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LIFE CYCLE ASSESSMENT OF ORGANIC PARMESAN CHEESE CONSIDERING THE WHOLE DAIRY SUPPLY CHAIN

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ABSTRACT

Agriculture and food manufacturing have a considerable effect on the environment emissions: holdings and farms play an important role about greenhouse gas emissions and water consumption. This study aims at evaluating the environmental impact of one of the most important Italian DOP product: organic Parmesan Cheese. Environmental performances of the whole dairy supply chain have been assessed according to the life cycle assessment approach (LCA).

In this analysis Parmesan Cheese is made from an organic dairy farm in Emilia Romagna, which uses the milk from three different organic livestock productions.

Organic agriculture is different from conventional; the major difference is represented by the avoidance of the use of synthetic fertilizers and pesticides made in chemical industry process. Organic agriculture uses organic fertilizers to encourage the natural fertility of the soil respecting the environment and the agro-system.

In this case, life cycle approach is used to assess the carbon footprint and the water footprint of organic Parmesan Cheese considering the milk and cheese production. The object at this level is investigating the environmental impact considering the situation before some improvement changes.

The functional unit is represented by 1 kg of organic Parmesan Cheese; inventory data refer to the situation in year 2017 and system boundaries consider the inputs related to the cattle and dairy farm until the ripening (included).

The carbon footprint is investigated using IPCC 2013 Global Warming Potential (GWP) 100a method, developed by Intergovernmental Panel on Climate Change, and reported in kg of CO2eq. Otherwise, water footprint allows to measure the water consumption and in this work it is assessed using AWARE method (Available Water REmaining).

Keywords: Life Cycle Assessment (LCA), organic Parmesan Cheese, Carbon footprint, Water footprint.

1. INTRODUCTION

In recent years, the global food system has proved to be unsustainable (Mancini et al., 2019). Overall in this sector there is a need for a general sustainable development, being producers and consumers looking for reaching both environmental, economic and social sustainability (Mancini et al., 2019).

Parmesan Cheese is one of the most important Italian DOP product and its manufacturing is strictly controlled by its consortium. This consortium has also the task of draw up the regulations and its experts examine all the wheels before declaring the DOP certification. The production of Parmesan cheese is authorized only in a specific area, which included the provinces of Reggio Emilia, Parma, Modena and parts of the provinces of Bologna and Mantua.

Life cycle assessment is a method of identifying the environmental impact of a product or service by analyzing all associated inputs and outputs, based on system boundaries. The method is divided into: goal and scope, inventory, impacts and interpretation of results (Uctug, 2019).

The dairy sector is a very impactful activity, in particular as far as the milk production is concerned (Bava et al., 2018). Several publications have been done on this sector to analyze several products obtained by cow milk, showing how the ripening phase (Sanjuan et al., 2011), the packaging (Manfredi et al., 2015; Bertolini et al., 2016,) and the needs of refrigeration (van Middelaar et al.,2011) play a crucial aspect in defining the environmental impact.

Based on these premises, the aim of this study is carried out the impact assessment of a wheel of parmesan Cheese manufactured in a farm before some improvements planned to reduce greenhouse gas emissions and water consumption. Some planned improvements are, for example, the inserting of photovoltaic panels, the modernization of machines and the introduction of a new concentration plant for whey, which allows to reduce the number of truck trips for disposal.

2. METHODOLOGY

2.1. Life Cycle Assessment (LCA)

This study is based on an attributional LCA analysis, in accordance with ISO 14040 (2006) and ISO 14044 (2006), using software SimaPro 8.5.2.0 (PRé

Consultants). Ecoinvent and Agri-footprint and Methods have been used as secondary data database, when primary data have been not available. Carbon footprint and water footprint have been considered as impact categories in this study.
The carbon footprint is investigated using IPCC 2013 Global Warming Potential (GWP) 100a method, developed by Intergovernmental Panel on Climate Change, and reported in kg of CO2eq. Otherwise, water footprint allows to measure the water consumption and in this work it is assessed using AWARE method (Available Water REmaining).

2.2. Goal and scope

This study is carried out to assess the environmental impact of organic Parmesan Cheese, in particular investigating the carbon footprint and the water footprint considering first the milk and then the cheese production. Three different organic breedings of bovine produce the milk, which is then transported to the dairy factory and used to produce cheese. Inside the dairy farm several phases are need to obtain the Parmesan Cheese (as reported in Figure 1).

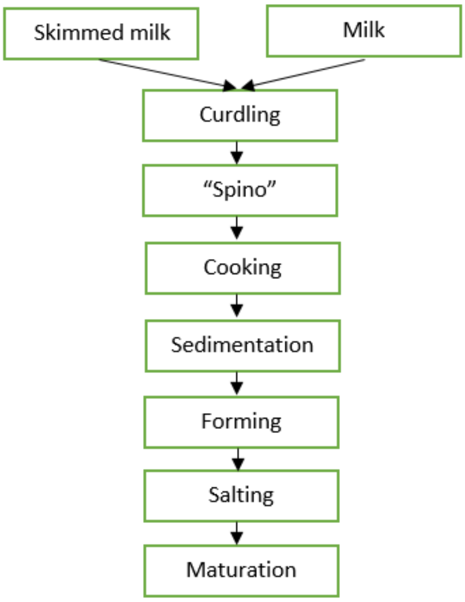

Figure 1: Parmesan cheese process

The considered dairy farm is located in Emilia Romagna (Italy); every day the evening cow milk is left to rest in large vats until morning of the day after to obtain the separation of the fattiest part. When the milk of the morning arrives from the three farms, this is added to the milk of the evening before and the blend is poured into bell-shaped copper cauldrons.
The next step is starting heating and adding to this blend the calf rennet and the whey obtained the day before. This mixture coagulates and produces the curd, which is broken into small granules using the "spino" tool. Then the cooking process starts and curd is heated to 55°C to obtain a single compact mass.

After about one-hour the cheese maker removes the cheese mass, which is then cut in two identical parts. Cheese wheels are wrapped in typical linens and placed in moulds to give the final shape.
Each cheese wheel has a unique number of identification. Some marking bands are used to mark the month, the year of production and the registration number around the circumference of cheese wheel. Then the cheese is immersed for few days in a solution saturated with salt. The final step is the ripening in maturation rooms.
The fattiest part of the milk is used to produce an organic butter, but this production process does not take place in this dairy farm.

2.3. Functional unit

In a LCA study, the functional unit (FU) is the reference for input and output data to quantify the performance of a product system (ISO 14040, 2006).
In this study functional unit is 1kg of organic Parmesan cheese. For each farm the unit of 1 kg of Fat and Protein Corrected Milk has been recreated, as suggested by IDF (2015):

$$FPCM\left(\frac{kg}{yr}\right) = Production\left(\frac{kg}{yr}\right) * [0.1226 * fat\% + 0.0776 * protein\% + 0.2534]$$

The term "Production" is the amount of milk produced while the percentage of fat and protein is related to the chemical analysis of each bovine herd. The amount of Fat and Protein Corrected Milk is used to reproduce the functional unit.

2.4. System boundaries

Environmental impact assessment is carried out from the "cradle-to-dairy gate", considering the cattle farms and the cheese production until the ripening phase, while packaging, distribution, consumption and packaging end-of-life are excluded.
Each farm has been analyzed separately with the aim of reproducing the daily quantity of Fat Protein Corrected Milk; subsequently the milk is used as input in parmesan cheese production process.
System boundaries generally includes the following phases:

- Seeds;
- Transports;
- Diesel;
- Crops production;
- Purchased feeds;
- Process of sowing;
- Water consumption;
- Detergents;
- Natural gas;
- Energy consumption in breeding and cheese factory;
- FPCM production;
- Daily feeding of cattle;
- Livestock manure;

- Whey;
- Treatment and disposal of whey;
- Rennet;
- Salt;
- Steam

Both the considered farms are organic, so livestock wastes are used as fertilizer; additionally, in two stables biogas plants have been already installed. The digestate, exiting by both the biogas systems, is used as organic fertilizer; both the plants produce also electricity.
Electricity produced from biogas is considered an energy from a renewable source and therefore it has a positive impact on the analysis, because it is demonstrated that biogas plant helps to reduce the environmental impact (Battini et al., 2014).

2.5. Life cycle inventory analysis

Inventory analysis consists of collecting input and output data to recreate the process units; the aim is to provide some objective data to allow their processing and evaluation in Life Cycle Impact Assessment and Life Cycle Interpretation phases (Baldo et al., 2008).
In each farm the daily amount of FPCM has been recreated, considering the feeding of cows, the consumption and emissions, as reported in Figure 2.

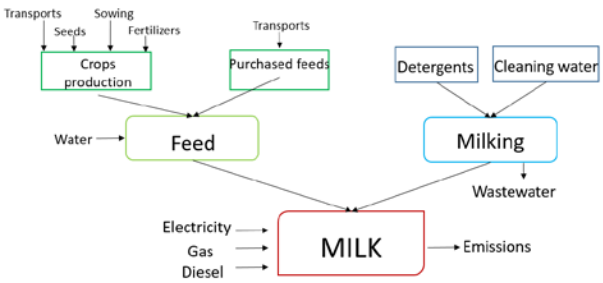

Figure 2: FPCM flow chart

The first two farms have only one stable each one. The third farm is instead composed by two sheds, so the values considered for the third farm have been obtained as the arithmetic mean of the two sheds.
The number of animals and the herd composition have been recorded on each farm, as shown in the table 1.

Table 1: Primary data about number and herd composition

	Farm 1	Farm 2	Farm 3
Lactating cows	289	320	253
Dry cows	70	75	80
Heifers	310	275	203

As cow's feeding is concerned, the production of fodder, cereals and the purchase of feed has been taken into account. Each forage and cereal has been reproduced considering seed, sowing and organic fertilizers.
The daily emissions (methane, nitrous oxide and ammonia) from animals and the farm operations have been calculated as an average of the data proposed by Baldini (Baldini et al., 2018). Data have been reported in Table 2.

Table 2: Daily emissions of animal category expressed as kg of gas head^{-1}

	Lactating	Dry
CH_4	0,59	0,19
N_2O	0,003	0,01
NH_3	0,11	0,09

So environmental impact of FPCM production is included in the assessment of functional unit impact.
All daily data related to cheese are collected in the dairy farm.
The input data are:

- Milk (Fat Protein Corrected Milk)
- Whey
- Rennet
- Energy
- Natural gas
- Water
- Salt

2.6. Allocation

Allocation is the breakdown between input and output flows of a process.
According to the ISO 14040, allocation between product and co-products should be avoided, but this is not always possible.
At farm level there are two products: milk and meat. So allocation is made according to IDF (2015):

$$AF = 1 – 6{,}04\ BMR$$

Where AF is the allocation factor for milk, and consequently (1 – AF) represents meat allocation factor. BMR is the ration between M_{meat}/M_{milk}; M_{meat} is the quantity of the live weight of all animals sold and M_{milk} is the amount of milk sold, considered as the total quantity of FPCM.
Allocation factor for milk and meat has been calculate for each farm. Table 3 shows the percentages.

Table 3: Allocation factors between milk and meat

	Milk (FPCM)	Meat
Farm 1	81 %	19 %
Farm 2	77 %	23 %
Farm 3	82 %	18 %

3. RESULTS AND DISCUSSION

3.1. Impact assessment

The aim is to estimate carbon footprint and water footprint of 1 kg of organic parmesan cheese. The impact categories considered are: climate change and water use. In the following section the results are presented separately for the two footprints. Carbon and water footprint have been calculated at first only for the milk and further for parmesan cheese.

3.2. Carbon footprint

The method to assess greenhouse gas emissions is IPCC, Intergovenmental Panel on Climate Change, which has only one impact category: climate change, measured in kg CO_2equivalent.

The environmental impact assessments of milk production, expressed for kg of FPCM are 1,33 kg CO_2eq, 1,01 kg CO_2eq and 1,1 kg CO_2eq for the three different farms. The results are aligned with values reported in other studies (Jayasundara et al., 2019; Baldini et al., 2018; Battini et al., 2016; Bacenetti et al., 2016).

These results are due, in particular, to emissions of animal and their daily feed.

Considering the materials and consumption to produce the functional unit of 1 kg Parmesan cheese, until ripening, the carbon footprint is 17,8 kg CO_2eq. The most impactful category is milk, which is used in large quantities; 1 kg of Parmesan cheese needs 14 liters of milk.

Whey disposal is considered in the Parmesan cheese production, because whey is a co-product. It is sent to Germany and Austria by a refrigerated transport and the distance is an average between the two destination.

In Figure 3 it is possible to notice the impacts of each process and milk has the largest contribution.

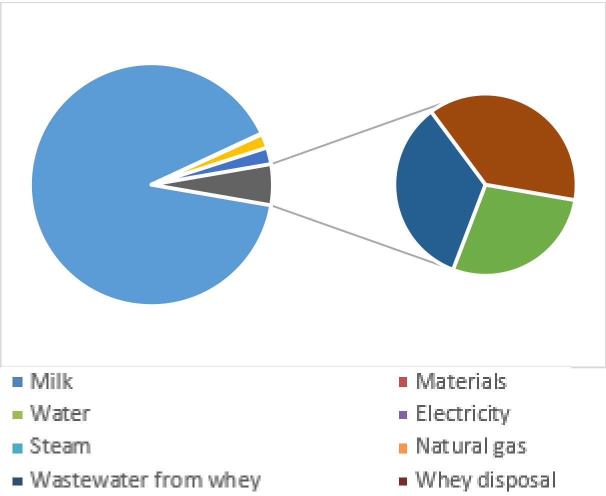

Figure 3: Carbon footprint contributions

3.3. Water footprint

The method to assess water footprint is AWARE. The method must be used as a water use midpoint indicator representing the Available Water Remaining per area and it assesses the potential water deprivation.

Considering the three farms, the water consumption to produce 1 kg of FPCM is in a range between 0,487 and 0,673 m^3.

Milking and feeding of lactating bovines are the most impactful phases; for milking process, the water is used to clean plant. Regarding the feeding, lactating cows drink daily 100 kg of water (it is an average data provided directly by the farmers).

As regards the water consumption to produce Parmesan cheese, the final result is 7,6 m^3.

As in the previous section, in Figure 4 it is possible to identify the different contributions about consumption of water resources.

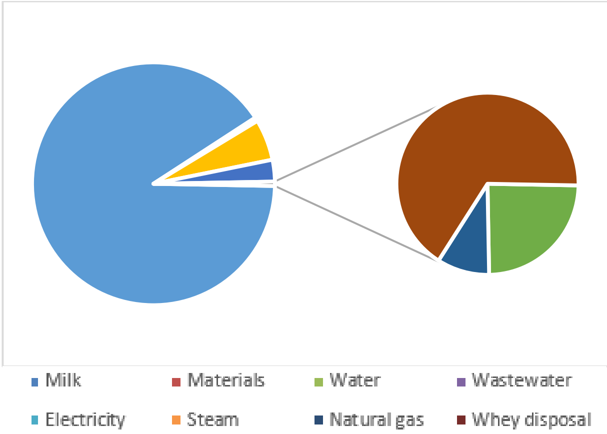

Figure 4: Water footprint contributions

As for the carbon footprint, milk is the category with the highest water consumption, due to cleaning activities and bovine water demand while dairy farm activities have a lower impact (Noya et al., 2018).

4. CONCLUSIONS

The aim of this analysis is to show the impacts related to greenhouse gas emissions and water consumption of 1 kg of organic Parmesan cheese considering the whole dairy supply chain. The study refers to the situation before future improvement measures based on the reduction of environmental impact. Future researches will be oriented to perform another Life Cycle Assessment study to compare the new situation with the previous one.

5. ACKNOWLEDGMENTS

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