
X Convegno dell'Associazione Rete Italiana LCA 2016

Life Cycle Thinking, sostenibilità ed economia circolare

Ravenna
23 - 24 giugno 2016

a cura di Arianna Dominici Loprieno, Simona Scalbi, Serena Righi



ALMA MATER STUDIORUM
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Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile



Atti del X Convegno della Rete Italiana LCA 2016
Life Cycle Thinking, sostenibilità ed economia circolare
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A cura di Arianna Dominici Loprieno, Simona Scalbi, Serena Righi

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Prefazione

La Rete Italiana LCA è stata lanciata nel 2006 con l'obiettivo di favorire la diffusione della metodologia di Life Cycle Assessment attraverso la creazione di un network nazionale e l'organizzazione di convegni e seminari. Nel 2012 la Rete si è costituita in Associazione scientifica rafforzando il suo impegno per lo sviluppo e l'adozione dell'approccio del ciclo di vita nell'implementazione dello sviluppo sostenibile.

Tra le iniziative intraprese dalla Rete Italiana LCA, particolarmente rilevante è il Convegno nazionale annuale al quale prendono parte le più importanti realtà del settore operanti sul tema del Life Cycle Assessment. Le sedi in cui si è svolto il convegno annuale dalla costituzione della Rete Italiana LCA sono state: ENEA Bologna (2006), Università degli Studi "G. d'Annunzio" Pescara (2008), Università degli Studi di Palermo (2009), dell'Università degli Studi di Padova (2010), ENEA Roma (2011), Università di Bari (2012), Politecnico di Milano (2013), Università degli Studi di Firenze (2014), Stresa e EXPO (2015).

Il Convegno del 2016, organizzato a Ravenna, rappresenta il X Convegno della Rete Italiana LCA e il V Convegno dell'Associazione Rete Italiana LCA e, dopo l'esperienza internazionale dell'anno scorso, torna ad essere il principale momento di confronto delle realtà nazionali operanti nell'ambito della metodologia LCA. Il Convegno quest'anno si svolge con il patrocinio di Ministero dell'Ambiente e della Tutela del Territorio e del Mare, SETAC Italian Branch, Società Chimica Italiana, Università degli Studi di Bologna Campus di Ravenna e Fondazione Flaminia per l'Università in Romagna; usufruisce, inoltre, della sponsorizzazione di Cassa di Risparmio di Ravenna, Thinkstep e YARA Italia.

Il tema del Convegno annuale 2016 è il ruolo del Life Cycle Thinking nel supportare l'adozione di scelte operative e strategiche efficaci nella definizione e valutazione di prodotti/processi/servizi ambientalmente e socialmente sostenibili e nell'implementazione dell'economia circolare. In tal senso il Convegno fa il punto sulle iniziative internazionali e sui più recenti sviluppi nazionali connessi all'evoluzione metodologica e all'applicazione dell'approccio del ciclo di vita, con un particolare focus sulle novità legislative di recente approvate in Italia. In particolare, lo schema nazionale volontario Made Green in Italy (art. 21 Legge 221/15) e le linee guida attuative in materia di offerta economicamente più vantaggiosa (art. 95 del Codice degli Appalti e delle Concessioni, D.lgs n. 50/16) rafforzano il ruolo del "Life Cycle Thinking" nel panorama nazionale.

I cinquasette contributi scientifici, raccolti in questo volume e presentati durante le sessioni orali e poster del Convegno, sono stati selezionati attraverso un processo di *double peer review* a seguito di una call for paper gestita dal Comitato Scientifico della Rete Italiana LCA. Il Comitato si è occupato della selezione degli articoli e della loro revisione con una procedura analoga a quella impiegata per la pubblicazione su riviste internazionali con impact factor. I contributi qui pubblicati sono stati suddivisi in otto sezioni: edilizia, energia, agro-alimentare, prodotti e processi chimici, rifiuti, aspetti metodologici, Life Cycle Costing e Social Life Cycle Assessment. L'ultima sezione è dedicata al Premio Giovani Ricercatori LCA nella quale sono pubblicati i contributi scientifici dei primi sei classificati fra i ventiquattro giovani ricercatori che hanno partecipato al concorso.

Gli autori degli studi LCA raccolti in questo volume sono rappresentativi di diverse realtà provenienti sia dal mondo Accademico, quali Politecnico di Torino e di Milano, Università di Torino, Bergamo, Milano-Bicocca, Genova, Modena e Reggio Emilia, Bologna, Padova, della Toscana, Siena, Politecnica delle Marche, Perugia, Chieti-Pescara, Sapienza di Roma, Roma Tre, Napoli, Bari, Mediterranea di Reggio Calabria, Palermo, sia dal mondo degli enti di ricerca pubblici e privati, come Consorzio CIMIS, CMCC, Consorzio Tre, D'Apollonia, Ecoinnovazione, ENEA, ICA, INDACO2, IRIS, RSE e STRESS scarl. Fra le affiliazioni degli Autori si trovano anche università ed enti di ricerca stranieri, quali: University of Manchester, Technical University of Denmark, Aalborg University, Hasselt University, University of Antwerp, JRC-IET (Petten), JRC-IES (Ispra), EMPA Swiss Federal Laboratories, University of Athens, University of Malta e University of Tehran.

Serena Righi (Chair del Convegno)

Maurizio Cellura (Presidente dell'Associazione Rete Italiana LCA)

Edilizia



Environmental impact evaluation of dairy farms through life cycle assessment: a case study in Malta

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Abstract

In this study the potential environmental impact of 12 dairy farm systems in Malta was quantified using the Life Cycle Assessment (LCA) method. The analysis was conducted until the farm gate through the life cycle of dairy systems. In addition to investigate the impact for the main impact categories, the work measures the major greenhouse gas (GHG) emissions associated with dairy farming. Emissions are reported per kg of Fat and Protein corrected milk (FPCM) units at the farm gate. The twelve farms of the study are distinguished by farm size in term of number of reared animals. The animals taken into account represent 20 % of all the dairy cows reared in the Maltese islands. With analysis on this population the study wants to realize the degree of environmental sustainability of the Maltese dairy industries, given the small size of the islands and the lack of available land that the dairy cows need for their supplying.

1. The dairy sector development at the global and European scale

In 2010, EU-27 cow's milk production amounted to 149300 million tonnes, with an average yield per cow of 6457 kg. The restricted development of some countries and small herds cause the reduction in average milk production when compared with efficiency reached in the most Member States (Eurostat, 2012). Over the past 15 years there has been a changing in milk production characterised with a reduction of the collection of bulk liquid milk (Faostat, 2015). In general the production in developed countries is going down, while efficiency is rising. At the same time milk production in developing countries is increasing together with the number of animals.

1.1 The cattle industry and milk production in Maltese islands

The dairy herd in Malta represented 43 % of all cattle stock in 2014, accounting for 6502 cows seated in about 120 dairy farms (NSO, 2015).

1.2 Maltese Dairy Industry

Milk production is a cornerstone of agriculture activity according to the National Statistics Data. The sector represents the 73 % of the Gross Agricultural Production for animal products. The Maltese dairy sector supplies the Maltese population and tourists with a daily stock of a variety of high quality fresh milk

products. The sector generates an important amount of economic activity by furnishing an annual production of 41,000 tonnes of fresh milk to dairy processing plant (Malta, 2009). The milk factory processes, packs and distributes fresh liquid milk from the majority of Maltese farms. The milk is collected daily, it is pasteurised and sold for the local market. The milk factory is a cooperative that is included in the Milk producers' cooperative KPH (Koperattiva Produttori tal- Halib).

1.3 Major limitation of Maltese Dairy sector

Nowadays Malta has the highest concentration of dairy cows in Europe when compared with the small Agricultural Area (Eurostat, Agriculture, fishery and forestry statistics, main results 2010-2011, 2012). The small size of the Maltese Islands creates different challenges for the dairy sector. The major restrictions are the very exiguous arable land, the scarce rainfall and the limited access to water that obligate the sector to depend on imported grains and other feeds. The reliance entails the high sea transport costs given by the small volume of purchases and imports and as well the logistical constraints associated with Malta's geographical size and location.

1.4 Livestock food in the diet and its environmental impact

In recent decades, (1961 - 2013), world milk production from dairy cows rose by 51 % (Faostat, 2015). With developing countries increasing their share in global dairy production. The growth is due to the increasing number of milking herds rather than an increase in productivity per head. Indeed, in many developing countries, dairy productivity is constrained by the low efficiency of the system, i.e. poor quality of feed resources, health challenges and restricted access to markets and animals' low genetic potential for milk production.

Over the years, the per capita consumption of livestock products has increased in all regions of the world (FAO, 2011). The constant rising of world population is linked to the consequent increase of the food demand.

Unfortunately, the necessity to increase the global production of food contrasts with the availability of natural resources. For this reason, food security is connected to the capacity of the world as a whole to produce food. The potential land utilized for human and animal supply is contended between them. In this context, animal production has become an important contributor to the depletion of natural resources. In recent years, the interest in the scientific community towards the impact that the consumption of animal products can lead to has raised significantly.

Livestock contributes to GHG emissions mostly for N₂O and CH₄, respectively from soil emissions, manure management and enteric fermentation from cattle. In general livestock production has been subjected to great transformation mostly in developed regions, with a constant increment in production per animal and crop yield per hectare that lead to a less input for the same output (Kristensen, 2015). Moreover an accurate diet for herds that permits to use the crude protein quota without waste of nutrients can play an important role in

environmental issue. Many authors affirmed that a reduction in terms of greenhouse effects from livestock takes place in comparison with 60 years ago.

A detailed assessment of the global dairy sector has been published by the Food and Agriculture Organization in 2010 and assesses, through the LCA method, as the dairy sector was responsible for 4 % of global emissions including the impact of by-products (Gerber, 2010).

2. Aim of the study

The purpose of this study is the evaluation of the potential environmental impact of twelve dairy Holstein farms of Maltese Island through the analyses of the life cycle, using Life Cycle Assessment approach. The study begins from the production of raw materials (cultivation's operations) and their procurement, raw materials transportation, feed processing at the mill of Malta, animal feeding, farm management, milking cow and the milk storage until the collection of the milk. The process will end at farm gate, so next phases, such as milking processing, packaging, use and waste scenarios will not be considered.

With this example the study wants to realize how the Maltese dairy industries is environmentally compatible, given the small size of the islands and the lack of available land that the dairy cows need for their supplying. Thanks to the application of this method it is possible to understand the heaviest phases that mostly weigh on the life cycle to improve the sector. From a zootechnical point of view, the purpose can be to understand which phases mostly influence the production of milk. In this way it could be possible to promote a more friendly management of the herd in Malta.

3. Methods: Impact assessment methodologies: Ecoindicator99 and IPCC

For this study for the evaluation of environmental impact, Eco-Indicator99 method was applied and 11 impact categories were considered (Table 1).

For the evaluation of the emission in air of GHG, the IPCC method 2001 was applied on the base of the IPCC Third Assessment Report (IPCC, Climate Change 2001: The scientific basis, 2001). Results are expressed in terms of GWP for a 100 year time horizon. Simapro7.1 was the utilised software utilised to elaborate data (Product Ecology Consultants, 1990).

4. Case of study

A group of 12 Maltese dairy farms was analysed in a "cradle to farm gate" life cycle assessment (LCA). All of these farms are members of the Maltese cooperative dairy company (KPH) that collects the milk daily and also assembles animal feed that is used by the milk producers to feed their herds. Selection criteria were based on farm size: farms with less than 50 cows (Farms A1 and A2), from 50 to 100 (Farms B1, B2, B3, B4) and more than 100 cows (Farms C1, C2, C3, C4, C5 and C6) were selected and analysed.

Table 1: Impact categories - Ecoindicator99 method

Impact Categories	Meaning	Units
Human Health		
1. Carcinogens	Arsenic, Benzene, Cadmium, Heavy metals etc.	DALY (Disability Adjusted Life Years)
2. Respiratory organics	All kinds of organic emissions to air	
3. Respiratory inorganics	Emissions to air, mainly of SO ₂ and NO	
4. Climate change	Emissions to air of hydrocarbons, carbon dioxide, methane etc.	
5. Radiation	All kinds of radioactive materials	
6. Ozone layer	All kinds of ozone-depleting substances (CFC, etc.)	
Ecosystem Quality		
7. Ecotoxicity	Emission to water, air and soil which cause toxic stress for the ecosystem	PAF*m2yr (Potentially Affected Fraction for square meter for year)
8. Acidification/Eutrophication.	Emissions to air and water, mainly of Nitrogen, Ammonia and Phosphorus	PDF*m2yr (Potentially Disappeared Fraction for square meter for year)
9. Land use	Occupation and transformation of land	
Resources Consumption		
10. Minerals	Aluminum, Iron, Lead, Copper, etc.	MJ surplus
11. Fossil fuels	Consumption of non-renewable resources	

All data collected are referred to 2014. Data concerning herd composition, herd parameters such as fertility rate, replacement and eventually mortality rate, farm land area and the eventually related crop production, ration composition, average milk yield and constituents, housing system, manure management and energy consumption were collected through a questionnaire by personal interviews to the farmers.

Farm buildings and machineries were not included in the assessment; medicines, detergents and trivial stable materials were kept out from the study. Origin of purchased items such as forages, concentrate feed, bedding materials were recorded. Regarding the concentrate feed, it is essential to underline that all the farms purchase these portion of the ration mainly from KPH's company, which arranges different commercial concentrates for each category of the herds as a complete mash in different forms, such as pellet, extruded or milled components. Differently, the forage portion of the ration is mainly bought from other Mediterranean countries directly by the farmer.

Forage such as alfa-alfa hay and ray grass come mostly from Sicily (Italy) and Spain, wheat-straw come in part from Malta and in part from Sicily. KPH's company bought directly the raw feed utilised in the commercial mash production, the raw material become from Europe except for soybean. The composition of each commercial concentrate was given by KPH company and the amount per animal were estimated on the basis of the concentrate fed and its composition with the help of CPM-Dairy Ration Analyser Beta V3 Software (Cornell-Penn-Miner, 2004).

Table 2: Main characteristic of the studied dairy farms

	Mean±SD	min	max
<i>Herd</i>			
Livestock Unit, n.	144.57±59.14	16.1	287.6
Lactating cows, n.	91.25±50.91	10	173
kg FPCM, cow ⁻¹ year ⁻¹	8028±1254	5791	10423
Forage % annual DM intake	51.10±10.57	26.85	62.73
Forage % annual DM intake in lactating cows	50.29±12.42	28.86	74.8
Feed efficiency (kg FPCM kg DMI ⁻¹ cow ⁻¹)	1.22±0.17	0.98	1.57
<i>Land and Farm</i>			
Arable Land, ha	4.85±6.48	0.54	20
Stocking rate, LU ⁻¹ of arable land	96.30±95.07	6.62	247.3
Feed self-sufficiency (based on DM)	2.95±2.76	0.22	8.86
<i>Milk quality</i>			
Gr%	3.62±0.16	3.3	3.8
Pr%	3.23±0.13	3.1	3.5

To estimate emissions from dairy system, a farm model was developed in Excel® including a model for herd structure and feed requirement for each category of animals, calculating the total feed intake by the herd in a year in order to estimate the land use required to obtain all the amount of raw materials. The farm model was built using the information derived from the questionnaire filled up during farm visits. The farm model includes the average potential herd consistency during the year, with the following categories: lactating cows, dry cows and replacements heifers.

Considering all of these parameters we have the distribution of the herd categories, obtaining the annual requirement (metric tons) of each diet ingredient per each herd category on the basis of the different diets used for each category. When obtained the annual feed requirement for each farm, the hectares needed to obtain the raw feed were then estimated, considering the average yield of South Italy for almost all the cultivations with the exception of soybean, for which was considered the average yield in South America. The main characteristics of the farms are reported in table and allotted in herd, land, farm and milk quality characteristics.

4.1 The system boundaries and functional unit

Each farm was analysed in a “cradle to farm gate” approach. The farmers deliver the milk individually every day to the cooperative where the milk is processed. The current study takes into account the following stages of the milk life cycle: the production and transport of feed and fertilisers, manure handling, farm operations, dairy processing and cooling; it stops before the delivery to the milking plant (Fig. 1).

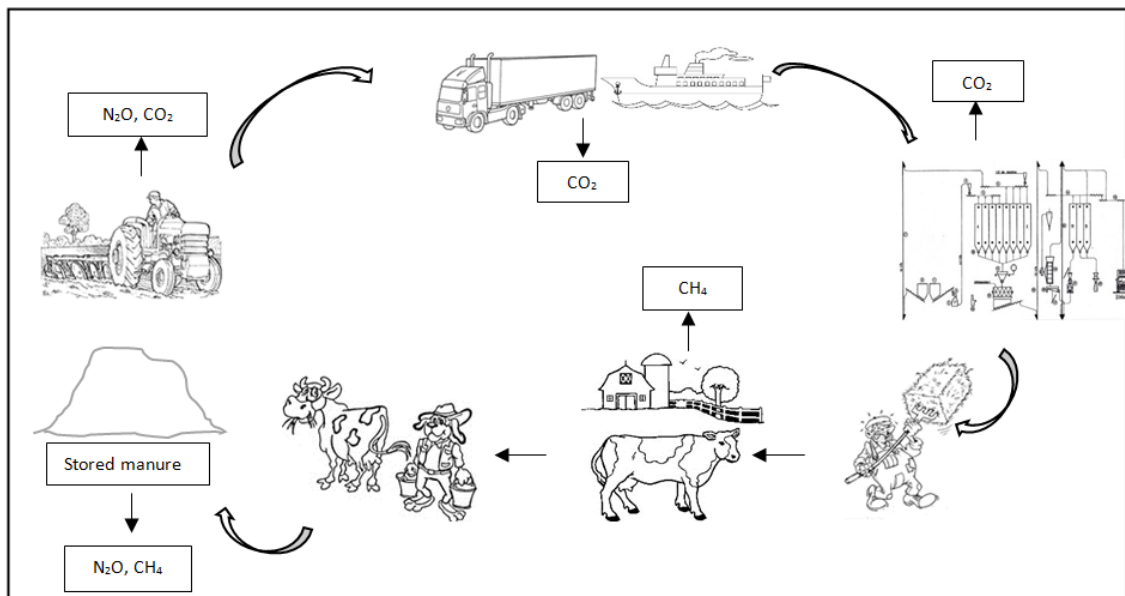


Figure 1: Schematic flow chart of the milk life cycle at farm gate

For every cultivation the entire production model was built from tillage to harvesting, considering all the inputs included into the process such as the amount of fertilizers and the outputs such as emissions to air, soil and water. The cultivation is one of the steps built into Simapro software, where all the processes were created including all the inputs and outputs required from the system, and all the transports (km*tons of material) of each phase were considered.

The functional unit considered for the LCA studies was 1 kg Fat and Protein Corrected Milk (FCPM) leaving the farm gate: $FCPM (kg) = kg \text{ of milk} \times (0.337 + 0.116 \times \% \text{ fat} + 0.060 \times \% \text{ protein})$ (Gerber P. V. T., 2010). Therefore, in relation to GHG emissions, these are expressed as CO₂-eq / kg of FCPM.

4.2 Inventory analysis

Three stages were implemented into Simapro software: Plant Production, Feed Production and Farm phase. For each phase the software asks for the inputs and the outputs.

Table 3: Inventory data

STAGES	INPUTS & OUTPUTS	
Plant Production	Agricultural operations, supply of fertilizers and herbicide, water requirements, harvesting, bailing and transports.	Yield per hectares.
Feed Production	Energy required to produce commercial concentrate and transports.	Feed consumption.
Farm phase	Diet, water requirement, fuel, energy used and transports.	Milk production.

For each cultivation the specific amount of fertilizer and its emissions into the land, calculated according to the Italian National handbook of factors emission (Gioia Bini, 2002), were considered. Concerning the transports, the output of every single crop was assumed to be transported by lorry if the point of origin was from the north of Europe to Sicily (Pozzallo); then the ship to Malta and the lorry from the harbour to the KPH's company mill or to the farm were accounted; differently, if the source of origin was East of Europe we considered ship from Greece to Malta and the same if the raw feed came from Spain.

Energy required to produce commercial concentrate at KPH's Company or to mix the different ration in the Total Mixed Ration wagon in the farm, were

estimated. So, the energy required (in terms of kWh) to obtain 1 tonnes of pellets is different respect the energy required to obtain a mixture of simple milled feed. Hence with the help of KPH's operators it was possible to estimate the energy required to produce the different commercial concentrates utilised by the dairy farmers expressed in kWh. After this step the transport of the commercial concentrate from KPH's Company to the farm was considered and was considered 20 km in average for each farm.

Farm phase represent the final step of the arrangement. All the components of the diet were considered: commercial and simple concentrates, forages, water requirements, fuel and energy used at farm for routine works and all the transports from the field to the herd and from the KPH's Company to the farm.

4.3 Type of data and impact assessment

In order to assess LCA, primary and secondary data were used. The primary data were assembled using direct interview to the farmer for the feed ingredients, the dairy rearing system, the consumption of energy and fuel consumed at farm level and at KPH's Company to produce commercial concentrate. The secondary data were used to calculate the transport emissions and carbon sequestration data and were mainly taken from the Ecoinvent database 2.2 (Ecoinvent, Ecoinvent Data V2.2, 2010).

5. Results

Emissions and resources that come from the inventory phase are arranged into different impact categories according to their potential impact on the environment. The results of Ecoindicator method show differences between farms mostly in three impact categories: Fossil fuels, Land use and Respiratory inorganics. It comes out that to farms with high content of fodder into diet are associated lower emission in comparison to farms with an high use of concentrate into the diet. This is linked to the energy used to produce concentrates and fossil fuel used for transports. Because "Feed production" stage results to be the phase with the highest weight in term of environmental impact. Among concentrates, soybean imported from Argentina is the main responsible. Soybean meal appears the main factor influencing Fossil Fuel as impact category, mainly utilised for soy cultivation, soy oil extraction, soybean meal drying and its shipping. Concerning GHG emissions calculated with IPCC 2001 method those varied from 1.14 to 3.00 kg CO₂-eq. kg of FPCM⁻¹ at farm gate. These values are in agreement to those observed by Weiss and Leip (2012) and carried out with CAPRI Model for EU27 countries. In the present study 60% of the GHG are attributable to purchased feed which represent the 50% of the DMI and in particular by commercial concentrate whose formulation is characterised by an amount of soybean meal which ranges from 13 to 45% representing the strongest environmental constrains in the purchased feed (Figure 2).

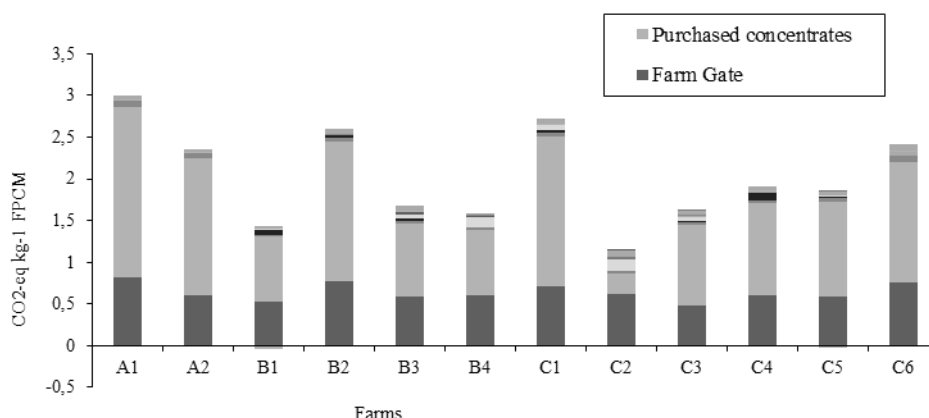


Figure 2: GHG emissions

Emission per kg of milk estimated in previous LCA studies for dairy production are showed in Table 4. Some of the results from precedent analyses are lower than the present study probably because of allocation technique or the choice of emissions factors as suggest Gerber, 2010.

Table 4: Emission per kg of milk estimated in previous LCA studies for dairy production

Reference	Country	Units
(Guerci, 2013)	Italy	1.11 – 1.91 CO ₂ -eq/ kg of ECM
“	Denmark	1.10 – 1.66 CO ₂ -eq/ kg of ECM
“	Germany	0.55 – 1.32 CO ₂ -eq/ kg of ECM
(Guerci, 2014)	Italian Alps	1.55- 1.72 kg CO ₂ -eq. / kg of FPCM
(Capper, 2009)	USA	1.35 kg CO ₂ - eq./kg of milk
(Thomassen, 2008)	Netherlands	1.5-1.6 CO ₂ -eq/kg of FPCM
(Basset-Mens, 2009)	New Zealand	0.65-0.75 CO ₂ -eq/kg of FPCM
(Cederberg, 2009)	Sweden	1 kg di CO ₂ -eq/kg of ECM

6. Conclusions

This study deals only 12 farms which are representative of the dairy production systems in a particular area study as Malta although each of them based on similar production strategies, management efforts, as feeding strategies, present little but significant differences. Indeed purchased feed quantities varies among them with a consequently different environmental impact.

Emissions intensities of cow milk seems to be leaded by a mixture of effects: usually, as studied from other authors (Weiss F., 2012), high emissions are related to low milk yields, on the other hand, high milk yields are often related to the consumption of feed concentrates. If feed concentrates are imported from other countries, they are frequently accompanied by high emissions of CO₂, as

the case of Malta, in which CO₂ emissions in the share of GHG emissions are relevant compared with the others GHG emissions. So in an environmental sustainability contest it has become necessary to start thinking different way to feed animal and in particular concerning proteins, as the case of soybean; one reason is linked to the high energy implied to transform soybean into available feed and the second is linked to the transport. In Europe in general, livestock protein requirement should be changed in order to use local raw material to reduce imports from abroad.

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