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Carbon footprint of extra virgin olive oil: a comparative and driver analysis of different production processes in Centre Italy

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ABSTRACT

In this research, five case studies located in Abruzzo (Italy) were analysed using the Carbon Footprint method aiming primarily to quantify the greenhouse gas emissions related to the cultivation of olives and the production of olive oil (respectively farm phase and mill phase) and to identify the drivers behind these emissions (excluding olive tree planting and distribution phase). In respect to the existing literature, the research presented here developed more detailed collection of data on farms and selected the case studies in order to represent the current production situation at the international level (Spain excluded) as regards technology and size. Furthermore, an uncertainty and sensitivity analysis was performed in order to assess the robustness of results. Five litres of extra virgin olive oil, with primary and secondary packaging, were chosen as a functional unit. Results showed that agriculture accounts for emissions of CO_2eq ranging from 3.34 to 7.74 kg (mainly due to fertilizer and pesticide treatments), followed by the packaging process in the industrial phase for which CO_2eq emissions range from 1.13 kg to 3.20 kg (for which glass bottles represent the largest load). The study revealed that a realistic reduction of greenhouse gas emissions should be based on an efficient use of pesticides and fertilizers. Drivers are mainly located in the farm factory phase, which is the one with the highest impact, but also the phase that proves most difficult as regards retrieving detailed data.

1. Introduction

The increase of greenhouse gas (GHG) concentrations is considered the main cause of global climate change (IPCC, 2014). It is increasingly accepted that of the various manufacturing activities responsible for GHG emissions, the whole agri-food supply chain is one of the major contributors to climate change; food production systems thus contribute a large share of anthropogenic emissions (Pelletier et al., 2013), estimated to be 19–29% of total GHG emissions (Vermeulen et al., 2012). Between 80 and 86% of these emissions are caused by agricultural production, while the remainder comes from pre-production (mainly fertilizer production) and post-production activities, such as primary and secondary processing, packaging, transport, etc (Avraamides and Fatta, 2008).

One of the most important agri-food sectors in the EU is the olive oil industry. In recent decades, this sector has been affected by major changes concerning cultivation practices, technologies of extraction and, above all, quality improvement and selection of typical characteristics. In addition to those changes mainly linked to strengthening the quality of extra virgin olive oil (EVOO) – such as nutritional, organoleptic, hygiene and typical characteristics –the scientific community has also tackled and analysed environmental impacts related to its production with particular interest. One of the reasons for this is that the olive oil industry is characterized by great variability deriving from different cultivation practices, production techniques and supply chain organization, as well as influences arising from local characteristics (Rinaldi et al., 2014; Salomone and Ioppolo, 2012).

Among the various environmental impacts, the assessment of GHGs in a product life cycle perspective is a significant aspect related to environmental issues that requires full, in-depth analysis. In fact, numerous international organizations (Environdec, 2014) are currently working on application rules (Product Category Rules –PCR) for the various national standards for calculating GHG emissions. For example, the European Commission has its Product Environmental Footprint (PEF) project underway, while the International Olive Oil Council (IOOC) is developing a protocol for the quantification and subsequent certification of GHG emissions

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generated by the production of EVOO. The IOOC and the Joint Research Centre (JRC) are currently developing the Product Environmental Footprint Category Rules (PEFCR) for olive oil, under the aegis of the European Commission (EC, 2013).

Also on the scientific research level, a number of authors have carried out Life Cycle Assessment (LCA) studies in the agri-food sector and on the specific field of olives and olive oil production. The LCA method was initially applied in the olive sector in the 2000s (Salomone et al., 2015), and proved to be an effective tool on which to base operational decisions at individual farm level (Fedele et al., 2014).

A recent publication reports the results of a critical review of the international literature (Salomone et al., 2015) in which 72 studies were reviewed, taking into account different aspects, such as the tool used (LCA, Simplified LCA, Carbon Footprint, Water Footprint, etc.) and the methodological issues. Four other papers were published after the literature review reported in Salomone et al., 2015: two apply the LCA method (Mohamad et al., 2014; Rajaeifar et al., 2014) and two refer to the Carbon Footprint (CF) method (Proietti et al., 2014; Rinaldi et al., 2014).

Therefore, the literature still has few cases where the footprint label has been applied in the olive oil sector. Indeed, at the time of writing this research, only five CF (Polo et al., 2010; Intini et al., 2011; Lucchetti et al., 2012; Proietti et al., 2014; Rinaldi et al., 2014), one Water Footprint (Salmoral et al., 2011) and one Ecological Footprint (Scotti et al., 2009) had been published.

In respect to the existing literature, the research presented here developed more detailed collection of data on farms by considering a broader sample, and considered the current trend in technological levels for central Italy, Greece and the countries of northern Africa. Indeed, the main goal of the study was to identify and assess the phases and inputs with greater environmental impact of each system in order to identify the potential optimization options of EVOO production practices and the drivers behind GHG emissions. In this sense the production system in Abruzzo is similar to that found in the central regions of Italy (Lazio, Tuscany, Marche, and Umbria) as regards cultivation, milling facilities, and quality of olive oil, as well as to that of emerging countries (Morocco, Tunisia, Argentina, etc.). The higher level of accuracy included the single processes of the agricultural and industrial phases, excluding the distribution and end of life that are, as is known, the stages in which quality and data accuracy are lower (Saner et al., 2012; Accorsi et al., 2015; Lazarevic et al., 2010).

Further goals of the study were to increase awareness among practitioners and local stakeholders of the use of environmental assessment tools in order to increase attention to environmental concerns and highlight the main methodological issues related to the application of the CF method in the specific sector of olive oil production.

This paper is structured as follows:

1. Introduction, summarizing the general aim of the paper, its collocation in relation to the existing literature and its structure;
2. Materials and Methods, split between the description of Case studies and of Carbon Footprint analysis (including the description of the main elements of the CF analysis framework implemented: functional unit and system boundaries, inventory analysis and impact assessment);
3. Results, where the Carbon Footprint results are presented;
4. Discussion, divided into:comparison of results with other carbon footprint studies; drivers and methodological choices affecting the impacts and uncertainty and sensitivity analysis;
5. Conclusions, summarizing the main findings of the paper (both in terms of identification of “hot-spots” and opportunities for reductions of GHG emissions, and methodological aspect of applying the CF method in the olive oil production sector).

2. Materials and Methods

In the context of a dearth of application of the CF method in the olive oil sector, and of growing interest in these kinds of life cycle perspective studies on climate change and a local/regional implementation, the present paper focuses on the results obtained by applying the CF method to the olive oil production sector in Abruzzo (Centre Italy), through a “cradle to gate” analysis which includes the phases of cultivation (farm factory phase) and olive oil extraction and bottling (mill factory phase). The method used for carrying out the study is the CF according to ISO/TS 14067: 2013 (ISO, 2013) and the PCR “A CPC 21537 Virgin Olive Oil And Its Fractions” (Environdec, 2014). A Monte Carlo analysis was also performed to assess the uncertainty of data for which higher variability was detected (in particular some specific farm processes, such as fertilization, transport, phytosanitary treatments, and diesel consumption for tillage processes); based on the outcome of which, a sensitivity analysis was then carried out (Huijberts et al., 2001; Weidema and Wesnaes, 1996).

2.1. Case studies

Five case studies are considered and analysed in depth that are representative of the regional, national and other Mediterranean production realities in terms of quality, quantity, cultivation, and extraction technologies. Leading producing Countries that present similar cultivation techniques and extraction technologies are Greece, Tunisia, Morocco, Argentina, and Syria; on the contrary, other leading producing Countries which do not present these main characteristics are excluded from this relation (e.g. Spain which is mainly characterized by super intensive cultivation and 2-phase decanter extraction technology).

Furthermore, to represent fully the structural framework of the olive oil supply chain in Central Italy (INEA, 2014) the five mills covered by the study include three cooperatives (Case studies 3, 4, and 5) and two private mills (Case studies 1 and 2). In fact, about 75% of the farms of North–Central Italy that produce olives have an average size of less than 5 ha and are associated with cooperatives for the processing of the olive oil (ISTAT, 2013).

Therefore, the choice of case studies (in term of their characteristics such as size, type, etc.) proportionally represents the distribution of the main characteristics of farms and mills in Abruzzo, Italy and other leading producing Countries, as highlighted in Table 1.

Fig. 1 shows the localization of the case studies, while Table 2 presents in detail the characteristics of the case studies, as regards:

- extraction technology (2-phase decanter, 3-phase decanter, and pressure) – the analysed mills cover all three types of olive oil processing systems currently used in the majority of Italian operating plants;
- working capacity expressed in terms of olive milled (quintals/year) – the pressure system is a discontinuous cycle and therefore presents working capacities lower than the centrifugal systems (2- and 3-phase decanter);
- size and organizational structure (large and medium-sized cooperative mills and medium and small-sized private mills);
- cultivation method (conventional or organic) – three organic productions and two conventional ones were considered. This choice was made to evaluate whether organic production, though representing a best practice in terms of safety of the inputs used, implies more energy consumption (fuel, electricity, etc.) due to a lower yield of product per hectare;
- farming system (traditional non-irrigated) – is the same in all the investigated realities as this is common throughout the