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Carbon footprint of truffle sauce in central Italy by direct measurement of energy consumption of different olive harvesting techniques

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ABSTRACT

The contribution of the European food sector to the total amount of greenhouse gases emissions is equal to 15%. The main environmental impact is due to the cultivation phase while the transformation has limited consequences. The sustainability of the food sector can be traced using an important indicator: Product Carbon Footprint. In this framework this paper presents the case of a traditional product: truffle sauce, which is a mixture of extra virgin olive oil and truffle. Its carbon footprint has been calculated based on ISO 14067, through the use of specific Product Category Rules, able to describe theoretical prerequisites and practical rules to be followed during the analysis in order to make results comparable with other studies. Different allocation techniques have been analyzed: system expansion has been compared with allocation based on mass and economical value. It was shown that 3% variation in the mass yield of olive oil implies 2% variation in the final carbon footprint. Different harvesting techniques were considered and their energy consumption was measured on site. Final carbon footprint for truffle sauce, assuming allocation based on system expansion, is equal to 1.93 kg CO_2eq/kg. Truffle sauce has a lower impact compared to other similar commodities (extra virgin olive oil for example). The final result of the Product Carbon Footprint is not the only scientific value added by this paper, because Product Category Rules can be used by other researchers to calculate emissions released during truffle sauce or olive oil life cycle in other particular environments. Knowing the value of these emissions, reduction measures can be designed. The limits of this study are represented by the fact that these values are deeply influenced by seasonal variability, so this aspect should be evaluated by further studies.

1. Introduction

The contribution of the European food sector to the total amount of greenhouse gases emissions in Europe is equal to 15% (CIAA, 2008). In the food industry production chain cultivation is responsible of 49% (CIAA, 2008) of the global emissions, while transport accounts for the 22%. In Italy the agricultural production accounts for 45.3% of the whole emissions of the food sector (Calabrò and Lagioia, 2013). Enteric fermentation, animal husbandry effluents, transport, industrial processing and packaging account respectively for 11.2%, 6.6%, 19.1%, 5.3% and 12.6% (Calabrò and Lagioia, 2013). The food supply chain comprises many stages and players: farmers, industry, transport, retailers, consumers and waste management. For this reason a meaningful strategy towards sustainable production and consumption requires an integrated approach. Important achievements in the field of local carbon dioxide emissions calculation are presented by Gomes et al., 2007, who analyzed the emissions caused by electricity use and solid and liquid waste treatment. In this framework Product Carbon Footprint (PCF) analysis can be introduced as a useful environmental indicator, according to the norm PAS 2050 (BSI, 2011) and ISO 14067 (ISO, 2013). Both norms are based on a Life Cycle Assessment (LCA) approach, standardized by ISO 14040 (ISO, 2010a) and ISO 14044 (ISO, 2010b). Several papers have analyzed the carbon footprint of different foods (Flysjö et al., 2012; Page et al., 2012; Pelletier et al., 2013; Ridoutt et al., 2014; Röös and Karlsson, 2013; Schäfer and Blanke, 2012; Teixeira et al., 2013; Trydeman et al., 2014; Vázquez-Rowe et al., 2013; Xu et al., 2013), but truffle sauce, which is a sauce made of extra virgin olive oil, truffles and minor ingredients, has never been taken into account. Besides there are only few PCF studies based on ISO 14067 norm (ISO, 2013) at present and they do not usually show Product Category Rules (PCR).

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Nomenclature

A.c.	Allocation coefficient -
d.m.	Dry matter -
FU	Functional Unit -
$M_{param.}$	Allocation parameter value for main product -
PCR	Product Category Rules -
PCF	Product Carbon Footprint kg CO_2eq/kg product
SD	Standard Deviation kg CO_2eq/kg product
SB	System Boundaries -
S_{param}	Allocation parameter value for secondary product -

On the one hand mass allocation is the most used criteria in Literature; on the other hand ISO 14067 (ISO, 2013) norm indicates that "wherever possible allocation should be avoided by dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes, or expanding the product system to include the additional functions related to co-products". This means that, according to ISO 14067 (ISO, 2013), system expansion has to be preferred to mass allocation and to economic value allocation. On the one hand two Life Cycle Analysis of olive oil presented by Salomone and Ioppolo 2012 and Michalopulos et al., 2011 use system expansion to avoid allocation in olive oil LCA; on the other hand Nucci et al., 2013 assign 100% of the impact to olive oil, so avoiding allocation. In the PCR on "Olive oil Extraction and its fractions" (2010), economical allocation is suggested. Literature review shows that there is not a unique method to perform allocation and for this reason in this study different procedures for impact allocation will be compared. The system expansion procedure is taken from Weidema 1999.

The object of this study (truffle sauce) is realized in a small family farm, situated in Giano dell'Umbria, Italy.

The farm cultivated area hosts vineyards and olive groves. Its main products are grapes, which are brought to a local consortium winery, and extra virgin olive oil. This is obtained by mechanically crushing olives in a local mill, and commercialized with a proprietary brand. The farm also maintains a small forest, were truffles are grown. The area covered by each olive variety and its production are shown in Table 1, data were obtained from direct measurements.

Truffle is a renown product of Umbria. Botanically it is the fruiting body of a subterranean fungus and belongs to the genus *Tuber*. The most important species are *Tuber magnatum* (also known as white truffle) and *Tuber melanosporum* (also known as black truffle). The latter is grown in the farm and has been recently considered as an interesting product, to be commercialized in a proprietary branded sauce. Truffle sauce is a mixture of vegetable oil and truffle in proportions of 67% and 33% respectively, and minor ingredients (garlic, pepper, etc.); it is a typical Italian product, realized using a traditional recipe and in small quantities. Truffle sauce can be used as a sauce for pasta or rice, and also as a dressing for meat or vegetables; it can also be eaten with bread or eggs to maximize its flavor.

Following what has been said above, the objectives of this study are the following: to calculate truffle sauce PCF; to develop Product Category Rules; to compare different allocation approaches and to test the reliability of results through sensitivity analysis and uncertainty analysis. These objectives derive directly from the need to develop a standardized procedure for the calculation of truffle sauce carbon footprint, that could be based on recognized norms and be used to promote the environmental sustainability of the product. The information gained though this work can be used to reduce truffle sauce GHG emissions.

2. Materials and methods

Olive cultivation was monitored on the whole plantation of olive trees, therefore on 4 different cultivars: Moraiolo, Frantoio, Leccino, San Felice (see Table 1). Olive harvesting was carried out with two different techniques, namely: hand handled rakes and a diesel tractor, equipped with a mechanical trunk shaker (Fig. 1A). For both solutions a specific energy consumption was calculated. Cultivation processes were monitored registering materials and energy flows, based on physical measurements. Data were recorded on a field register. In particular, electric consumptions were measured through an analyzer: PQA823, made by HT Italy and complying to EN50160 norm. Mass and energy balances were recorded in check lists. LCI calculation and PCF calculation have been made using SimaPro software, realized by Prè Consultants. According to ISO 14044 (ISO, 2010b), LCI is defined as the "phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle". According to ISO 14044 (ISO, 2010b), LCIA is defined as the "phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout its life cycle". In this case the only impact that was investigated was GHG emission, that was analyzed using the method "GWP on 100 years", available in SimaPro software. The version used in this study is SimaPro 7.2 and it permits to perform LCA, based on ISO 14040-44 norms (ISO, 2010a; ISO 2010b).

In this paper PCF calculation is based on ISO 14067 (ISO, 2013). Product Category Rules (PCR) have been developed. The calculation of the footprint in this study is focused on truffle sauce. Both truffles and olives are cultivated in a farm in Umbria (Italy) and harvested. Olives are crushed in a nearby mill and the resulting extra virgin oil is then transported together with truffles to an external facility to obtain bottled truffle sauce. The boundaries of the system analyzed are shown in Fig. 2. Truffle sauce Life Cycle has been divided in the

Table 1
Olive trees production and harvest.

Variety		Area covered (%)	Plant main production (kg/plant)	
Olea europaea L. cv Moraiolo		27.29%	14.3–14.9	
Olea europaea L. cv Frantoio		22.74%	15.9–16.1	
Olea europaea L. cv Leccino		32.75%	16.5–17.3	
Olea europaea L. cv S.Felice		16.72%	15.7–16.3	
Weighted Average		/	15.83	
Harvesting capacity	Electric rakes		Trunk shaker harvester	
Variety	Daily harvested plants (n)	Daily harvested area (ha)	Daily harvested plants (n)	Daily harvested area (ha)
Olea europaea L. cv Moraiolo	34.5–48.3	0.10–0.14	107.4–111.9	0.32–0.34
Olea europaea L. cv Frantoio	50–62.5	0.15–0.19	99.4–100.6	0,29–0.30
Olea europaea L. cv Leccino	59–71	0.18–0.21	92.5–97.0	0.28–0.29
Olea europaea L. cv S.Felice	50–62.5	0.15–0.19	98.2–101.9	0.29–0.31
Average	54.7	0.16	101.1	0.3
Energy consumption		Electric rakes	Trank shake harvester	
Energy consumption per hectare		8485 Whe/ha	35 l diesel/ha	
Energy consumption per plant		25.5 Whe/plant	0.10 l diesel/plant	
Energy consumption per ton		1631 Whe/t	6.7 l diesel/t	