LIFE CYCLE ASSESSMENT OF A SPREADABLE CREAM MADE FROM PARMESAN CHEESE

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ABSTRACT

The aim of this work is to evaluate the environmental impact of a spreadable cream based on Parmigiano Reggiano by means of the Life Cycle Assesment methodology (hereinafter referred to as LCA methodology), and to minimize its environmental impact through a sensitivity analysis. The considered product is a spreadable cream consisting of two ingredients: grated Parmigiano Reggiano and organic extra virgin olive oil.

Two main packaging materials can be used and have been considered in the analysis: jars made of PET and glass jars. The LCA analysis was carried out using SimaPro 8.2 software. Primary data have been obtained by interviewing the owner of the dairy company, which produces the analyzed product, while secondary data have been taken by the Ecoinvent 3.2 database and by using specific literature.

The impact method is based on the Environmental Product Declaration (EPD) standard: the impact categories considered are: (i) acidification, (ii) eutrophication, (iii) Global Warning Potential (GWP 100a), (iv) Photochemical oxidation, (v) Ozone layer depletion (vi) Abiotic depletion.

The results show that the most influential phase is the Parmigiano Reggiano's production with impacts ranging from 58% to 92% of all the considered categories. Some solutions to improve the environmental impact of the product have finally been reported.

Keywords: LCA, cheese, cream, olive oil, sustainable production, environmental assessment.

1. INTRODUCTION

Life Cycle Assessment (LCA) is a process that allows you to estimate potential environmental impacts associated with a process or activity product by analyzing the entire production process "from cradle to grave" or parts of it "from cradle to gate".

It quantifies the consumption of matter, energy and emissions in the environment and identifies and evaluates the opportunities to reduce the associated impacts.

It consists of four basic phases:

- Definition of the goal and scope of the LCA
- Life cycle inventory analysis (LCI) phase
- Life cycle impact assessment (LCIA) phase
- Interpretation phase

Frequently associated to these four steps there is also a reporting and critical review of the LCA.

The main rules for applying the LCA method are:

ISO 14044. Environmental Management – Life Cycle Assessment. Requirements and Guidelines.

ISO 14040. Environmental Management – Life Cycle Assessment. Principles and Framework.

The first one is of a more general nature that outlines the principles and describes the structure of an LCA; the second one reports the requirements and guidelines, and (it) is the main support for the practical application of a lifecycle study.

From 2006 to nowadays several other international rules and standards have been realized (ISO 14021, ISO 14024, ISO 14025) but among them especially the ILCD handbook is of particular interest. In response to the commitments in the Integrated Product Policy (IPP) communication of the European Commission, the Joint Research Centre prepared the ILCD handbook to meet suggestions made by the European Commission in the Integrated Product Policy (IPP) communication. The ILCD Handbook was published in 2010. It is based on ISO 14040/44, but provides much more detailed technical guidance. The ILCD Handbook contains detailed descriptions and requirements in order to reduce flexibility in choices and to support consistency and quality assurance of LCA results.

Based on this acknowledgement to perform an environmental assessment of products, especially in the food sector, an increased attention is attributed to certification and to defining standard methods for the food product evaluation.

Well known in the food sector is the Environmental Product Declaration (EPD) standard. Based on this standard it is possible to certify for example a Food Product by evaluating the impact associated to all its phases along its supply chain. Aim of this standard is to compare products with the same sector and provide the customers with a certified evaluation on six different environmental impact categories.

For each category of products there is a specific Product Category Rule (PCR), which has to compliant to the EPD standard. In 2017 there are 41 PCR's in "Food & Agricultural Products", which are frequently updated and available on the website www.environdec.com/PCR.

The LCA of food products is particularly complex because of the several/various phases of the food supply chain (Agricultural, postharvest, processing, packaging, distribution, consumption, end of life) and due to the presence of losses and waste in each of these phases (Manfredi and Vignali, 2014; Cellura et al, 2012).

Commonly some phases are neglected or less investigated by being excluded from the system boundaries. In the food packaging phase, e.g. the evaluation of the equipment consumptions have been investigated only sometimes (Manfredi and Vignali, 2015; Bertolini et al., 2016). Furthermore, the examination of Food waste is often not considered, despite of its high impact on the environmental profile of food products (Manfredi et al., 2015; Mosna et al., 2016).

Based on these premises, the aim of the paper is to evaluate the environmental impact of a spreadable cream based on Parmigiano Reggiano by means of the LCA methodology following the EPD standard, and to minimize the environmental impact through a sensitivity analysis. The considered product is a spreadable cream consisting of two ingredients: grated Parmigiano Reggiano and organic extra virgin olive oil. The remainder of the article is composed as follows: The second chapter describes the state of art of LCA evaluation in the field of milk cheese and vegetable oil. In the third chapter, all the inventory needed for an LCA evaluation will be analyzed. Section 4 summarizes the main results obtained; section 5 discuss the main results while the conclusion section shows the main aspect of the work and the future researches.

2. LCA STUDIES FOR CHEESE AND EXTRA VIRGIN OLIVE OIL

The analyzed product being composed by Parmigiano Reggiano cheese and extra virgin oil, this chapter will evaluate the state of art of LCA studies for dairy products and extra virgin oil.

As far as LCA studies of dairy products are concerned, the literature mentions some articles, of which the majority were performed d in Europe and some in North America. A summary of the most interesting for our scope are reported below.

Kim et al., 2013 analyzed the environmental impact of cheddar cheese and mozzarella from cradle to grave, using several impact methods and subsequently several impact categories. Results showed that the raw milk production is the main source of influence in all the considered impact categories, both for mozzarella (on average 60%) and Cheddar cheese (on average 80%).

Dekic et al., 2014 examined some dairy products (milk, yogurt, cheese, cream and butter) from birth to death, throughout their life span using the CCALC 2013 impact method. They use five impact categories, showing how the raw milk is the main source of impact, although impossible to generalize said impact for all the dairy products. As far as the GWP is concerned, the impact values vary from 6.73 to 9.47 kg/CO2 eq. per kg of product.

Finnegan et al, 2017 studied other dairy products such as whole milk, skimmed mild, semi skinned milk, butter, cheese, cream, milk powders and whey powders from cradle to gate using IPCC impact Method, with only GWP 100 as an indicator. They found a minimum of 6.7 kg/CO2 eq. per kg of product. In the case of cheese, the authors found that raw milk production counts about 93% of the environment impacts and that a possible way to reduce them is to optimize the use of natural resources (water and energy).

Van Middelaar et al., (2011) analyzed the production of semi-hard cheese in the Netherlands with a cradle to gate approach using the IPCC Impact method and GWP100 as impact category. They discovered an impact of 8.5kg of CO2 eq. per kilogram of the complete product. In this case, the cultivation of concentrated ingredients and the raw milk production are the two main sources of environmental impact.

Berlin (2002) investigated a semi-hard cheese in Sweden, using the IPP and CML impact methods and also adopting the Nordic guidelines. As explained by other authors she observed that the main impact is to the result of the raw milk production and that the best solution to reduce the environmental impact was to decrease the waste during the collection and the process.

In the USA, Milani et al. (2011) found in their review that in order to reduce the environmental impact of dairy processing it is necessary to diminishing the use of the water and also to optimize the recovery system of the grey water.

Brokema and Kramer (2014) discovered that if the impact of the soil cultivation was accounted for, the total impact of the cheese production increases. In their study, which was performed in the Netherlands and considers a cradle to grave approach, the impact in GWP of a skimmed milk and semi-cured cheese was 8.67 kg/CO2 eq. per kg of product.

In Portugal, Gonzales-García et al. (2013) defined the value of GWP for a Galician cheese as 10.44 kg/CO2 eq. per kg of the product. Additionally, they demonstrated that the environmental impact could be reduced if the processing waste was reused to produce other products, instead of being landfilled together with grey water.

Flysjo et al. (2014) introduced the concept that a milk concentration could be useful to reduce the impact of dairy products. Very important is also the waste of product along the whole supply chain and in particular at a household level. Each innovation to reduce the waste will give a positive contribution to the environmental impact of such product.

Doublet et al. (2013) showed that in the cheese production in Romania the most impactful phase is the raw milk production, but also the energy consumption could have a significant effect in some impact categories.

As far as olive oil is concerned, several studies have been performed by private companies to certify their products according to the EPD standard, especially in Italy. Monini (Monini, 2012), Oassi and Castillo Canena obtained an EPD certification for extra virgin olive oil with values of GWP between 2.2 to 4.3 kg/CO2 eq. per kg of product.

Among the scientific studies, Avramides and Fatta (2008) showed with a cradle to gate approach realized in Cyprus that the main environmental impact lies within the agricultural phase. Particularly the inorganic fertilizer, the olive oil transformation and the landfill of liquid effluents are the hot spots of the entire process.

Salomone et al. (2010) underlined the importance of the choice of Functional unit in the case of an olive oil assessment. It is also very difficult to collect reliable data in this sector due to the different treatment applied by the producers. Therefore, a consistent variability in the data is present. They found overall 4.305 kg/CO2 eq. per kg of product, considering also the impact of nitrogen compounds.

One year later (2012), Salomone and Ioppolo also performed a sensitivity analysis in order to demonstrate a way of reducing the environmental impact of olive oil production. They proved the anticipated necessity of using Olive Mill Pomance (OMP) and Olive Met Wastewaters (OMW) instead of Olive Wet Pomance (OWP).

Busset et al. (2012) performed an LCA analysis in France, by using Recipe midpoint and endpoint. They reported a high value of GWP (6.6 kg/CO2 eq. per kg of product), mainly due to the use of fertilizer and to phytosanitary treatment.

In Greece (2014), Tsarouhas et al. found that in Italy only the cultivation phase for olive oil has an impact of 1.08 kg/CO2 eq. per kg of product. Nevertheless, the only way to reduce the impact in their view was to optimize the management of grey water, which is produced by the oil skin during the olive oil production.

Based on this analysis of peculiarities of the existing studies, a LCA of a spreadable cream made from parmesan cheese and extra virgin olive oil will be demonstrated in the following sections.

3. LCA OF SPREADABLE CREAM MADE FROM PARMESAN CHEESE AND EXTRA VIRGIN OLIVE OIL.

3.1. Goal and scope definition

According to the prescription of ISO 14040 and ISO 14044 the objectives of the analysis, the choice of the functional unit, the system boundaries and the assumptions used for the analysis are defined in the goal and scope definition.

The goal of the study is to assess the environmental impact, by means of an LCA approach, of a spreadable cream made from parmesan cheese and extra virgin olive oil, which can be packaged in a glass or polyethylene terephthalate (PET) jar.

The functional unit chosen for the LCA is a unit of 290g of this cream packaged both in glass and in PET.

As far as the system boundaries definition is concerned, the authors have chosen to have a cradle to grave approach, considering both the production of raw material and the end of life of the product and the packaging materials.

The system boundaries are reported in Fig. 1.

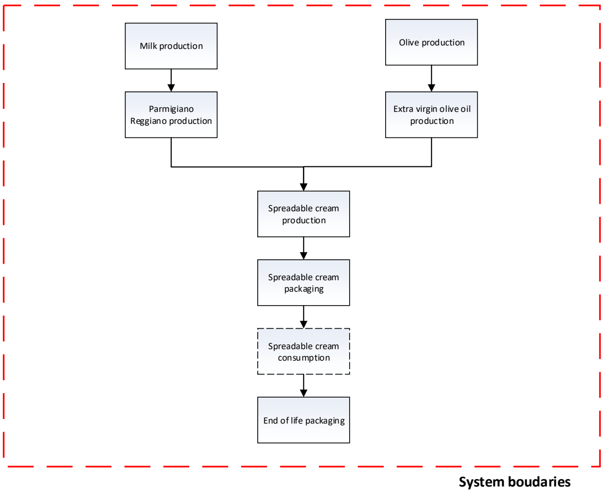

Fig.1: System boundaries of the analyzed product

The first phases of the process include the production of the milk and of the olives. As regards the olive oil, the company delivering the oil for the cream production decides to cultivate and crop the olives in Italy.

The olive grove is made of plants cultivated partially with a traditional extensive system and partially with intensive systems. The difference between the two systems is connected to the density of the plants, which is higher in the case of intensive systems.

The process of **extra virgin olive oil** production is composed of:

1. Olive grove preparation: trenching, weeding, tillage and harrowing, followed by the creeping thistle planting;
2. Olive grove cultivation: this phase is before the plant is productive and it needs water, fertilization, and phytosanitary treatments;
3. Olives' crop: once the plants have reached their maturations, they start to be productive and give olives, which can crop manually or automatically.
4. Olives' transport to oil mill: olives are collected in bins and then sent to an oil mill
5. Oil milling: the analyzed process is continuous and consists of:
    a. Olive storage in bins
    b. Weighting
    c. Defoliation
    d. Cleaning with cold water
    e. Olives pressing

f. Kneading operation
g. Extraction of oil and olive pomace
h. Storage and soil deposition of pomace
i. Centrifugal oil separation
j. Oil storage in stainless steel tank
k. Oil filtration with plate system

6. Bottling and labelling of extra virgin olive oil in glass bottle or metallic jar.
7. Secondary packaging of glass bottles or metallic jars
8. Transport of packaged extra virgin olive oil to spreadable cream production site

In regards to Parmigiano Reggiano, a previous LCA studies has been performed (Caseificio Caramasche Soc. Coop. 2014). In the analyzed process local milk producers transport the raw milk to the cheese production site every day in the morning and in the afternoon. To obtain this seasoned hard cured cheese, several activities will be performed in the milk processing company. As indicated by the flow described below, the process can last until 24 months (due to the seasoning of this particular product) and the final product has a substantial weight decrease in respect to the weight before the seasoning process.
Parmigiano Reggiano production begins with milk collection, which is done twice a day: once in the evening, and once in the morning, after milking.
The whole milk of the evening milking is left to rest overnight. Overnight, the fatty part of the milk, the cream, floats naturally to the surface, and is then used later to make butter. The milk remaining below the cream layer is the skimmed milk.
Early in the morning, this mixture of milk are inserted in the copper cauldrons with their typical upturned cone shape. In this very delicate phase, only the skimmed milk is poured into the vats, without the cream. At this stage, the whole milk, delivered to the cheese factory after the morning milking, is also added to the cauldrons.
The proportions of skimmed and whole milk are determined day by day. Milk is then turned into Parmigiano Reggiano in 3 separate phases:

- Heating
- Curd Breaking
- Cooking

Heating: Once in the cauldron, the milk is heated slowly. During this process, the whey starter culture is added, a liquid mixture rich in lactic ferments obtained from the processing of the previous day's milk. The milk is heated to around 30° C and then the calf rennet is added. The mixture is stirred carefully then left to rest for 8-10 minutes to allow for natural coagulation. This produces the curd.
Curd breaking: In this phase the curd is broken into small granules, and the cheese maker checks that the curd has reached the right density. A special tool, the "spino", is used to break the curd.
Cooking: the mixture is then heated to 55° C. At this temperature, the micro-granules lose their humidity and sink to the bottom of the cauldron. After around 50 minutes, the compact mass can be removed from the cauldron. Using a wooden paddle, the solidified cheesy mass is removed and wrapped in muslin. The mass is ready to be cut into 2 equal parts. Each half is placed in a plastic mold, the buckle known as “fascera”, and pressed down with a Teflon weight.

Every wheel produced during the day is turned four times; the first and second time, the wet muslin is replaced with a dry one to absorb more humidity.
The third time it is turned, the muslin cloth is taken out. The wheel is then wrapped in a special belt issued by the Parmigiano Reggiano Consortium.
The next morning, the wheels are placed in a special steel belt that gives them their rounded shape.
Packaging and sale. At the end of the maturation process, which lasts between 12 and 36 months or more, the Parmigiano Reggiano is ready to be enjoyed by consumers.

Spreadable cream production
The first phase of the process involves the crust removal from the Parmigiano Reggiano cheese as well as the cheese cutting in portions, which can be grated.
The cheese is grated using several types of sieves, in function of the seasoning and consistency of the product.
The grated product is then mixed with the extra virgin olive oil; to realize the specific dough in a specific kneading machine. This spreadable cream is produced by mixing 70% of Parmigiano Reggiano Cheese with 30% of extra virgin olive oil.
This homogeneous dough is then filled in glass or PET jar and capped with a plastic (for PET jar) or metallic (for glass jar) cap. Up to this point, due to the low level of production of this spreadable cream, these activities will be performed manually by a company worker.
Finally, all the jars are checked and subsequently labelled by means of a manual labelling machine.
More details about the flow and the production process are given by the diagram in Fig. 2 and Table 1.

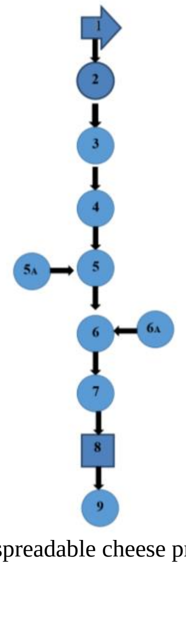

Fig.2: Flow of spreadable cheese production process

Table 1: phases of production process of spreadable cream.

Phase	Description	Quantity	Waste	Time
1	Transport of Parmigiano	6 wheels	none	2 min
2	Cutting wheel	6 wheels	3 kg/wheel	2min/wheel
3	Grater	6 portioned wheels	none	2min/wheel
4	Sieving	205 kg	5 kg	3 min
5	Mixture	250 kg	none	3 min
6	Filling	900 jars	none	1 s/jar
7	Capping	900 jars	none	3 s/jar
8	Checking	900 jars	none	1 s/jar
9	Labelling	900 jars	none	6 s
5a	Oil adding	50 kg	none	1 min
6a	sterilization of jars	900 jars	none	3 s/jar

3.2. Inventory Analysis

The first aspect to be underlined is that both primary and secondary data have been used for this phase.
Primary data was collected by the spreadable cream production company, whereas secondary data have been taken from the Ecoinvent 3.2, other databases available in SimaPro 8.2 software and from scientific literature.
Starting with the raw milk production the first series of data is connected to the pre-lactation activities of cows. These activities are considered to last for 3 years.
Table 2 shows the inventory data related to this process.

Table 2: inventory data of pre-lactation phase

	Unit	Quantity	Reference	Database
Pre-lactation				
Inputs				
Alfalfa	kg/cow	12	primary data	Alfalfa-grass mixture, Swiss integrated production {GLO}| market for | Alloc Def, U
Concentrated feeds	kg/cow	12	primary data	Maize, at farm/IT Economic
Water	kg/cow	60	primary data	Tap water {Europe without Switzerland}| market for | Alloc Def, U
Electricity	kwh	0,4	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U
Output				
Manure and sewage	kg/cow	34	primary data	

The next phase evaluated in the inventory is the milk production, which has a reporting period of 10 years. This is in fact the lactation period, which we assumed for a cow.
Several aspects have been considered and reported in table 3. 28 kg of daily milk production has been assumed for a cow, which is raised following the specific Parmigiano Reggiano cheese disciplinary proceedings.
Some allocations have been made considering the economic value of each produced good.

Table 3: inventory data of raw milk production phase

	Unit	Quantity	Reference	Database
phase of milk production	kg/day	28		
Inputs				
Alfalfa	kg/cow*day	8	primary data	Alfalfa-grass mixture, Swiss integrated production {GLO}| market for | Alloc Def, U
Hay	kg/cow*day	8	primary data	Hay, Swiss integrated production, extensive {GLO}| market for | Alloc Def, U
Maize	kg/cow*day	16	primary data	Maize, at farm/IT Economic
	kg/cow*day	75	primary data	Water, unspecified natural origin, IT
Equipment cleaning	kg/cow*day	2	primary data	Tap water {Europe without Switzerland}| market for | Alloc Def, U
Cooling of milk	kg/cow*day	28	primary data	Tap water {Europe without Switzerland}| market for | Alloc Def, U
Electricity	kWh	0,4	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U
transport to cheese factory	Kg*km	252	primary data	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO3, carbon dioxide, liquid refrigerant, freezing {GLO}| market for t
Output				
Manure and sewage	kg/cow*day	50		

From the milk processing we obtained the data to evaluate the cheese production in the dairy production site. The inventory of the cheese production process is reported below in table 4.

Table 4: inventory data of parmesan cheese production phase

	Unit	Quantity	Reference	Database
Skimming in basins	kg	4400	primary data	
Inputs				
milk	kg	4400	primary data	
Draining pump	kwh	0,51	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U
Output				
Biologic purifier	kg	5200	primary data	Water, IT
cream	kg	704	primary data	
skimmed milk	kg	3696	primary data	

	Unit	Quantity	Reference	Database
boiling in double bottoms	kg	1100		
Inputs				
whole milk	kg	550	primary data	
skimmed milk	kg	550	primary data	
Fuel oil	l	6.25	primary data	Heavy fuel oil {Europe without Switzerland}| market for | Alloc Def, U
celaning	kg	1100	secondary data	Water, decarbonised, at user {GLO}| diethyl ether production | Alloc Def, U
Output				
Biologic purifier	kg	438	primary data	Water, IT

	Unit	Quantity	Reference
Rest of the wheels	wheel of parmigiano	1	
Inputs			
Curd extraction	kg/wheel	40	primary data
wheel after the rest	kg/wheel	39	primary data
Linen sheet	g/wheel	125	secondary data
Teflon mold	kg/mold*wheel	2	secondary data
Zinc mold	kg/mold*wheel	1	secondary data
Wooden boards	kg/wheel	0.25	secondary data

	Unit	Quantity	Reference	Database
Brine bath	wheel of parmigiano reggiano	1		
Inputs				
water	m^3	0.5	primary data	Tap water {Europe without Switzerland}| market for | Alloc Def, S
salt	kg/wheel	2.5	secondary data	Sodium chloride, production mix, at plant, dissolved RER
gantry crane	kwh	1.955	secondary data	Electricity, low voltage {IT}| market for | Alloc Def, U

After the wheels production of parmesan cheese, these wheels are storage in specific warehouses for at least 12months. During this period, the wheels are cleaned by means of a specific robot.

Table 5: inventory data of parmesan cheese seasoning

	Unit	Quantity	Reference	Database
Phase of seasoning	1 wheel of parmigiano reggiano	1		
Input				
Electricity (winter)	kWh	22.97	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U
Electricity (summer)	kWh	68.926	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U

Based on the previous reported inventory we have evaluated the inventory for the production of a finished wheel of a Parmigiano Reggiano cheese. The weight of a 12 months seasoned wheel, ready for the market, has been considered of 39kg.

Table 6: summary of inventory data of parmesan cheese

	Unit	Quantity	Reference
production of a wheel of parmesan cheese	wheel of parmesan cheese	1	
Inputs			
Milk production	l	550	primary data
boiling nei doppi fondi	l	550	primary data
bagno in salamoia	days	20	secondary data
phase of rest	h	24	secondary data
seasoning	months	12	secondary data

After this phase, the inventory connected to the production of the spreadable cream has been reported.

Table 7: inventory data of spreadable cream production

	Unit	Quantity	Reference	Database
Cutting of a wheel	jar	1		
Input				
electricity	kwh/jar	0.0048	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U

	Unit	Quantity	Reference	Database
Grater	jar	1		
Input				
electricity	kwh/ vas	0.02	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U

	Unit	Quantity	Reference	Database
Sieving	jar	1		
Input				
electricity	kwh/jar	0.014	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U

	Unit	Quantity	Reference	Database
mixture	jar	1		
Input				
Extra virgin oil	kg	0.0945	Secondary data	EPD monini group
Grated cheese	kg	0.203	Primary data	
electricity	kwh/jar	0.014	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U

Table 8: summary of inventory data of spreadable cream production

	Unit	Quantity	Reference
Production process spreadable cream	jar	1	
Inputs			
cut della wheel	kg	0.203	primary data
gratuggia	kg	0.203	primary data
sieve	kg	0.203	primary data
mixture	kg	0,300	primary data

After the spreadable cheese preparation, this product can be filled in glass or PET jar, thanks to the same equipment. To complete the packaging phase, the capping, labelling and secondary packaging are needed.

Table 9: : inventory data of spreadable cream packaging

	Unit	Quantity	Reference	Database
Filling	jar	1		
Input				
filling	kwh/h	0.0055	primary data	Electricity, low voltage {IT}| market for | Alloc Def, U

	Unit	Quantity	Reference	Database
Glass jar packaging	g	1		
Inputs				
jar di glass	g	174	primary data	Packaging glass, white {GLO}| market for | Alloc Def, U
Capping	g	8	primary data	Aluminium, primary, ingot {IAI Area, EU27 & EFTA}| market for | Alloc Def, U
Labelling	g	2	primary data	Paper, bag and sack, unbleached kraft, average production, at mill/kg/RNA
Secondary packaging	g	1,25	primary data	Paper, bag and sack, unbleached kraft, average production, at mill/kg/RNA

	Unit	Quantity	Reference	Database
PET jar packaging	g	1		
Inputs				
jar PET	g	34	primary data	Polyethylene terephthalate, granulate, amorphous {GLO}| market for | Alloc Def, U
Capping	g	6	primary data	Polyethylene terephthalate, granulate, amorphous {GLO}| market for | Alloc Def, U
Labelling	g	2	primary data	Paper, bag and sack, unbleached kraft, average production, at mill/kg/RNA
Secondary packaging	g	1.8	primary data	Kraft paper, bleached {GLO}| market for | Alloc Def, U

Both PET and glass jars are then sent to the market using similar transports, but in the case of PET jars, they are sold in Italy, while Glass jars are sold abroad. Inventory analysis has considered an average distance for the two products.

Table 10: inventory data of spreadable cream transport

	Unit	Quantity	Reference	Database
Transport of PET jars	Filled jar	1	primary data	
Input				
jar di elisisr in PET	kg.km	100.8	primary data	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO3, R134a refrigerant, cooling {GLO}| market for | Alloc Def, S

	Unit	Quantity	Reference	Database
Transport of glass jars	Filled jar	1	primary data	
Input				
jar di elisisr in PET	kg.km	202.3	primary data	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO3, carbon dioxide, liquid refrigerant, cooling {GLO}| market for | Alloc Def, S

Finally, the end of life of packaging materials has been considered, by adopting a landfilling process to be conservative.

Table 11: inventory data of packaging end of life

	Unit	Quantity	Reference	Database
Glass jar end of life	jar	1		
Inputs				
transport to landfill of jar glass	kg.km	9.3	primary data	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO3, carbon dioxide, liquid refrigerant, cooling {GLO}| market for | Alloc Def, S
glass jar	g	174	primary data	Landfill of glas/inert waste EU-27
cap	g	8	primary data	Landfill of iron metals EU-27
etichetta	g	2	primary data	Landfill of paper waste EU-27
packaging secondary	g	1,25	primary data	Landfill of paper waste EU-27

	Unit	Quantity	Reference	Database
PET jar end of life	jar	1		
Inputs				
transport to landfill of PET jar	kg.km	2.3	primary data	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO3, R134a refrigerant, cooling {GLO}| market for | Alloc Def, S
PET jar	g	34	primary data	Landfill of plastic waste EU-27
cap	g	6	primary data	Landfill of iron metals EU-27 U
Labelling	g	2	primary data	Landfill of paper waste EU-27
secondary packaging	g	1.8	primary data	Landfill of iron metals EU-27 U

3.3. Method of impact assessment

The data collected in the inventory analysis are the basis for the impact assessment phase whose aim is to evaluate the potential environmental impact of the system (ISO 14040, 2006) caused by effluent emissions, releases into the environment and resources consumption.

The impact analysis was carried out using the EPD (2013) method.

Impact values were calculated at midpoint level for 6 impact categories: (i) Acidification (fate not incl.), (ii) Eutrophication, (iii) Global warming (GWP100a), (iv) Photochemical oxidation, (vi) Ozone layer depletion (ODP), and (v) Abiotic depletion.

4. LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The first analyses, which have been performed, are related to the two main ingredients of the spreadable cream, i.e.: extra virgin olive oil and parmesan cheese. Table 11 and 12 shows the related impacts.

Table 11: LCA of 1 kg of extra virgin Olive oil

Impact category	Unità	Totale	Coltivazione	produzione olio	Confezionamento e packaging	trasporto
Acidification (fate not incl.)	kg SO2 eq	3,21 E-03	0,000438	0,000042	0,002693826	0,000032
Eutrophication	kg PO4--- eq	4,20 E-03	0,003525	0,000178	0,000240439	0,000258
Global warming (GWP100a)	kg CO2 eq	3,78 E+00	3,078	0,238	0,45132049	0,008
Photochemical oxidation	kg C2H4 eq	1,72 E-02	0,016	0,000948	0,000162014	0,00013
Ozone layer depletion (ODP)	kg CFC-11 eq	1,89 E-07	0,000000116	0,000000037	2,19417E-08	0,000000014
Abiotic depletion	kg Sb eq	4,19 E-05	8,82808E-06	4,34952 E-07	1,49509E-05	1,76562E-05

Table 12: LCA of 1 parmesan cheese wheel

Impact category	Unità	Totale	litro di latte	boiling nei doppi fondi	bagno in salamoia	fase di rest	stagio natura
Acidification (fate not incl.)	kg SO2 eq	1,21 E+01	11,91678421	1,59E-02	0,006144422	-0,000880577	0,202350132
Eutrophication	kg PO4--- eq	7,85 E+00	7,824706692	1,81E-03	0,000571436	-0,000435546	0,01871616
Global warming (GWP100a)	kg CO2 eq	8,26 E+02	777,3028463	1,50E+00	1,331339195	-0,138433557	46,19820759
Photochemical oxidation	kg C2H4 eq	1,03 E-01	0,091839506	8,28E-04	0,000331539	-3,67177E-05	0,010418405
Ozone layer depletion (ODP)	kg CFC-11 eq	3,29 E-05	2,31E-05	3,75E-06	1,53546E-07	-7,44003E-09	5,91879E-06
Abiotic depletion	kg Sb eq	1,10 E-03	9,72E-04	-1,39E-05	3,99793E-06	-2,65552E-07	0,000137722

Using then all the inventories previously described, it has been possible to discover the total impact of the spreadable cream, packaged in glass and in PET.

Tables 13 and 14 and figures 3 and 4 show the total impacts for all the considered categories and the relative impacts of each of the considered phases.

Table 13: LCIA of 1 glass jar of spreadable cream

Impact categories	Unit	Total	Parmesan wheel production	Extra virgin olive oil	Spreadable cream production	Glass jar packaging	Filled jar transport	Glass jar transport to landfill	Landfill
Acidification (fate not incl.)	kg SO2 eq	7.396E-02	6.319E-02	7.178E-03	5.791E-05	2.040E-03	7.177E-04	7.599E-04	1.719E-05
Eutrophication	kg PO4--- eq	4.420E-02	4.084E-02	2.915E-03	5.356E-06	1.580E-04	1.131E-04	1.198E-04	5.342E-05
Global warming (GWP100a)	kg CO2 eq	6.118E+00	4.300E+00	1.276E+00	1.322E-02	2.662E-01	1.246E-01	1.319E-01	5.093E-03
Photochemical oxidation	kg C2H4 eq	1.136E-03	5.381E-04	4.418E-04	2.981E-06	1.032E-04	2.357E-05	2.496E-05	1.635E-06
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	2.990E-07	1.714E-07	5.325E-08	1.694E-09	2.795E-08	2.167E-08	2.294E-08	6.830E-11
Abiotic depletion (optional)	kg Sb eq	1.446E-05	5.722E-06	6.910E-06	3.941E-08	4.943E-07	6.271E-07	6.640E-07	1.410E-10

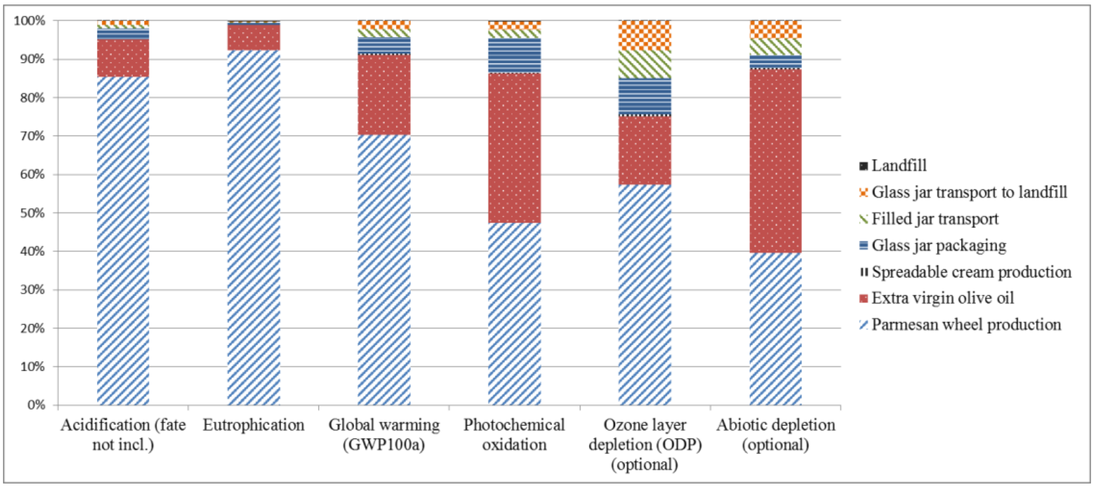

Fig.3: Relative impact of each phase of spreadable cheese packaged in glass jar

Table 14: LCIA of 1 PET jar of spreadable cream

Impact categories	Unit	Total	Parmesan wheel production	Extra virgin olive oil	Spreadable cream production	PET jar packaging	Filled jar transport	PET jar transport to landfill	Landfill
Acidification (fate not incl.)	kg SO2 eq	7.185E-02	6.319E-02	7.178E-03	5.791E-05	9.947E-04	3.579E-04	5.965E-05	1.028E-05
Eutrophication	kg PO4--- eq	4.394E-02	4.084E-02	2.915E-03	5.356E-06	9.322E-05	5.640E-05	9.399E-06	2.069E-05
Global warming (GWP100a)	kg CO2 eq	5.885E+00	4.300E+00	1.276E+00	1.322E-02	2.101E-01	6.751E-02	1.125E-02	5.787E-03
Photochemical oxidation	kg C2H4 eq	1.055E-03	5.381E-04	4.418E-04	2.981E-06	5.698E-05	1.176E-05	1.960E-06	1.432E-06
Ozone layer depletion (ODP) (optional)	kg CFC-11 eq	2.917E-07	1.714E-07	5.325E-08	1.694E-09	1.223E-08	4.541E-08	7.568E-09	1.139E-10
Abiotic depletion (optional)	kg Sb eq	1.387E-05	5.722E-06	6.910E-06	3.941E-08	8.377E-07	3.130E-07	5.216E-08	2.109E-10

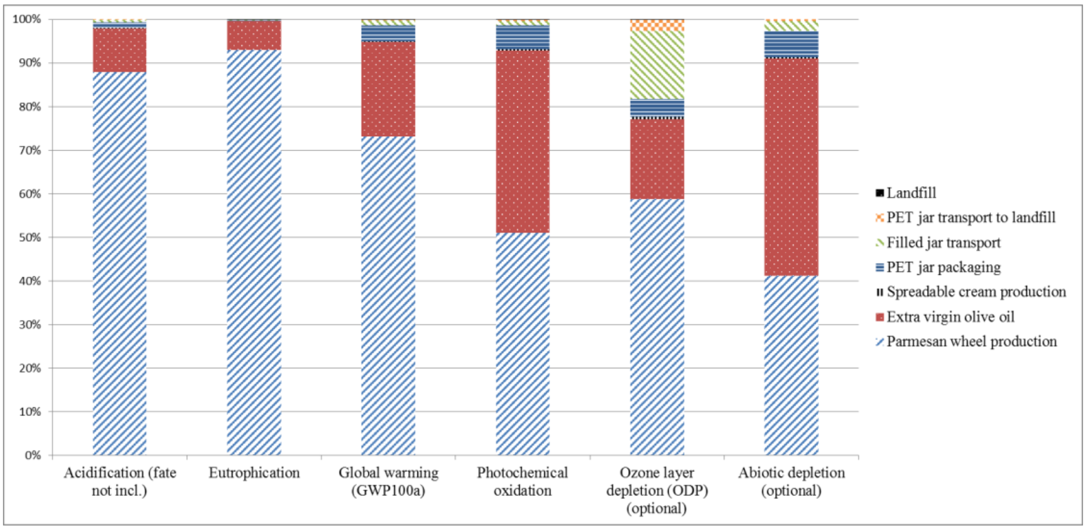

Fig.4: Relative impact of each phase of spreadable cheese packaged in PET jar

5. DISCUSSION AND SENSITIVITY ANALYSIS

Some sensitivity analyses have been performed in order to understand which phase could be improved in order to have the main benefit from an environmental point of view:

- An environmental impact analysis of the pre-lactation phase has been performed by replacing 50% of the amount of corn used with other feeds. This new scenario has been then compared to the present situation.
- An analysis was made by increasing the productivity of a cow from 28l, as it is currently done, to produce 30 l.
- An environmental impact analysis has been done by valorizing more the by-products (cream).
- Another analysis was done by replacing all the electricity with the photovoltaic energy and the fuel oil used with methane.
- Comparative analysis replacing all electrical and photovoltaic energy for the current production process of the spreadable cream.
- By reducing the weight of the glass jar by 20%, we made a comparative analysis of the environmental impacts due to the different weights of the jar.
- Another comparative analysis of environmental impacts was made by replacing the PET jar with one of bioplastics (PLA).

From an environmental point of view, all these changes have given benefits, but most of them have also an important economic impact, which has to be assessed.

6. CONCLUSIONS

Starting from the process definition of a spreadable cream of Parmesan cheese packaged in jar, we were able to quantify the environmental impact of two products, throughout the life cycle. As can be seen from the analysis, the stage of production of raw milk is most impactful, followed by the impact due to olive oil production and by the impact due to the packaging (mainly for the jar of glass).

To reduce the environmental impact connected to the analyzed product, particular attention should be paid to the stages of cow breeding and milking. Some effective active to improve the actual process could be:

- Using less impacted maize feed then that currently used (reduce the use of corn and increase the amount of other feeds)
- Increasing the cow productivity, by means of decreasing the prelate phase and by increasing the lactation rate and increasing the daily milk production (changing the breed of cows)
- Optimizing the amount of food to give to animals. In fact, less food could be given to the cows, without decreasing the productivity.
- valorizing the by-products (cream and whey); this would decrease the impact of a wheel of Parmigiano Reggiano.
- Use methane instead of fuel oil for boiling the curd
- Replace all electricity with photovoltaic energy.
- Assess the technical feasibility of reducing the current weight of the glass jar by 20%
- Use a bioplastic jar (PLA) as thye jar packing materials.

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