrassi, A.C. Taramasso, M. Gallo*

Department of Civil, Chemical and Environmental Engineering (DICCA), University of Genoa, Via all'Opera Pia 15, 16145 Genova, Italy

A B S T R A C T

Agri-food sector highly contributes to the consumption of water and energy resources and presents significant environmental impacts that can be comprehensively evaluated through a Life Cycle Approach (LCA). This paper investigates the environmental sustainability of a set of legumes (i.e. peas, beans and chickpeas) manufactured in Italy by a Group representing one of largest agri-food European companies, thus allowing to drive eco-design measures for the product–package system. Such products are packaged in glass bottles or in steel tin cans and sold as singles or in multipacks. A deep process analysis was performed through a LCA approach in order to identify environmental hot-spots in the whole life-cycle. The results are expressed through a set of impact categories, which can be read also as stand-alone indicators, identified in order to pave the way for water–energy–food nexus quantification: global warming potential, non-renewable cumulative energy demand, water scarcity index and toxicity potentials. Direct inventory data were collected from the involved farms and the production plants along the whole supply chain. Packaging production and crop cultivation have proven to be the most relevant subsystems for all the studied products and impact categories. In particular, the production of packaging is the major hot-spot accounting for over 70% of the total global impacts, for all the legumes under study. Only the water use impact category presents a peculiar pattern depending on the examined product. On the basis of these findings, different packaging options were compared according to eco-design principles by means of LCA methodology. Change of material, various format options and different recycling rates were investigated to quantify the relevant achievable benefits. Moreover, the variation of crop yields and fertilizers rates was studied to assess the importance of these parameters in the whole life-cycle.

Keywords: Life Cycle Assessment; Vegetables; Packaging; Crops; Agri-food; Eco-design

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1. Introduction

Safeguarding the future of the planet and the right of future generations to live healthy and fulfilling lives is one of the main aims of the research in environmental sustainability (Klugman, 2011). Feeding the growing world population without harming the environment and the resources is a critical trial that the researchers in environmental sustainability and the agriculturist are struggling to solve. The Milan Expo 2015 "*Feeding the Planet, Energy for Life*" established as its inheritance

* Correspondence to: University of Genoa, Via all'Opera Pia 15, 16145 Genova, Italy.
E-mail addresses: adriana.delborghi@unige.it (A. Del Borghi), carlo.strazza@unige.it (C. Strazza), fabio.magrassi@edu.unige.it (F. Magrassi), A.C.Taramasso@unige.it (A.C. Taramasso), michela.gallo@unige.it (M. Gallo).

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a chart enclosing all the goals to attain in order to understand the links between environmental sustainability and food equity, preserving biodiversity and ecosystems through a smart agriculture (EXPO 2015, 2015). Similar goals were presented by Roadmap to a Resource Efficient Europe (COM (2011) 571) and later on by the European Common Agricultural Policy (CAP) (European Commission, 2012) defining the following three priority areas: improve the sustainability of the agriculture, develop the preservation of biodiversity and of ecological farming and forestry systems, regulate the water management and use, dealing with climate change. The CAP was reformed in 2013 with a long plan named "CAP Reform 2014–2020" in order to answer the need to produce a higher level of safe and quality food while preserving the natural resources that agricultural productivity depends upon. To reach this goal, the agricultural sector should operate a radical change becoming more competitive, implementing a properly functioning supply chain which contributes to the maintenance of a thriving rural economy (European Commission, 2013; European Parliament and Council, 2013). Agri-food sector, as all industrial processes, presents along its life cycle and production chain considerable environmental impacts. Life Cycle Assessment (LCA) (ISO, 2006a) is a tool used to quantify the environmental burdens along the life cycle of a product or process.

In relation to LCA in the agri-food sector, over the last years, several products and consumer goods have been assessed. Historically the LCA methodology has been applied to industrial products and processes involving either agricultural production or industrial refining (Roy et al., 2009; Al-Ansari et al., 2015). Examples of such products and processes include, but are not limited to: industrial food products, such as bread (Espinoza-Orias et al., 2011), beer (Cordella et al., 2007), wine (Pattara et al., 2012) and tomato products (Andersson et al., 1998; Del Borghi et al., 2014); dairy, such as milk (Eide, 2002) and butter (Flysjö, 2011); meat production (Nunez et al., 2005; Gallo et al., 2015); other agricultural products, such as apple (Milài Canals et al., 2006), sugar (Yuttitham et al., 2011), olive (Avraamides and Fatta, 2008; Proietti et al., 2014), lettuce (Foteinis and Chatzisymeon, 2016), beans (Romero-Gámez et al., 2012; Abeliotis et al., 2013), peas (Naudin et al., 2014); breakfast cereals and snacks (Jeswani et al., 2015); animal feed (Strazza et al., 2015).

Within the agri-food sector, legumes account for 27% of the world's primary crop production representing an accessible and easily available protein sources that can help to improve the nutritional status of the low-income population enhancing the protein content of cereal-based diets (Iqbal et al., 2006). Japanese, Swedish and Mediterranean long-lived food culture are associated with the wide consumption of legumes in their traditional recipes and diets, awarding legumes as an integral part of the diet and a healthier alternative to traditional meat-based products (Darmadi-Blackberry et al., 2004).

Despite the widespread application of LCA for the evaluation of different crop cultivation modes for legumes production (Abeliotis et al., 2013) and their positive impacts on biodiversity and soil quality (Abberton, 2010; Goglio et al., 2017), there are still no published studies on the overall environmental impacts of legumes from the cultivation of crops to the end-of-life stages of the supply chain. As an attempt to fill this knowledge gap, the present paper aims to investigate the supply chain of legumes through the application of Life Cycle Assessment.

This paper in particular investigates a set of legumes products (i.e. peas, beans, and chickpeas) from a life-cycle perspective in order to focus the environmental hot-spots along with their supply chain, thus allowing to drive eco-design measures for the product–package system. The products examined here are produced in Italy by a Group representing one of the largest agri-food industry, that decides to embed environmental sustainability in product design with the aim of guiding consumers towards making more sustainable choices, such as in the case of tomato products (Del Borghi et al., 2014). The aim of this paper is therefore to highlight the importance of eco-design along the life cycle of vegetables products and to compare different options according to eco-design principles by means of LCA methodology.

2. Methods and data

In order to guarantee an objective comparability among rules and results, the LCA study was performed following a methodological pattern consistent with the requirements of the environmental labels (Schau and Fet, 2007; Del Borghi, 2012). The studied products can be classified as processed food products and belong to the following Central Product Classification (CPC) classes: "vegetable juice" (CPC 2132) and "other prepared and preserved vegetables, pulses and potatoes" (CPC 2139) (United Nations - Department of Economics and social affairs, 2015). Therefore, the ISO 14040 (ISO, 2006a) compliant LCA was performed following the specific rules defined in the Product Category Rules (PCR 2014:09) document on "prepared and preserved vegetables" (International EPD System, 2014a; International EPD system, 2014b) published in the framework of the International Environmental Product Declaration (EPD) System® (International EPD system, 2015) and according to ISO 14025 (ISO, 2006b).

2.1. *Goal and scope of the study*

The goal of the study is to investigate the supply chain of legumes in order to identify the environmental hot-spots along their life-cycle. Furthermore, a set of key parameters has been identified for each relevant subsystem and a sensitivity analysis has been performed in order to investigate the effect of their variation to the relevant impact categories and to quantify their achievable benefits. Some improvement options have also been investigated and compared in the paper from eco-design perspective.

Peas, beans, and chickpeas, both traditionally and steam cooked, have been studied. So, the paper focuses on the following five products: peas, borlotti beans, steam cooked peas, cannellini beans, and chickpeas. The legumes are of Italian origin and their cultivation is performed by agricultural cooperatives directly controlled by the same Group following integrated farming practices coherent with Regional Integrated Production specifications. The legumes are grown in Northern and Central Italy (Emilia Romagna, in the Provinces of Ferrara, Piacenza, Bologna, Modena and further afield in Cremona, the Lodi Valley and the areas found between the Provinces of Verona and Mantova). Peas, borlotti, and cannellini beans are processed in a plant located in the Province of Ferrara, while steam cooked peas and chickpeas are processed in a plant located in the Province of Piacenza.

These products are normally packaged in glass bottles or in steel tin cans and sold as singles or in multipacks.

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