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The Impact of Alternative Apricot Conservation Techniques on Global Warming Potential

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Some food production industries, like jams' and marmalades' ones, use as starting materials semi-finished products for seasonal, technical and quality reasons. To extend the shelf life of foodstuffs, to maintain low the level at which microbial spoilage and deterioration reactions occur, fresh fruits have to be treated. The industry under study uses two different techniques to produce and preserve semi-finished fruits: one is based on deep-freezing and one on ohmic aseptic treatment.

The aim of this work is to use a life cycle approach to compare the global warming potential (GWP) emissions of these two different techniques to guarantee the quality of semi-finished apricots to the customer. The GWP is determined using a detailed Life Cycle Assessment (LCA) analysis, normalizing to the functional unit (one apricots' kg) all the consumptions and emissions. Data were analysed using SimaPro 8.0.4 software, whereas the Ecoinvent database and information collected from the chosen industrial site were used for the life cycle inventory, according to the reference standard for LCA (i.e., ISO 14040-14044).

1. Introduction

At present, different research's branches show interest in attainment of natural, environment friendly food production, with high quality and extended shelf life (Gol et al., 2013). In particular, fruits are frequently treated to obtain semi-finished products to be used in industries, such as the one of jams and marmalades (Sesmero et al., 2007). The main scope of the food preservation is to limit foodstuffs' modifications with no or few alterations of chemico-physical and organoleptic properties, in order to maintain the fruit nutritional integrity (Torreggiani and Bertolo, 2001). Considering the increasing attention on environment protection and global warming potential (GWP) reduction, industries tend to proceed towards sustainable productions. An approach to determine, in a quantitative way, the environmental impact of a product, a process or a service throughout its life cycle is given by Life Cycle Assessment (LCA) analysis. Different papers were published in which LCA was used to quantify environmental emissions due to food productions (Andersson, 2000). For example, LCA was used to evaluate (Iannone et al., 2014) or to lower (Iannone et al., 2015) the environmental emissions related to the production of red and white wines. Other studies were made on tomato products (Karakaya and Özilgen, 2011), on citrus fruit production (Beccali et al., 2010) or on fruit powder production (De Marco et al., 2015a). In some cases, LCA studies are made comparing different solutions in order to choose the less impacting from the environmental point of view (De Marco et al., 2015b). The aim of this paper is to analyze and compare in terms of GWP different preservation techniques for semi-finished apricot production. The choice of preserve semi-prepared products instead of finished products and the one made by jams' and marmalades' industries to buy semi-finished products instead of fresh fruit are due to diverse reasons. For example, temporal reasons are due to the fact that canning industries deal their products during the whole year, nevertheless the fresh fruit production takes place in a limited period (de Ancos et al., 2000); therefore, the product has to be preserved in a period different from the production one and it is better to preserve semi-finished products because their economical value and their needed fixed assets are lower than the very high value of the finished product and of the plants needed to produce them. In particular, the industry under study uses two different techniques to produce and preserve semi-finished fruits: one is based on deep-freezing (Jiménez et al., 2008) and one on

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ohmic aseptic treatment (Parrott, 1992). The study has been validated using data set provided, for both the preservation techniques, by a Southern Italy industry. A gate-to-gate approach was used to perform the detailed LCA study, where all the industrial stages were considered in the system boundaries. A comparison, in terms of GWP, between 1 kg deep-frozen apricots' package and 1 kg ohmic aseptic apricots' package was performed.

2. LCA methodology

LCA is a method for determining, using a broad set of collected and organized data, the environmental impact of a product or a process through a life-cycle analysis. In that way, it is possible to compare different products or different life-cycle of the same product or to identify the most critical stages, from the environmental point of view, of a specific product. In the LCA methodology, some steps have to be pointed out: 1) goal definition and scope of the LCA analysis; 2) functional unit and system boundaries; 3) data collection and life cycle inventory.

2.1 Goal definition and scope of the LCA analysis

Goal definition is one of the most important phases of the LCA methodology, because entire study bases on the assumptions made at this step. The goal of this study is to evaluate the environmental impacts (with an in-depth analysis in terms of GWP) of the production of semi-finished apricots. In Figure 1, a flow sheet of the *gate-to-gate* process is reported with two different packaging lines: in the first one, apricots are frozen before packaging and, then, stored at -20°C; in the second one, they are ohmic aseptic packaged and stored at room temperature.

2.2 Functional unit and system boundaries

The definition of the functional unit (FU) is based on the mass of the product under analysis, and it is a reference to which all the inputs and outputs have to be related. The functional unit of this study is 1 kg of semi-finished apricots obtained by deep-freezing or ohmic aseptic packaged. The boundaries of the system include all the industrial stages, from apricots arrival to the factory to storage after packaging. The agricultural stages, the distribution of the products and the waste management were not included in the system boundaries.

2.3 Data collection and life cycle inventory

In Table 1, the main activities of the observed process are reported. The life cycle inventory (LCI) is one of the most effort-consuming step and consists on the activities related to the search, the collection, and interpretation of the data necessary for the environmental assessment of the observed system. Fresh apricots arrived at the factory by truck from different sources and, if they passed the quality control, they were stored under refrigerated conditions (3 °C) for three days before their processing. After storage, they were washed with water and calibrated. Therefore, they were cut and pitted; the apricots were, then, orientated with the halves previously filled by the pits undermost (cup-down) and treated with a mixture of hot water and caustic soda at 80 °C. The fluid corroded the porous external skin, which is separated from the pulp by a polishing machine. After a manual sorting, where all the fruit halves with defects were discarded, the apricots were fed into an automatic cutting machine to obtain apricot particulates (that, according to the customer's request, can be cubes, slices, cloves, slivers or flakes).

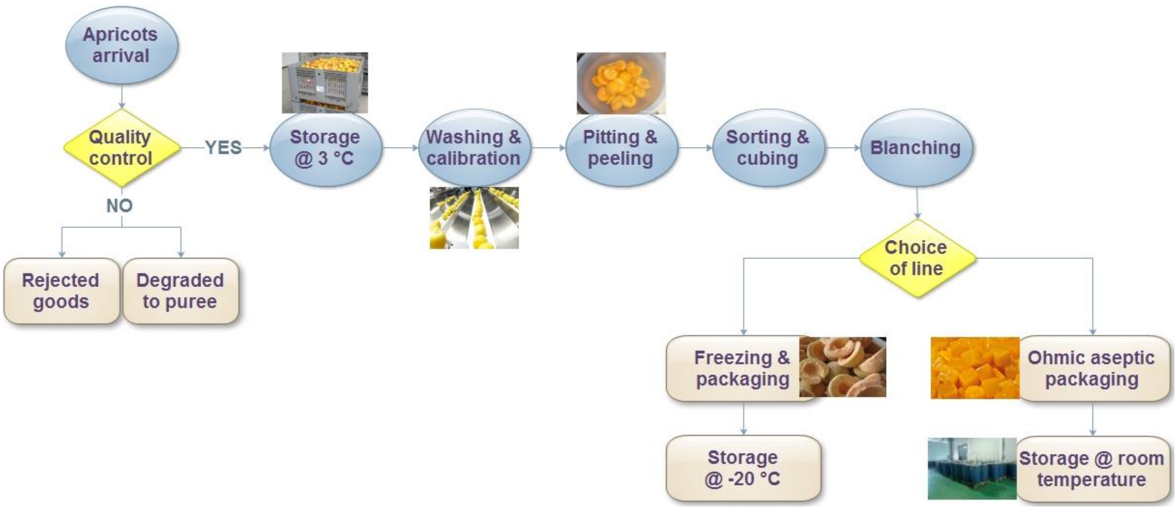

Figure 1: Flow sheet of the process.

Table 1: Process details and assumptions

Process	Characteristics and details
Apricots supply to facility	Transport by truck, 40 t from Caserta (CE) (distance = 80 km), from Canosa (BT) (distance = 150 km) and from Greece (distance = 850 km) and transport by large tanker by Greece (distance = 300 km)
Energy supply to facility	Italian energy mix low voltage
Storage	T=3 °C; t=72 h; energy supply for cooling
Washing and calibration	Energy and water supply
Decoring and peeling	Energy, water and sodium hydroxide supply
Sorting and cubing	Energy supply
Blanching	Energy and water supply
Deep-freezing	T = -20 °C; energy supply for cooling
Packaging	Energy supply, supporting materials and components supply
Storage	T = -20 °C; energy supply for refrigerated storage
Plant sterilization	T = 120 °C; t = 45 min; energy and water supply
Ohmic aseptic treatment	Energy supply
Packaging	Energy supply, supporting materials and components supply

Before packaging, the apricots were blanched in hot water at 90 °C for 90 seconds to avoid enzymatic reactions (like browning) and to remove the air entrapped in the apricot tissues. Two different packaging methods (as detailed in Table 2) were, at this point, used by the factory under study. In the first one, the apricots were IQF (Individually Quick Frozen) at -20 °C, packaged and stored at that temperature. In the second one, the plant was sterilized with saturated steam (at 120 °C for 45 minutes), then the plant conditions were cooled at 80 °C and 0.8 bar using sterile nitrogen; the apricots were, therefore, charged and the ohmic aseptic treatment was applied for 120 s, using a temperature equal to 90 °C; finally, the apricots were packaged and stored at room temperature. The two packaging solutions were compared from an environmental point of view.
The LCA study was conducted using the LCA software SimaPro 8.0.4 in accordance with the reference standard for LCA (i.e., ISO 14040-14044). The Ecoinvent 3.1 database was employed as the principal source of background data, but the majority of the processes and materials information required for the analysis are specific of the observed system and collected using “primary data”. For each unit process within the system boundary, input data, such as energy, water, natural sources and output data in terms of emission to air, water and soil were collected. Table 2 lists the main energy and direct material input to the product systems under the study of 1 kg packaged apricots.

3. Results and discussion

The aim of this study is the interpretation of the data collected through the LCI phase and the evaluation and comparison of the impacts related to two different semi-finished apricot productions. First of all, the results were interpreted using the fifteen midpoint categories defined by the IMPACT 2002+ life cycle impact assessment method: carcinogens (C), non-carcinogens (NC), respiratory inorganics (RI), ionizing radiations (IR), ozone layer depletion (OLD), respiratory organics (RO), aquatic ecotoxicity (AET), terrestrial ecotoxicity (TET), terrestrial acidification/nitrification (TAN), land occupation (LO), aquatic acidification (AA), aquatic eutrophication (AE), global warming potential (GWP), non-renewable energy consumption (NRE) and mineral extraction (ME). Then, the environmental emissions were linked to four damage categories: human health, ecosystem quality, climate change and resources. Finally, a comparative in-depth analysis that takes into account the single steps of the two processes was made in terms of GWP.
The emissions in terms of midpoint categories related to the two different productions are reported in Table 3 and the relative contributions are graphically reported in Figure 2. It is evident that the process based on the deep-freezing generated higher emissions in terms of all the midpoint categories, with the exception of RO, for which the emissions of the two processes are comparable. This is due to the high quantity of electricity used to freeze the apricots and to maintain the temperature at -20 °C during the final storage of the product before its distribution. The environmental impacts were then grouped, according to IMPACT 2002+ method, considering the damage on the endpoint categories. Figure 3 shows for both the productions the emissions in terms of normalized four damage categories. Emissions related to frozen-apricots production are higher on each of the four categories; considering the total emissions, the frozen-apricots process impacts 1.55E-04 mPt vs 1.11E-04 mPt of the aseptic-apricots process. The higher difference between the two productions is related to the climate change. In order to understand the contribution of each stage of production, an in-depth analysis was made, evaluating the GWP of each step of the two processes. The results are shown in Figure 4, from which it is clear that the higher contribution on GWP of the production of frozen apricots is due to the final storage at -20 °C (32 % of the total emissions), followed by freezing (27 %) and, then, by transportation (14 %).

Table 2: Life cycle inventory of the main inputs and outputs for semi-finished apricots' production.

Industrial Phase	Input/Output	Unit	Frozen	Aseptic
Transportation	Apricots	kg	1.31E+00	1.30E+00
	Transport by truck	tkm	4.83E-01	4.80E-01
	Transport by tanker	tkm	1.31E-01	1.30E-01
	Output			
	Apricots at factory	kg	1.27E+00	1.26E+00
	Waste	kg	3.92E-02	3.90E-02
Storage	Electricity	kWh	9.42E-03	9.37E-03
	Diesel	kg	6.29E-04	6.26E-04
	Output			
	Stored apricots	kg	1.24E+00	1.24E+00
	Waste	kg	2.54E-02	2.52E-02
Washing	Water	kg	7.46E-02	7.42E-02
	Electricity	kWh	1.24E-03	1.24E-03
	Output			
	Washed apricots	kg	1.23E+00	1.22E+00
	Waste	kg	1.24E-02	1.24E-02
Calibration	Electricity	kWh	4.10E-04	4.08E-04
Pitting	Electricity	kWh	1.48E-03	1.47E-03
	Output			
	Pitted apricots	kg	1.10E+00	1.09E+00
	Waste	kg	1.35E-01	1.35E-01
Peeling	Caustic soda	kg	8.22E-03	8.18E-03
	Electricity	kWh	3.29E-03	3.27E-03
	Water	kg	1.10E-01	1.09E-01
	Methane	m^3	9.99E-03	9.94E-03
	Output			
	Peeled apricots	kg	1.06E+00	1.05E+00
	Waste	kg	3.83E-02	3.82E-02
Sorting	Electricity	kWh	3.52E-03	3.51E-03
	Output			
	Sorted apricots	kg	1.03E+00	1.02E+00
	Waste	kg	3.17E-02	3.16E-02
Cubing	Electricity	kWh	3.08E-04	3.06E-04
Blanching	Electricity	kWh	1.79E-03	1.79E-03
	Water	kg	8.97E-02	8.93E-02
	Methane	m^3	8.18E-03	8.14E-03
	Output			
	Blanched apricots	kg	1.02E+00	1.01E+00
	Waste	kg	1.03E-02	1.02E-02
Deep-freezing	Electricity	kWh	2.15E-01	
	Output			
	Freezed apricots	kg	1.00E+00	
	Water	kg	1.52E-02	
Ohmic aseptic treatment	Electricity	kWh		6.87E-02
	Output			
	Aseptic apricots	kg		1.00E+00
Packaging	Polyethylene sack	kg	4.76E-03	
	Packaging film	kg	3.81E-02	
	Citric acid	kg	4.76E-03	5.66E-03
	Ascorbic acid	kg	3.17E-03	3.77E-03
	Cardboard	kg	4.76E-03	
	Pallet	kg	3.31E-02	1.18E-01
	Metallic barrel	kg		9.12E-03
	Aseptic sack	kg		3.77E-02
Final storage	Electricity	kWh	2.57E-01	

Table 3: IMPACT 2002+ midpoint results for semi-finished apricots' production. Data are referred to the FU.

Midpoint category	Unit	Frozen	Aseptic
C	kg C_2H_3Cl eq	8.32E-03	6.26E-03
NC	kg C_2H_3Cl eq	4.21E-03	3.19E-03
RI	kg PM2.5 eq	4.18E-04	3.04E-04
IR	Bq C-14 eq	7.65E+00	3.55E+00
OLD	kg CFC-11 eq	1.61E-07	1.30E-07
RO	kg C_2H_4 eq	3.10E-04	3.12E-04
AET	kg TEG water	6.30E+01	5.16E+01
TET	kg TEG soil	9.25E+00	5.84E+00
TAN	kg SO_2 eq	9.48E-03	7.27E-03
LO	m^2 org.arable	1.99E-02	1.72E-02
AA	kg SO_2 eq	2.63E-03	1.86E-03
AE	kg PO_4 P-lim	2.20E-04	1.91E-04
GWP	kg CO_2 eq	4.84E-01	3.03E-01
NRE	MJ primary	7.76E+00	6.17E+00
ME	MJ surplus	1.52E-02	8.27E-03

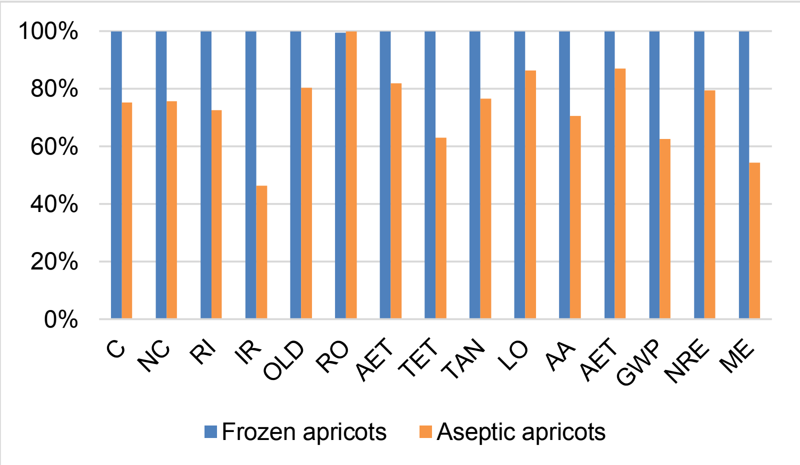

Figure 2: Relative contributions of semi-finished apricots production per FU.

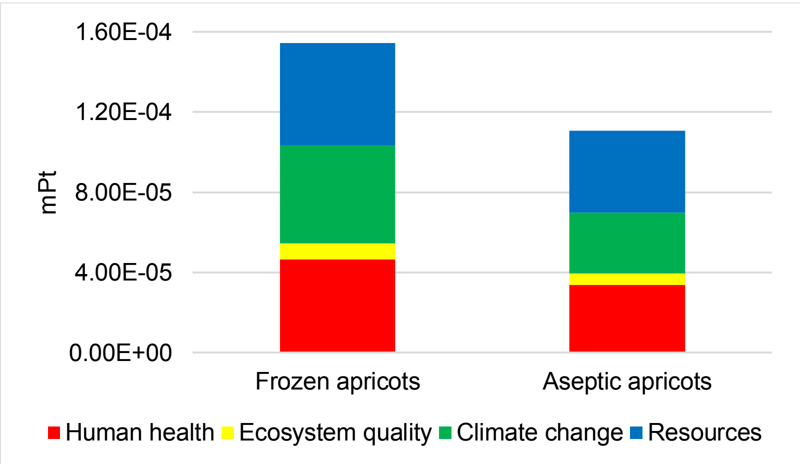

Figure 3: Total environmental impact according to the four main endpoint categories of IMPACT 2002+ method on relative scale (millipoint, mPt).

In the case of the production of aseptic apricots the higher contribution on GWP is due to packaging (38 %) followed by transportation (23 %) and, then, by the ohmic aseptic treatment (13 %).

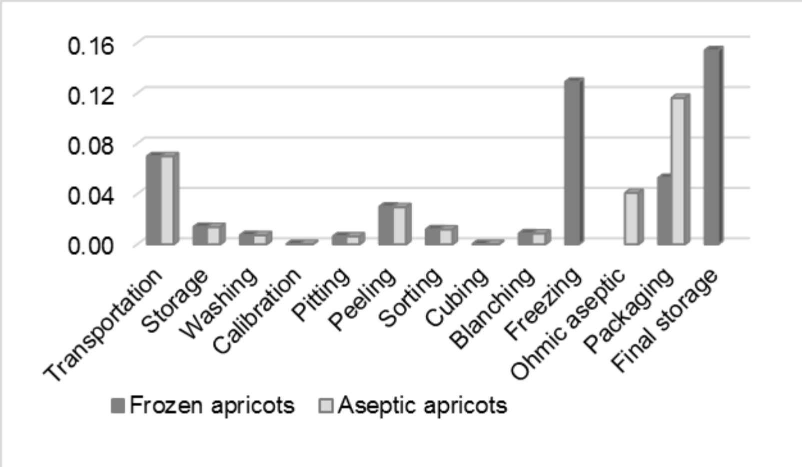

Figure 4: GWP (kgCO₂eq)/FU of the two processes.

4. Conclusions

In this work, a comparative LCA analysis on two different semi-finished apricot productions was performed, considering a “from gate to gate” analysis. The process based on the deep-freezing has higher impacts on all the midpoint categories, due to the very high quantity of electricity needed for freezing and storing the semi-finished apricots at low temperature. Considering that this impact cannot be lowered unless varying the process, the ohmic aseptic has to be considered the preferred method to produce semi-finished apricots from the environmental point of view. A further step could be the inclusion in the boundary system of the waste management that is different for the two processes mainly because of the packaging solutions.

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