Assessing environmental sustainability of different apple supply chains in Northern Italy

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Abstract The application of environmental assessment methods in the fruit sector is conventionally divided into a field phase and a retail phase. Although there are important differences in the environmental impacts in field phase, a major part of the impacts is related to the management of the fruit and the distribution chain in the retail phase. In this paper, the environmental impact of fruit production is quantified in the production and retail phase of apple production in Piedmont in Northern Italy. Three main scenarios have been identified: (I) direct selling, (II) distribution to local markets and (III) distribution to national markets. A complete life cycle assessment (LCA) has been performed on the three apple supply chains. Results show the importance of retailing strategies for the environmental sustainability of such food item.

1 Introduction

Over the last 50 years, the advance of new technologies, improved facilities and infrastructure at all levels of the food supply chain has led to an enormous expansion of the food availability in the markets. Recently, this transformation of the food retail system has arise concerns about the environmental impacts of transporting food increasingly long distances prior to its consumption [1]. This during the last years an ongoing debate about the environmental convenience of regionalization versus globalization of alternative food systems has emerged [2]. Although assessments generally show that impacts of for locally produced food are smaller, the results are often controversial both in terms of methodology and concepts [3]. Several studies aim to quantify the contribution of transportation in the food sector in a given area; e.g. it is estimated that greenhouse gases (GHG)

emissions from transporting food around the UK contribute 3.5% to total UK GHGs [4].
There are several assessment approaches available to estimate the potential environmental impacts of a product or service, and Life Cycle Assessment (LCA) is estimated to be one of the most sophisticated [1]. Although many aspects of environmental accounting methodologies in food production are already investigated, applications of LCA in the fruit sector are still rare. Particularly, most of investigations in the fruit sector, are focus or on the orchard stage [5] or on different retailing scenarios of fresh fruits [6] or fruit products [7].
Most of LCAs on food supply chains are done from a consumer point of view [3]; particularly, evaluations are conducted for products that arrive from different supply chain at the same consumer point, e.g. apple in UK [1] or orange juice in Denmark [8]. In this study, the environmental assessment has been conducted from a producer/retailer point of view, comparing different transport strategies form the same area of production.
Thus, the objectives of this research are (I) to quantify the main environmental impacts of the apple supply chain in Piedmont (II) to evaluate the relative impact of the two investigated phases (production and retail) on the overall environmental burden of the fruit; (III) to quantify the differences in environmental impact of the investigated distribution systems, particularly the impact of transportation..

2 Methodology

This study has been performed in accordance with the guidelines and requirements of the ISO 14040 standard series and with the cradle-to-use approach as the basis for the Life Cycle Inventory (LCI) of the study. Data regarding agricultural inputs production and distribution, resources consumption and agrotechniques have been obtained directly from the growers, who filled in a questionnaire for the season 2009-2010. Collected data were weighted consulting the Italian protocols for such production. Data regarding supply chains have been obtained from retailers thorough interviews and field surveys.
The assessment covers the whole supply chain, including all the stages from the agricultural production up to the beginning of the consumer's phase, of apples of the cultivar Golden Delicious cultivated in Piedmont. This cultivar has been chosen because of the wide range of distribution, compared to ancient cultivars that present mainly local commercialization.
According to previous studies [5,9], the production phase has been modeled in 6 different stages: nursery, orchard installation, low production due to young plants,

full production, low production due to old plants, and orchard destruction (Fig. 1). Resource consumption and emissions from each stage has been quantified; also the production of differentiated apple farming inputs and their transport to the field are included in the system boundary of the production stage. Pesticides were accounted for both in terms of the production and in terms of emissions. Emissions were calculated using Pest-LCI tool [10]. If characterization factors were not available for the exact pesticide, alternative pesticides with the same chemical and physical properties were chosen for the evaluation. The lack of data about the effects of pesticide residues in crops and groundwater and of sprays on 'bystanders' continue to be matters for general debate [1]. Fertilizers are accounted both for production and emissions through a nutrient balance according to average physiological requirements of the plants. Construction of all buildings and infrastructure was omitted, as is common in LCA studies [1]. Although farm machinery is often included [5] in LCA studies, in our case it was not possible to consider production and maintenance of farm machineries because of the lack of on-farm data.

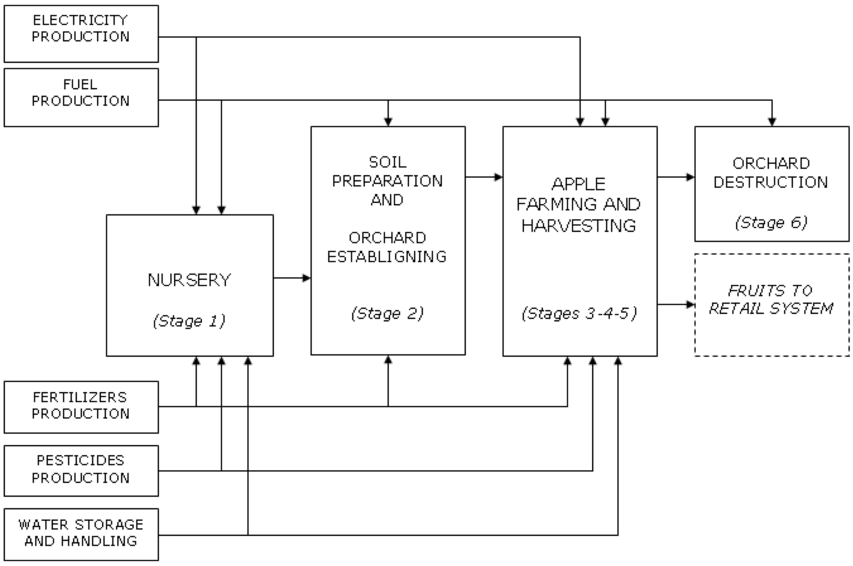

Fig.1: **System boundary and modelling of the apple production phase. Dotted box refers to processes that differ according to the three scenarios.**

The retailing phase has been modeled in three different scenarios according to the major supply chains that start from Piedmont orchards (Fig. 2). The three supply chains consist of the following steps: (A) direct selling; after harvest, fruits are collected in the retailing deposit, stored in refrigerators, then washed and processed for the selling directly in the store without packaging, just reusable bags, bins or paper shopping bags, (B) distribution to local markets; after collection and refrigerated storage, fruits are processed in plastic bins for transportation to regional wholesale markets in local fresh markets up to 150 km from the retailer deposit, than sold in paper shopping bags; (C) distribution to national markets; after collection and refrigerated storage fruits are processed in plastic bins for transportation to national wholesale markets up to 800 km, were fruits are both packed for large-scale distribution and sold without packaging to local fresh markets in paper bags. Distances and means of transportation were obtained primarily from the farmers, the processing industry and relevant websites. The inventory data on the transport was obtained by assuming truck "specifics" as modeled by the GaBi 4 Professional Database. For all the transportation an average load of 85% was assumed and backhaul journeys were not considered because of modern logistic providers try to avoid as much as possible to move empty vehicles, and often the returning journey is utilized for move products from other systems. Plastic containers have been modeled according another LCA case on fruit packaging [11].

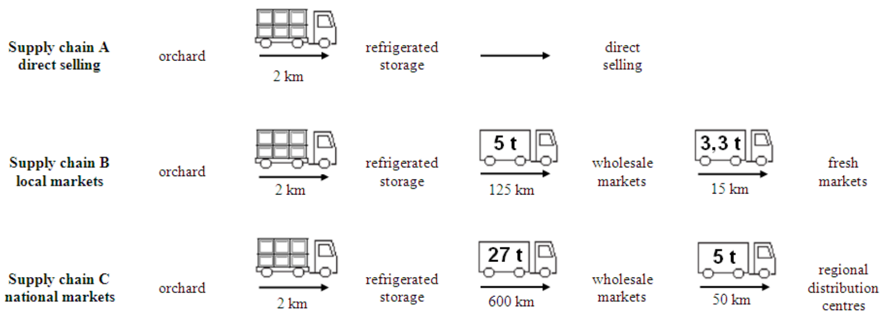

Fig.2: Schematic description of transport channels for the considered supply chains.

Storage and consumption within the consumer's house have not been included because of the high variability of possible situations in consumer's behaviours [12].

The functional unit was 1 kg of 'Golden' apple delivered to the consumer. This is consistent with the general function of a supply chain from the perspective of the major Piedmont retailers, and it is also the most commonly used functional unit for such kind of studies [e.g. 1, 5, 6]. As the cultivar was the same for the three supply chains, it was not necessary to consider more specific functional units such as nutritional values or income based units [12].

3 Results

3.1 Characterization

Based on the emissions estimated in the inventory analysis, the environmental impacts in the impact categories of the EDIP method was calculated. The impacts from the three supply-chains are illustrated in figure 3. The complete production phase (including annual and whole orchard processes) results in the main impact in the categories Acidification potential, Nutrient enrichment potential and Photochemical oxidant potential. In contrast, the contribution of the production phase to Ozone depletion potential is below 35% of the total impact, in the three scenarios. The contribution of the retail phase from scenario A to C increase slightly in most of the impact category, but dramatically in Global warming potential. Most precisely in the complete supply-chain of a kilogram of Golden Deliciuos apples collected into an average Piedmont retailer, the Global warming potential ranges from 0.0661 to 0.1221 kg CO_2-Eq. The production phase accounts for 0.0622 kg CO_2-Eq in all of the scenarios; on the contrary contribution of greenhouse gasses from the retail phase varies very much. Retail phase in scenario A accounts for 0.0038 kg CO_2-Eq (5,84% of the whole Global warming potential of the scenario) although it includes storage, processing and direct selling only. The retail phase of the other two scenarios include packaging and transport as well, and it account for 0.0919 kg CO_2-Eq (59,65%) and 0.1221 kg CO_2-Eq (66,25%) in scenario B and C respectively.

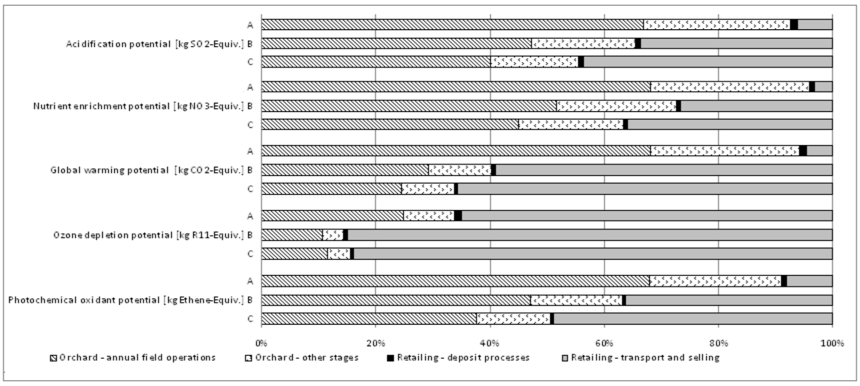

Fig.3: Hotspot analysis for the three supply chains. "Orchard – other stages" considers: nursery stage, installation and destruction of the orchard, low production years due to young and old plants. "Retailing – deposit processes" considers: storages, processing and selling of fruit.

3.2 Normalization and weighting

In order to be able to assess the impact of the different impact categories compared to the impacts that an average person would otherwise be responsible for, the results were normalized and according to the EDIP method (1997). The results of the characterization were normalized with reference to the total impacts of activities in Europe. The unit of the normalized results is person equivalents (PE) which corresponds to the impact one person have in a given category. The dominating impact categories are similar to those commonly identified in agricultural LCAs; Global warming potential, Nutrient enrichment potential and Acidification potential (Fig. 4). Those three categories have almost the same values in supply chain A (from 5.59E-06 to 7.59E-06 PE), but they wary in supply chain B and C with a dominant contribution of Global warming potential (1.77E-05 and 2.12E-05 PE in B and C respectively).

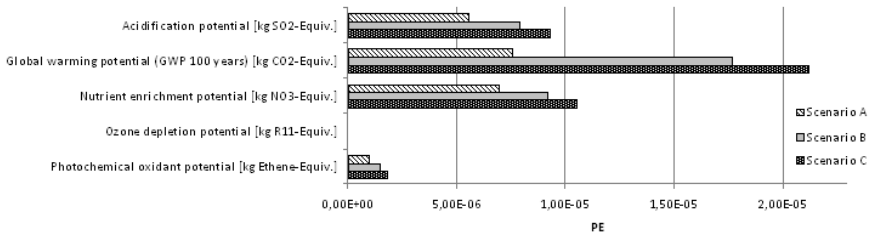

Fig.4: Normalized impact assessment for 1 kg of Golden Delicious produced in Piedmont, at the end of three main supply chain scenarios.

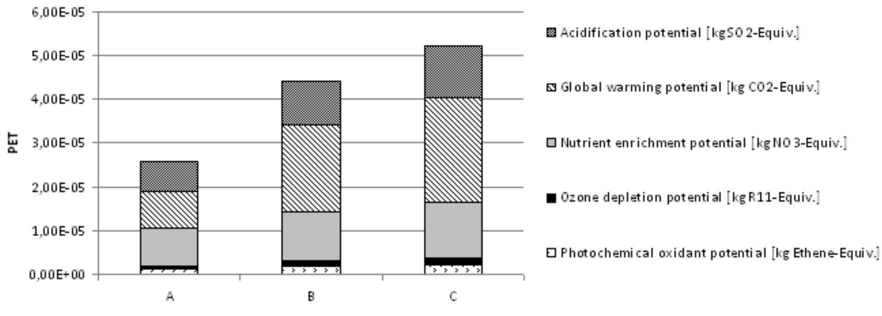

Fig.5: Weighted results (EDIP method 1997) presented as the sum of the weighted personal equivalent (PET) for each investigated supply chain A, B and C.

In order to compare the total environmental impacts of the three scenarios against each other, weighing was performed in accordance with the EDIP (1997). In this method, political targets are used to scale the importance of the different impact categories against each other. The unit of the results are person equivalents according to the target that are given for the future. The results are presented in figure 5, and shows that supply chain A results in 2.71E-05 PET; supply chain B, results in 4.60E-05 PET and supply chain C results in 5.42E-05 PET. According to this weighting method to total impact of distributing apples on national markets are this approximately twice as big as at the local market, indicating the impact of transportation is a great importance.

4 Conclusions

As scenarios were set-up considering the same production phase (as average values of the investigated orchards in Piedmont) it was obvious that the longest supply chain would present the largest environmental impact. Therefore, the purpose of the study was not to compare the three scenarios in terms of which supply chain results in the largest impacts, but more to quantify the impacts of the various parts of the supply chain.

As expected, the complete production phase contributes significantly to the environmental impacts of the direct selling scenario (supply chain A) and decreases in percentage with increasing transport distance. Considering the weighted results from all impacts categories, the production phase contribute 92% of the environmental impacts in supply chain A, 54% in supply chain B and 46% in supply chain C. That means that transportation from producers to consumers plays an important role in determining the environmental impacts of apple supply-chains in Northern Italy. Particularly, in the longest supply chain, more than a half of the environmental impacts are due transportation.

As highlighted in previous works [5, 9] the application of LCA just to full production years will underestimate the environmental impacts of the production phase. In our study, field processes out of the full production years (such as nursery, installation, low yield years etc.) contribute from 13 to 26% of the weighted values of the assessment for the whole supply chain, in scenario C and A respectively and contribute of 28% of the weighted impacts of the whole production phase.

Furthermore, from figure 5 it can be easily seen that the contribution to the overall environmental impacts (expressed as the sum of weighted contribution per impact category) remains almost constant in the three scenarios except for Global warming potential that varies from 8.51E-06 PET in scenario A to 1.98E-05 and 2.37E-05 PET in scenario B and C respectively.

5 References

[1] Sim S., Barry M., Clift R., Cowell S.J., The relative importance of transporting in determining an appropriate sustainability strategy for food sourcing, International Journal of LCA, Vol. 12, No. 6, 2007, 422-431.

[2] Clemente G., Escobar N., Sanjuan N., Anton A., Orange juice, which one should I drink? VII International conference on life cycle assessment in the agri-food sector, Bari, 2010, Vol. 2, 253-258.

[3] Van Passel S., Food miles to assess sustainability: a revision, Sustainable Development, 2010, DOI: 10.1002/sd.485.

[4] Garnett T., Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food policy, Vol. 36, 2011, S23-S32.

[5] Mila i Canals, L., Clemente Polo, G., Life cycle assessment of fruit production. In: Mattsson, B., Sonesson, U. (Eds.), Environmentally friendly food processing. Woodhead Publishing Limited and CRC Press LLC, Cambridge and Boca Raton, 2003, 29–53.

[6] Blanke M.M., Burdick B., Food (miles) for thought – Energy balance for locally-grown versus imported apple fruit, Environmental science and pollution research, Vol. 12, No. 3, 2005, 125-127

[7] Cholette S., Venkat K., The energy and carbon intensity of wine distribution: a study of logistical options for delivering wine to consumers, Journal of Cleaner Production, Vol. 17, 2009, 1401-1413.

[8] Knudsen M.T., Environmental assessment of imported organic products. Focusing on orange juice from Brazil and soybeans from China. PhD Thesis, Aahus University, 2010.

[9] Cerutti A.K., Bagliani M., Beccaro G., Peano C., Bounous G., Comparison of LCA and EFA for the environmental account of fruit production systems: a case study in Northern Italy. VII International conference on life cycle assessment in the agri-food sector, Bari, 2010, Vol. 2, 99-104.

[10] Birkveda M., Hauschild M.Z., PestLCI—A model for estimating field emissions of pesticides in agricultural LCA, Ecological Modelling, Vol.198, 2006, 433–451.

[11] Singh P.S., Chonhenchob V., Singh J., Life cycle inventory and analysis of re-usable plastic containers and display-ready corrugated containers used for packaging fresh fruits and vegetables, Packaging Technologies and Science, Vol. 19, 2006, 279-293.

[12] Roy P., Nei D., Orikasa T., Xu Q., Okadome H., Nakamura N., Shiina T., A review of life cycle assessment (LCA) on some food products, Journal of Food Engineering, Vol. 90, 2009, 1–10.