Environmental Impact Assessment of the Portuguese Dairy Sector

Castanheira, É. G.[1]; Dias, A. C.[2]; Ferreira A. J. D.[1]; Pereira, C. J. D.[1]; Arroja, L.[2]; Carreiras, M.[1]
[1] *CERNAS, Escola Superior Agrária de Coimbra, Instituto Politécnico de Coimbra, Bencanta, 3040-316 Coimbra, Portugal.* ecastanheira@esac.pt
[2] *CESAM, Departamento de Ambiente e Ordenamento - Universidade de Aveiro, Campus Universitário Santiago, 3810-193 Aveiro, Portugal*

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ABSTRACT

Dairies typically present a set of environmental impacts, namely high water and energy consumption, and discharge of wastewater with high organic load. Therefore, this sector of activity requires an effective evaluation of their environmental impacts at national level. This evaluation must address each one of the different productive processes, together with an evaluation of the global environmental impacts. The present study contributes to this evaluation through the use of LCA as an environmental management tool. It evaluates the global environmental impacts of the dairy industry in Portugal, and analyses the individual impacts associated to the main cow milk based products: milk for consumption, yoghurt and cheese. The results allow us to define the key issues for the implementation of measures to minimize the identified impacts.

This tool proved to be valuable for both the private entrepreneur community and the public governmental authorities, and should result in the adoption of good practices or implementation of the legislation in force. This study also allowed to pinpoint the gaps of information in what concerns the consumption of energy and resources and the emission of pollutants, in all the stages of the life cycle of dairy products in Portugal.

Introduction

Dairies industries are characterized by presenting several environmental impacts, namely high water and energy consumption, and discharge of wastewater with elevated organic loads. By this reason, it is urgent to do an effective evaluation of the environmental impacts associated to each one of the different productive processes of this sector in Portugal, as well as an evaluation of the global environmental impact.

This study intends to contribute to this evaluation through the use of Life Cycle Assessment (LCA) as a tool for environmental management. LCA is a methodology that evaluates environmental impacts associated to a product, process or activity throughout all its life cycle, through the identification of the needs of energy and resources and the produced emissions and wastes. LCA has also been applied to the diary sector in other European countries. For example, in Norway, LCA was applied to the industrial milk production [9], whereas in Sweden it was applied to the milk production [3] and to the production of cheese [1]. In Germany, LCA was also applied to the production of milk and to the main impacts associated to agriculture [3, 7].

The objective of this work was to apply the LCA technique to the Mainland Portugal dairy sector, more specifically to the productive processes of milk for consumption, yoghurt and curd cheese from cow milk. These products were selected because about 85% of the raw cow milk produced in Mainland Portugal in 2005 was used in their production.

Methodology

The methodology used in the present study is consistent with ISO 14040 and 14044 standards [14, 15]. According to these standards, LCA comprises four distinct phases: goal and scope definition, inventory analysis, impact assessment and interpretation.

Goal and Scope Definition

The goal of this study was to evaluate the environmental impacts associated to the dairy sector in Mainland Portugal, for the year 2005, as well as to identify the relative contribution of each one of the different cow milk products, namely: milk for consumption, yoghurt (including other acidified milk byproducts) and curd cheese.

The functional unit for this study was the amount of raw milk collected from cows, in Mainland Portugal, in 2005, for milk, yoghurt and cheese curd production (1626880 tonnes).

The boundaries of the system include the phases of raw milk production and raw milk processing. The processes considered in each one of these phases are indicated in Table 1. The stages of use/consumption and final deposition of the products were excluded from this study, as well as packing production, transport of products to the final user and capital goods production (equipment, buildings).

Table 1. Sources, period and geographical origin of data.

Life cycle phase	*Process*	*Source*	*Period*	*Geographical origin*
Raw milk production	Fertilizer production	[17]	1999	Denmark
	Animal's food production			
	Lubricant production			
	Energy production			
	Transport			
Raw milk processing	Raw milk fluxes	[12]	2005	Mainland Portugal
	NaOH (100%) production	[2]	1990-1994	Occidental Europe
	Acid solution production	[6]	1990-1994	Occidental Europe
	Thermal energy production	[6]	1990-1994	Occidental Europe
	Electricity production in Portugal	[2]	1990-1994	Occidental Europe
	Milk, yoghurt and curd cheese production	[13]	2002	Europe (average values)

Inventory analysis

The inventory analysis was carried out throughout the conception of flowcharts for the productive processes under study and the compilation of the respective data of inputs and outputs. Table 1 presents the source and the temporal and geographic coverage of the data used for each process.

SimaPro 7 was used as support software in this study.

Impact assessment

According to ISO, the environmental impact assessment may include the following phases: selection of the impact categories, classification (the inventory parameters are assigned to each impact category), characterization (the inventory parameters are affected by characterization factors), normalization, grouping and weighting. In this study the impact assessment was made only until the phase of characterization.

The impact categories considered in this study were Global Warming for a horizon of 100 years (GW100), Photochemical Oxidation (PO), Acidification (A) and Eutrophication (E). The inventory parameters associated to each impact category and the source of the characterization factors used in this study are presented in Table 2.

Table 2. Impact categories, associated parameters and characterization factors.

Impact category	***Parameters***	***Characterization factor (source)***
Global Warming (GW100)	CH_4, CO_2, N_2O	[10]
Photochemical oxidation (PO)	CH_4, SO_x (includes SO_2)	[5, 16]
Acidification (A)	NH_3, SO_x, NO_x	[11]
Eutrophication (E)	NO_3^-, NH_3, CQO, NO_x, PO_4^{3-}	[8]

Results and Discussion

The number of inventory parameters considered in this study is very high, summing a total of 431 parameters. For this reason, only the parameters considered as the most significant are presented and analyzed, namely, ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), sulphur and nitric oxides (SO_x and NO_x), chemical oxygen demand (COD) and nitrates (NO_3^-). Figure 1 shows the relative contribution of each product life cycle for the considered inventory parameters.

The emission of NH_3 into the atmosphere amounted to 7370 tonnes, of which about 60% are related with milk for consumption (especially in the phase of raw milk production at farms), since the major part (59%) of the raw milk produced in Portugal is used for the production of consumption milk. As for NH_3 emissions, about 60% of the 32400 tonnes of CH_4 emitted are related with the production of consumption milk.

The curd cheese production was the major contributor to CO_2 emissions, being responsible for half of the CO_2 emissions in the dairy sector in Portugal (694000 tons), even though only about 35% of raw milk produced in Portugal in 2005 was employed in the production of curd cheese. This is due to the higher consumption of different forms of energy during the processing of curd cheese. This situation is also verified for the emissions of SO_x.

The production of milk and curd cheese have similar contributions (approximately 45%) to the global NO_x emission of the dairy sector (2760 tonnes).

The production of milk has the largest contribution to COD and NO_3^- emissions, which are responsible for the contamination of superficial and underground water. This fact is justified because, although the processing of

milk is associated to a lesser wastewater production in comparison with the processing of curd cheese, the amount of raw milk going to the production of milk for consumption is significantly higher. Of the 68100 tonnes of COD discharged in the water lines from the dairy sector, 53% are due to the production of milk for consumption, 42% to the cheese production and 6% to the yoghurt production. The 47900 tonnes of NO_3^- emitted in this sector are basically due to the production of raw milk at farms.

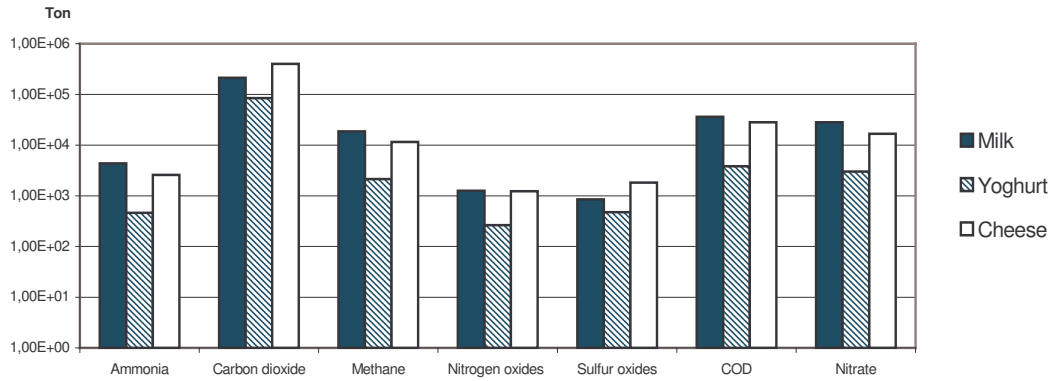

Figure 1. Inventory analysis results (logarithmic scale).

It should be noted that the yoghurt production has a relatively small contribution for the considered inventory parameters in comparison with the other two products, as only 6% of collected raw milk in Mainland Portugal in the year of 2005 was used in its production. The highest contribution of this product was around 15% and it refers to the emission of SOx.

The contribution of each product life cycle for the considered impact categories is presented in Figure 2.

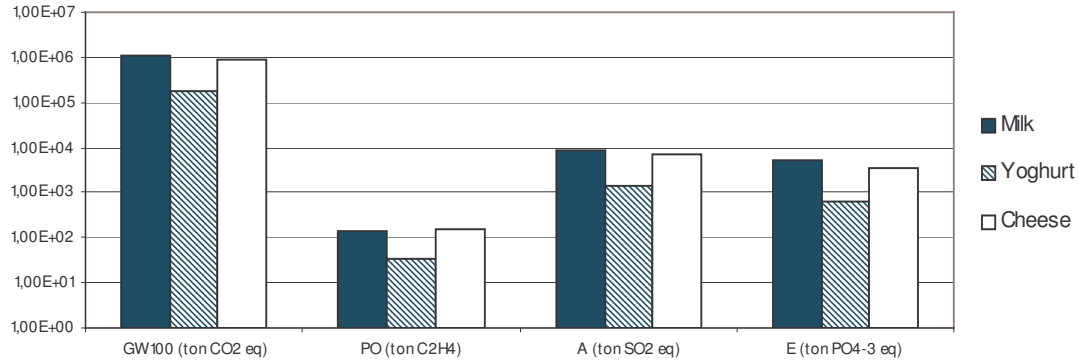

Figure 2. Impact assessment results (logarithmic scale).

The production of milk for consumption has the largest contribution to global warming (49%), acidification (51%) and eutrophication (57%), whereas the production of curd cheese has the main contribution to photochemical oxidation (42%).

The emissions of CH_4, CO_2 and N_2O have similar contributions to the global warming impact category, being that N_2O and CH_4 emissions are more significant for the production of consumption milk, and CO_2 emissions are higher for the production of curd cheese.

The emissions of CH_4 and SO_x, are responsible for about 58% and 42% respectively of the photochemical oxidation, being that CH_4 emissions are more important in the milk life cycle, whereas SO_x emissions are more significant in the curd cheese life cycle.

The NH_3 emissions contribute almost in 70% for the acidification impact category, followed by the emissions of SO_x (21%). Emissions of NH_3 are higher in the milk production, whereas the emissions of SO_x are more significant in the curd cheese production.

The eutrophication is largely due to NO_3^- emissions, although COD and NH_3 emissions have also remarkable contributions to this impact category. These emissions are mainly released in the production of milk for consumption.

The raw milk production is the phase of the life cycle that mostly contributes to all impact categories.

Conclusions

The use of a quantitative tool for impact evaluation such as LCA makes it easier to accomplish the objectives of this study, namely the identification of the productive processes with the largest environmental impacts and the most significant impacts to which mitigation measures should be proposed. This fact is very relevant, either at the private or the governmental level, and should result in the adoption of good practices or implementation of the legislation in force. In addition, this study allowed us to identify the gaps of information in what respects to the consumption of energy and resources and the emission of pollutants, in all the stages of the life cycle of dairy products in Portugal.

The improvement of the environmental performance of this sector can be a solution for the consolidation in the national market and for the opening to new markets. Thus, tools such as LCA should be of widespread use in the identification and implementation of development strategies and marketing.

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