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Contribution of Anhydrous Milk Fat to environmental impacts generated by the dairy processing

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ABSTRACT / RESUME

Milk constitutes an important ingredient in the Algerian population diet. it is obtained by recovering process from milk powder or the recombination-based milk powder and anhydrous milk fat (AMF). These are the two main processes in place in Algerian dairies. In this study, carried out in a dairy processing situated in Boudouaou (Algiers), a comparative analysis of these two processes was conducted in order to determinate the contribution to environmental impacts of different basic elements of manufacturing milk. The approach used was based on the life cycle assessment (LCA), which is a standardized method (ISO 14040-14044). Results showed that the milk powder is the main hot spot in almost all the categories under assessment. Furthermore, adding the AMF has allowed the reduction of all impacts of the order of 3 to 6% resulting in a decrease of 4.74 E-02 kgCO_2eq of Global Warming Potential, 0.21MJ of the consumption of non-renewable energy, a reduction of 2.60 E-03kg SO_2eq for terrestrial acidification/nitrification potential. A decrease of 0.16kg TEGsoil is recorded to terrestrial ecotoxicity and 2.80 E-05kg PM2.5eq to respiratory inorganics.

I. Introduction

The focus on sustainable development in recent years in the food industry mainly environmental aspects has motivated the emergence of several evaluation studies in this sector in particular the dairy industry. The most used tool was the Life Cycle Assessment (LCA) witch is a performing tool for environmental management that provides knowledge about the environmental impacts associated with a product or human activity. Several authors assessed the environmental impacts generated by milk production have used this method **[1-5]**. Various authors **[6,7]** used the LCA method to compare the modes of production of milk. LCA was also used by some other authors **[8-12]** in plants transformation. LCA was also used to measure the environmental impact of dairy derivatives such as cheese **[12,13]**, yogurt **[14]** and butter **[15]** and to compare the impact of different methods of cleaning in place (CIP) in dairies. The Algerian dairy industry mainly operates on the basis of imported raw materials i.e. milk powder and anhydrous milk fat (AMF). Technologically, two transformation processes allow us to obtain pasteurized milk: reconstitution and recombination. The first process consists in rehydrating the whole milk powder while in the second process; the finished product is obtained from a mixture of reconstituted milk, based on skim milk powder and AMF. A lack of studies on the environmental analysis of reconstituted milk powder was observed, hence the interest of this approach to determine the impacts of various basic elements of this product. The study was carried out at a dairy processing plant in Algeria to assess the environmental impacts of the main constituents of pasteurized milk, especially the AMF used in the process of recombination.

II. Materiels and methods

The method used in this study was LCA, an environmental assessment tool standardized according to ISO 14040 (ISO, 2006a) and 14044 (ISO, 2006b). LCA methodology includes four major stages: goal and scope definition, life cycle inventory (LCI), life cycle impact analysis (LCIA) and interpretation of the results (ISO, 2006a). In the goal and scope phase, a functional unit, system boundary and allocation procedures are defined, depending on the subject and intended use of the study. For the LCI, all input and output processes are defined, quantified and summarized. The LCI is linked to environmental impact categories and indicators by the LCIA, and interpreted relative to the FU. SimaPro7.1.5 was used as support software in this study. System boundaries of this study encompass production of raw materials (milk powder, raw milk, AMF), milk processing, packing production (polyethylene, metal drums), and transportation of the raw materials to the milk plant. The delivery of final product from the dairy factory to retailers was excluded from the system boundaries as well as the consumption phase of the product **[9,12].** Production of capital goods (machinery and buildings) was excluded from the study in accordance with several studies **[7,8]**. Production, transportation and use of detergents and disinfectants were also excluded from this study **[3]** as well as the different scenarios of waste management.

Inventory analysis

The inventory analysis involves the collection of data concerning resource use, energy consumption, emissions, and products resulting from each activity in the system studied. In this study, inventory data for the dairy factory were collected by means of surveys, interviews and visits to the plant. The data processing steps, transportation, energy and packaging were collected from the Boudouaou dairy plant which refers to 2013.

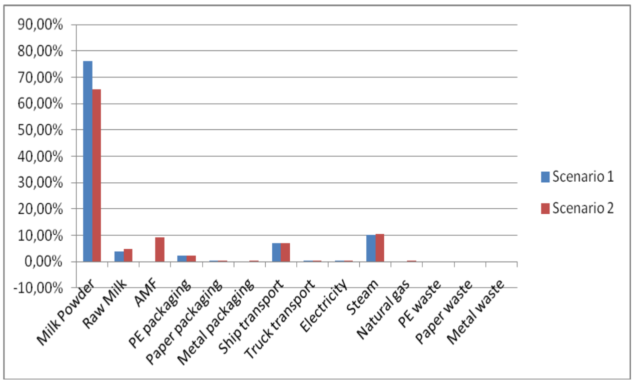
III. Results and discusion

The results for the characterization step are shown in Table 1 referred to the functional unit. The values of impacts related to the production of reconstituted milk are higher than those of the recombined milk and in order to determine the origin of these impacts, we will discuss the contribution of both systems to main categories of impact.

Respiratory inorganics

This type of impact (Fig.1) represents the health hazards caused by breathing inorganics particles released into the air, in kg equivalent PM2.5. Table 2 shows that for 1 liter of milk, this impact in scenario1 is more important than the scenario2 of the order of 0.17 E-4kg PM2.5eq. This difference is attributed to the milk powder which is the main contributor in both scenarios (76% vs. 65.5%). The adding of the AMF in scenario2 will decrease this value of the order of 0.713 E-4kgPM2.5eq (9.12%). The amount of raw milk in the scenario2 was higher than in Scenario1, this will play a role in the reduction of the order of 0.071 E-4kgPM2.5eq of this impact. The production of steam also plays a role in this impact category where it intervenes at 10% of the overall impact at both scenarios, because milk reconstitution requires large amounts of hot water and steam (It takes about 1 to 12 liters of water heated to 400°C to reconstitute 1 liter of milk). The steam was used mainly in the processing operations including milk pasteurization. These two energy sources are generally produced in boiler fuel (fuel used in the dairy industry) resulting in the emission of carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NOx). According to the operation of the boiler, unburned can be produced, giving rise to the emission of solid particles. A contribution of 6.88% of transport by ship was noted at both scenarios. Indeed, the environmental impact of shipping was accompanied by emissions of different gases (CO_2, NOx, SO_2 and CO) and fine particles smaller than 2.5 microns. The PE packaging production intervenes at 2.17 and 2.25% respectively in both scenarios. In fact, the production of 1kg of PE generates 12g of NOx, 9g of SOx, 16.6 g of NMCOV and 3g of particles (BUWAL 250, 1996). The contribution of the remaining elements was <1% of the overall impact. These values were considered negligible. We can therefore conclude that this impact category was attributed mainly to the milk powder and the use of the AMF contributed to the reduction of 3.46% of this impact.

Figure.1: *Contribution to respiratory inorganics (for 1l of milk)*



Global Warming

This effect contributes to the climate change (Fig.2). It is due to the greenhouse gas (GHG) emissions such as CO_2, CH_4, and N_2O. It is expressed in $kgCO_2eq$. As shown in Table 1, for 1 liter of milk, the GWP was higher in the Scenario1 of the order of 2.60 E-02kgCO$_2$eq (4.28%). These emissions were mainly attributed to the milk powder, whose the contribution in Scenario1 was greater than that in scenario2 of the order of 77.10 and 66.78% respectively. This is explained by the need to use a large quantity of milk for the production of milk powder (it takes about 7.8 kg of milk to make 1 kg of powdered milk (LCA Food) and several studies confirmed that the production of raw milk is the main source of GHG (Eide, 2002; Hospido et al, 2003; Castanheira et al, 2010; Fantin et al, 2012; González-García et al, 2013). In the same way, the production of raw milk added in both process intervenes at the rate of 3.34 and 4.29% respectively. The manufacture of PE packaging and transport ship, come at a same rate (≈ 2.63%) in both scenarios. The production of PE emanated several GHG (per 1 kg of PE, 2.32 kg of CO_2 4.4 g of CH_4 and 12g of NOx were emitted) (BUWAL250, 1996). The impact of thermal energy was important for both scenarios (13.28 and 13.87%) respectively, this was observed in the various processing operations, because the pasteurization of milk requires great amount of steam. The production of the latter requires natural gas, which generates greenhouse gases both in its production than consumption (boiler). The impact of other Process was considered negligible (<1% of the total impact). For 1 liter of milk, the use of the AMF in the second scenario contributed at 8.16%, this allowed the reduction of the order of 4.28% of the impact.

Terrestrial acidification/nitrification

The terrestrial acidification (Fig.3) is mainly caused by atmospheric deposition of acidifying compounds such as SO_2, NOx, NH_3,.... etc.. It is expressed in equivalent $kgSO_2$. For one liter of milk, the total contribution to the terrestrial acidification and nitrification was 6.64E-02 kgSO$_2$eq in Scenario1 and 6.38E-02 kgSO$_2$eq in scenario2 (Table 1). The difference between the two scenarios was mainly due to the milk powder which represents 89.91% of the impact in scenario1 and 77.43% in scenario2. The impact of raw milk in both scenarios was about 4.55 and 5.83% respectively. Its production was the main contributor to acidification **[1,4,8,12].** The production of steam followed by ship transport, contributed in both scenarios up to 2.50% and 2.06% respectively. The AMF contributed in scenario2 with 6.97E-03kg SO$_2$eq (10.92%), hence a reduction of this impact of about 2.60 E-03 kg SO$_2$eq.

Figure.2: *Contribution to the global warming potential (for 1l of milk)*

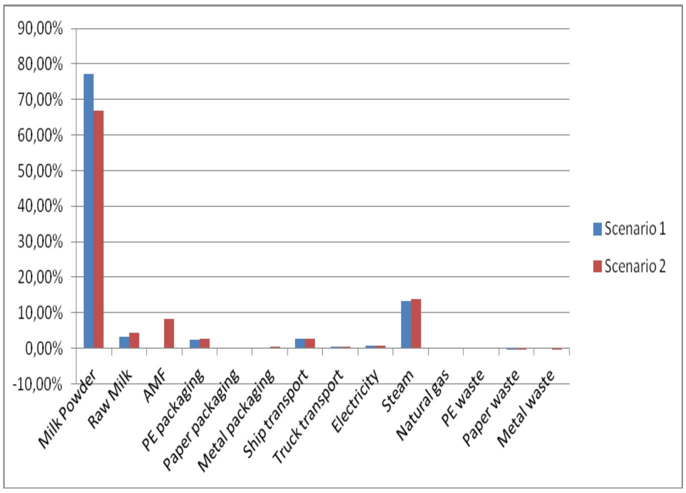
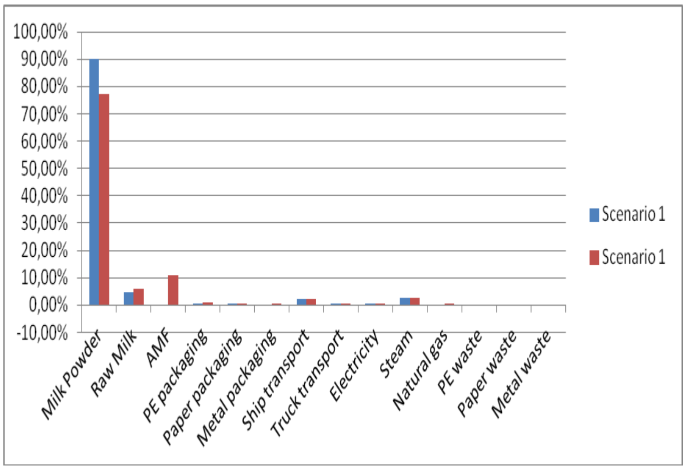


Figure.3: *Contribution of two processes in terrestrial acidification (for 1l of milk)*



Availability of data

The inventory data is a crucial step in any LCA study. However, accurate inventory data are not always available **[7].** Most LCA on the dairy industry are focused on the primary production of milk "cradle-to-farm-gate" **[1-7]**. There are very few studies on the impacts of milk processing plants **[8,9-12]** and no studies have addressed the reconstitution milk production or milk powder. Hence the difficulties in comparing our study to those mentioned above. It is important to note that few authors have included in their studies respiratory inorganics and ecotoxicity categories, mostly due to the lack of available information **[7,17].**