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The relevance of supply chain characteristics in GHG emissions: The carbon footprint of Maltese juices

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ABSTRACT

Aims: Foods and drinks are major contributors (17%) to the greenhouse gas (GHG) emissions caused by private consumption in Europe. The carbon footprint (CF) of a certain product expresses the total GHG emissions over its whole life cycle, and its calculation for foodstuff is a necessary first step to reduce their contribution to global warming. The calculation of the CF of Maltese food products is especially relevant for two reasons: the economic characteristics of the island, whose food sector is highly dependent on imports, implying longer transport distances; and the Maltese electricity production mix, based almost exclusively on oil combustion.

Methods and results: The CF of ten multi-fruit juices marketed in Malta has been determined, covering all the processes from the agricultural stage to the distribution of the final products. As a functional unit (FU), a 250 ml bottle of packaged product arriving at the retailer has been considered. The Maltese orange juice, the only final product in which only local ingredients are used, presents the lowest CF (0.50 $kgCO_2/FU$), while the remaining ones range from 0.67 $kgCO_2/FU$ to 0.80 $kgCO_2/FU$. The major contributor to all the CFs is juice processing at the Maltese plant (0.42 $kgCO_2/FU$), mainly due to the use of electricity (78%).

Conclusions: The influence of both the electricity mix and the Maltese supply chain in the CF of the final products has been demonstrated. Alternatives to reduce the impacts of the final products have been proposed and evaluated that could lower the average CF of the juices by 32%.

Significance and impact of the study: The calculation of the CF of Maltese juices represents an innovative case study due to the characteristics of the island, and it is expected to act as a first step to lower their environmental impacts.

1. Introduction

Food and drinks consumption is a major contributor to the greenhouse gas (GHG) emissions caused by private consumption worldwide, being responsible from 17% of the GHGs in Europe (Watson, Acosta Fernandez, Wittmer, & Pedersen, 2013). The fact that transport (14%) and agricultural production (10–12%) are major contributors to the GHG emissions of the anthropogenic productive activities justifies the need to evaluate the supply chains of products of plant origin, in order to achieve both sustainable production and consumption.

Moreover, the environmental evaluation, if made public, can be also a good marketing strategy for those products sold in developed countries, where consumers start demanding food produced with minimal environmental losses (de Boer, 2003) and increasingly base their purchase decisions on environmental indicators shown in food packaging.

Life Cycle Assessment (LCA) is an environmental management tool that allows evaluating the potential environmental impact of a product, process or activity throughout its entire life cycle. LCA can be used to evaluate several impact categories, being Climate Change -caused by the aforementioned greenhouse gases- the most widely assessed, since it is one of the most pressing environmental issues that humankind must address nowadays (Kingston, 2013). The potential contribution of a certain product to climate change can be evaluated through its Carbon Footprint (CF), an indicator defined as the total GHG emissions of the product over its whole life cycle, and expressed as CO_2 equivalents.

The CF has achieved widespread development over the past decades, because of being very intuitive and easily understandable for non-expert users, which facilitates the diffusion of the results (Weidema, Thrane, Christensen, Schmidt, & Løkke, 2008).

The urgency of the climate change issue, the important contribution that food supply chains represent to the problem, the growing interest of consumers and the simplicity of the indicator have resulted in the

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publication of many Carbon Footprint studies of companies, processes and products, especially in the food industry: the British supermarket chain Tesco included the CF of its products in their label, and published a report containing all the values (Tesco, 2012); the Danish dairy company Arla Foods evaluated the CF of their butter (Nilsson et al., 2010); Kellogg's determined the environmental impacts of their breakfast cereals (Jeswani, Burkinshaw, & Azapagic, 2015); and Nestlé compared the environmental performance of their packaging alternatives (Humbert, Rossi, Margni, Jolliet, & Loerincik, 2009).

In this context, this study aims to estimate the CF of several fruit juices manufactured by a small company located in Malta. This calculation will cover all the processes from the agricultural stage to the distribution of the final products, thus including processing of the final products and all the intermediate transport stages. The Maltese juices represent an innovative case study for several reasons that are expected to increase their GHG: the economic characteristics of the island, whose food sector is highly dependent on imports (OEC, 2016), implying longer transport distances; the Maltese electricity production mix, based almost exclusively on oil combustion (IEA, 2013); and the drinking water mix of the island, highly dependent on desalination (WSC, 2011).

This paper has been structured as follows: the next section describes the methodology followed and presents the data used to perform the assessment, the CF results are then shown in a third section and a discussion is included in the fourth part, where the results are compared to those found in other studies and improvement actions are proposed and evaluated. Last, the main conclusions of the study are presented in the fifth section.

2. Methods

The carbon footprint of the fruit juices under study has been determined following the Life Cycle Assessment methodology, as defined in ISO (14040:2006), where the steps required to perform the analysis are presented; and in ISO (14044:2006), which complements the former and details implementation guidelines and requirements to be met by the studies.

Moreover, to determine the Carbon Footprint, another two specific standards have been followed: ISO (14067:2013), which starts from the LCA ones and provides more specific guidelines for the calculation of the CF, and PAS 2050:2011 (BSI, 2011), which provides guidance on how to carbon footprint products and reduce emissions along supply chains.

Last, the recommendations for the obtaining of Environmental Product Declarations (EPDs) have also followed. EPDs are independently verified and registered documents that communicate transparent and comparable information about the life-cycle environmental impact of products. These declarations of environmental impacts comply with ISO (14025:2006), and they are prepared following a set of operational rules, specific for each product category, known as Rules Product Categories (PCR). Thus, in this study, the corresponding PCR for vegetable juices has been followed (PCR 2014:09).

Data have been mainly gathered directly from the company, and correspond to 2014. In addition to these primary data, secondary data for the characterization of the impacts of raw materials such as fruit or packaging have been taken from the Ecoinvent 3.2 database (Wernet et al., 2016) as well other sources from the literature as detailed later on.

Regarding the allocation procedures, i.e. the distribution of the impacts of a certain process in which more than one product is obtained, a mass-based allocation has been followed, based on the recommendations of the aforementioned ISO standards.

The environmental impacts of the capital goods having a lifetime longer than 3 years are also excluded from the assessment, as recommended by the PCR. This standard also allows excluding those components which represent less than 1% weight of the final product.

Table 1
Codification and main ingredients of the final products under study.

Juice code	Main ingredient(s)	Percentage distribution
O	Orange[a]	4.90%
M1	Mango	23.78%
M2	Pineapple and orange	6.18%
M3	Kiwi	3.55%
M4	Pineapple and strawberry	4.73%
M5	Strawberry and banana	38.29%
M6	Cranberry	9.18%
M7	Blueberry and cranberry	7.53%
M8	Apple	0.72%
M9	Fig	0.96%

[a] Orange juice is the only single-ingredient juice.

The system description and the main inventory data are presented below.

2.1. System description

The reference year chosen was 2014, since that was the only one for which all the required data were available. Ten final products have been evaluated (Table 1): nine multi-fruit juices (codes M1 to M9) and pure orange juice (code O). Table 1 presents the main ingredient(s) of each type of juice, since the detailed recipes cannot be published due to confidentiality issues.

Apart from the main components displayed in Table 1, the company also purchases other fruit ingredients that are used in different proportions in the multi-fruit juices: banana, passion fruit, lemon, raspberry and spices.

These ingredients are purchased from foreign companies and received in different formats. Bananas, mangos and passion fruit are acquired in the form of puree. Apple is bought in the form of 1 l packaged cartons. Lemons and oranges are the only ingredients which are received fresh since they are grown in Malta, while the rest of the fruit is received either chopped or whole, and it is always frozen. In summary, all the fruit ingredients except lemons and oranges are pre-processed before reaching the Maltese plant.

As a functional unit for each of the final products (Table 1), a 250 ml bottle of packaged product arriving at the retailer has been considered, since this is the only format in which the juices are sold.

A cradle-to-gate study has been carried out, starting from the cultivation of the fruits and up to the distribution of the final products, ending with the delivery of the juices to the retail stores.

Thus, in practice, the emissions occurring in all life cycle stages of the supply chain until the final products reach the retail stores have been accounted for: fruit cultivation, pre-processing and all transport stages linking them (Fig. 1).

The production at the processing plant is not continuous but demand-based. The production cycle (Fig. 2) takes place approximately once a week, with an average of 2.116 juice bottles produced per cycle in 2014, with distribution shown in Table 1.

Once at the factory, a quality inspection is performed only for the products that are acquired fresh (oranges and lemons), in which the pieces that don't meet the necessary quality standards are discarded and sent to waste management facilities in Malta. After the quality control, the fresh fruit is stored in a cold room until it is needed for production. When a production cycle starts, the fresh fruit is washed before it enters the squeezing process. The lemon and orange juices obtained are then mixed with the rest of the ingredients in stainless steel tanks.

The remaining ingredients, which don't undergo the screening process, are stored until needed: the frozen fruits are held in a cold room, while the remaining ones are stored at room temperature. Once the production process begins, the frozen ingredients are partially thawed at room temperature before being incorporated to the mixing

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