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Life cycle analysis of raw milk production in Tunisia

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Abstract. Life Cycle Assessment (LCA) is a tool to calculate greenhouse gas (GHG) emissions of dairy production. A survey was conducted in 20 dairy farms at the governorate of Sousse. The present study aimed to evaluate environmental impact of milk production at the farm regarding GHG emission and energy consumption. In the 20 dairy farms total GHG emissions resulted in a mean of 0.63 ± 0.2 kg CH_4/kg ECM and forage can contribute with a means 0.35 Le kg CO_2eq/DM. The main reductions in GHG emissions per kg of FPCM started from 2,347 kg per cow per year and then the reduction slowed down to stabilize at around 6,127 kg FPCM per cow per year.

Keywords: Life cycle analysis; Mitigation; Carbon footprint; Milk corrected.

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Introduction

Global climate change has become a global challenge, caused by greenhouse gas (GHG) emissions that pose a risk to the environment, human health and safety (Mantyka-Pringle et al., 2015). Agricultural production is a major source of GHG emissions, accounting for 15% to 25% of total a GHG emissions, including about 5% of dairy products (Laratte et al., 2014, Hawkins et al., 2015).

GHG emissions associated with dairy products are increasing each year due to continued increases in consumer demand (Baek et al., 2014; Adler et al., 2015). However, the development of low-carbon foods is a practical need for the food industries to reduce their GHG emissions and continue their long-term commercial success (Biggs et al., 2015). The carbon footprint is an effective indicator to embody the concept of low carbon, considered as the total carbon emission of a certain product or service throughout its life cycle (Dong et al., 2014). Due to this increased demand and the environmental impact of milk production, in terms of greenhouse gas emissions, it is important that milk can be produced in an efficient and environmentally friendly way.

This study is expected to provide a simplified assessment approach based on a milk LCA framework, which focuses on presenting information on carbon emissions to consumers, in order to help local dairy farms, identify the most relevant sector, more carbonaceous life cycle. Dairy companies with higher environmental morality to have an attempt at carbon labeling of the product, to provide effective measures for reducing emissions in the dairy supply chain

Materials and methods

Study area and sampling

This study was conducted in conducted in 20 dairy farms at the governorate of Sousse (Tunisian littoral). The climate is hot-summer Mediterranean climate, where winters are mild with moderate rainfall and summers are hot and dry. Temperatures in July and August can exceed 40 °C. To allow a good cross-checking of the collected information, a standardization of the methodology was then necessary. A first selection criterion was membership in the OEP dairy control program. The number of breeders surveyed being 20 individuals who are the most cooperative and understanding to be able to get the most information. Given the time available to collect the information, the large extent of the survey area, the requirements of the methodology adopted and the number of visits that could be made to each area were limited: It would have been difficult to form two samples of sufficient size to offer a correct representation of the producers.

Survey

Given the objective of the study, it was decided to proceed with a guide to the LCA method designed as a virtually exhaustive checklist of topics that needed to be addressed to assess the impacts of livestock systems on the environment. The questionnaire includes the presentation of the farm (bioclimatic floor, slope, size, vocation ...), the herd of dairy cattle and other animals on the farm, annual and perennial crops (type of crop), production, consumption of energy and electricity as well as phytosanitary products and fertilizers.

Functional unit and Tools for calculating GHG emissions

The functional unit we adopted at the farm level in this study is FPCM kg, or milk corrected energy (ECM), since the energy in the food is converted to fat and milk protein. However, FM and P percentage vary between farms depending on the ration. To standardize at a milk of 4% FM and 3.3% P, we used the approach developed by the National Research Council (NRC, 2001):

$$FPCM = \frac{PL(0{,}929MG + 0{,}05882P + 0{,}192)}{0{,}929 * (4\%) + 0{,}05882 * (3{,}3\%) + 0{,}192}$$

With:

FPCM is the production of milk corrected for fat and protein (kg/year);
PL is the estimated milk production (kg/year);
FM is the percentage of milk fat and P is the percentage of protein in milk.

GHG emissions from the farm were estimated using Holos Software (Version 2.2). Holos is a model that predicts GHG emissions at a monthly time step for livestock operations and at an annual time step for cropping systems as well as land use and management changes (Little et al., 2013). Emission factors at ecological zone level adjusted for variations in climatic and edaphic conditions across Tunisia are incorporated into the model. The total expected GHG emissions at the farm level include: enteric CH_4 emissions from rumen fermentation; CH_4 and N_2O emissions from manure; N_2O emissions from soils and crops on the farm; N_2O emissions from leaching, runoff and nitrogen volatilization (indirect N_2O) off-farm; and CO_2 emissions from energy use and non-agricultural production of agricultural inputs. CO_2 emissions of carbon sequestration due to soil carbon change were predicted using the Introductory Carbon Balance Model (ICBM) (Andrén and Kätterer, 1997) using simulation approach of Kröbel et al. (2016).

SimaPro version 7.1 software facilitate the management of data and scenarios. In our study, it was used to calculate the impact flows of the various components of the production systems. The outputs of SimaPro will be used as the inventory for their simulation with Holos software.

Results and discussion

The characteristics of the farms

The characteristics of the farms studied are summarized in Table 1. The average size of the herd was 16 heads and varies from 5 to 50. The average annual milk production expressed in kg FPCM per cow present is 6,074 kg FPCM and varies between 4,527 kg FPCM and 7,124 kg FPCM. The average feed efficiency is 1.17 ± 0.17 kg FPCM/kg DM/cow. In terms of the average FM and P composition, it is 3.54% and 3.22%, respectively, for FM and P. The land cover for animal feed production has been divided into arable land (to the farm and off the dairy farm for purchased food) and in natural pastures. For land use, we recorded an average of 4.86 ha.

Total energy consumption

The total energy consumption is on average 13.16 MJ/kg milk (Table 2). It ranges from 5.8 to 23.36 with a standard deviation of 2.14 MJ/kg milk. About 16.56% of this energy consumption was attributable to electricity and fuel consumption. 43.61% due to the production and transport of concentrated feed purchased. the application of chemical fertilizers and fertilizers consumes 39.81% of the total energy. Our results are inferior to those of Upton et al. (2011) who reported an average consumption of about 31.73 MJ/kg milk in dairy farms in Ireland.

Table 1: Characteristics of farms visited.

	Min	Means± SD	Max
Herd			
Lactated cows	5	16±5	50
kg FPCM/cow/year	4527	6074±958	7124
% DMF/year	37.11	52.17±11	63.43
% DMF/in lactation cow/year	35.12	51.13±13	57.25
FE (kg FPCM/kg DM/cow)	0.97	1.17±0.17	1.27
Farm and land use			
CA (ha)	2	4.86±2.76	12
FS (DM)	0.78	2.77±1.87	6.13
Milk quality			
FM (%)	3.27	3.53±0.14	3.84
P (%)	3.1	3.22±0.13	3.5

kg FPCM = kg of fat and protein corrected milk. % DMF/year = consumption of forage dry matter per year; %DMF/cow/year= annual dry matter feed consumption per lactating cow per year; FE (kg FPCM/kg DM/cow) = feed efficiency per kg of milk adjusted for fat and protein per kg of dry matter per cow; FS (DM) = Food sufficiency; CA = Area cultivated (ha); FM= fat matter; P, protein of milk.

Table 2: Total consumption values expressed in MJ / kg of milk.

Energie consumption (MJ/kg milk)			
Category	**Min**	**Mean ±SD**	**Max**
Fertilizer	3.54	5.24 ± 2.12	9.17
Concentrates	1.14	5.74±1.7	9.65
Electricity	1.11	2.01±1.2	3.41
Fuel	0.01	0.17±0.02	1.13
Total	5.8	13.16±2.14	23.36

Flow analysis during the milk production cycle

The results of Sima Pro (version 7.1) in Figure 1 show the impact of dairy production on the environment. The flowchart shows the flow of impact across the system and illustrates the processes involved in milk production. The red line indicates the negative impact and more the red line is thicker, higher the impact flow is important. The impact is gradually totalized at each stage of the production system. According to this flow chart. the production of one liter of milk at the farm level accounts for all components of the farm: all categories of animals contribute 11.7%. lactating cows at 9.9%. The most important impact is recorded by food (concentrated feed, forage and pasture). it is estimated at 67%. The percentages charged to the equipment are relatively low. since the farms visited are considered small production units and do not require powerful power-consuming machines or excessive fertilizer application. they value the existing manure. Our results are similar to those of Orphant (2004).

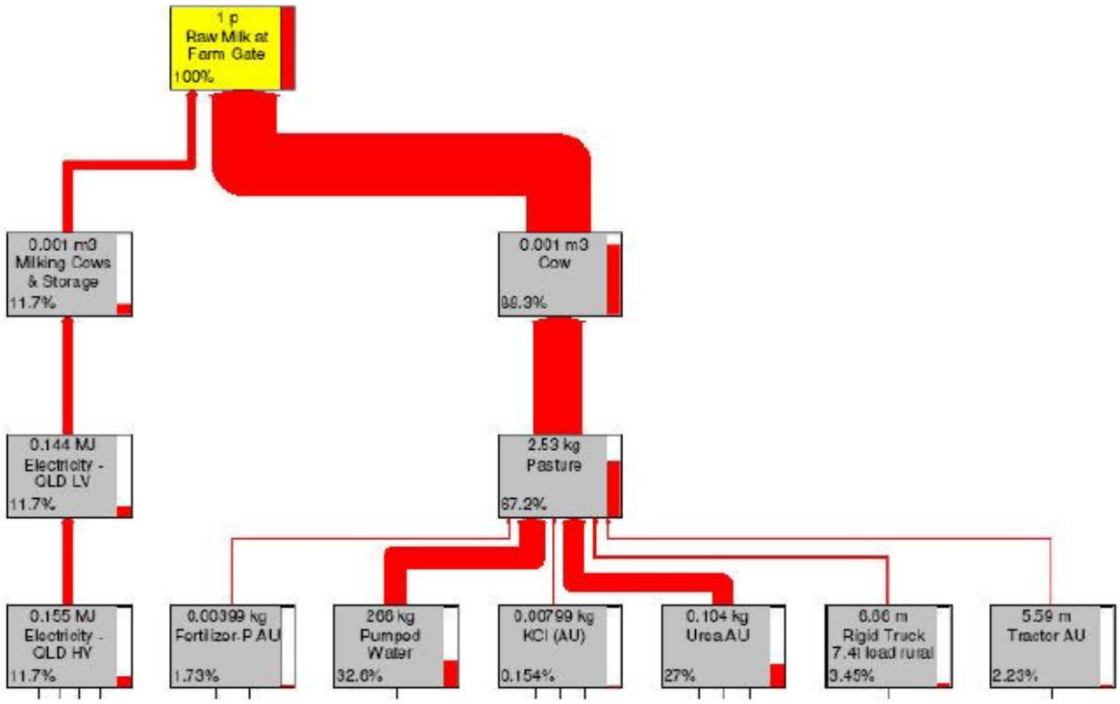

Figure 1. Organizational Chart of LCA for Dairy Production at Farm Level.

Greenhouse gas emissions at the farm level

It is very important to put the issue of methane production by cattle back into the overall context of the farm and to consider all the greenhouse gas emissions. Indeed, if an intensification of the farming system reduces the amount of methane eructated per liter of milk. this modification of the system generally implies an increase in emissions of other greenhouse gases. Figure 2 shows the average CH_4, CO_2 and N_2O emission fluxes in farms expressed in kg CO_2eq emitted per kg FPCM. Average enteric methane emissions for the flock. was 0.63 ± 0.2 kg CH_4/kg FPCM. This value is lower than that found by Tieri et al. (2017) who reported enteric methane emissions in the order of 0.83 kg kg CH_4/kg FPCM in Holstein cows with an average milk production of around 7500 kg FPCM/ cow/year. Capper et al. (2009) found that a cow in the United States producing approximately 9050 kg of milk has a carbon footprint of approximately 1.52 kg CO_2eq/kg of milk. A study conducted in Canada by Verge et al. (2013) on cows with a milk yield of 9,400 kg has a carbon footprint of 0.98 kg of CO_2eq/kg of milk.

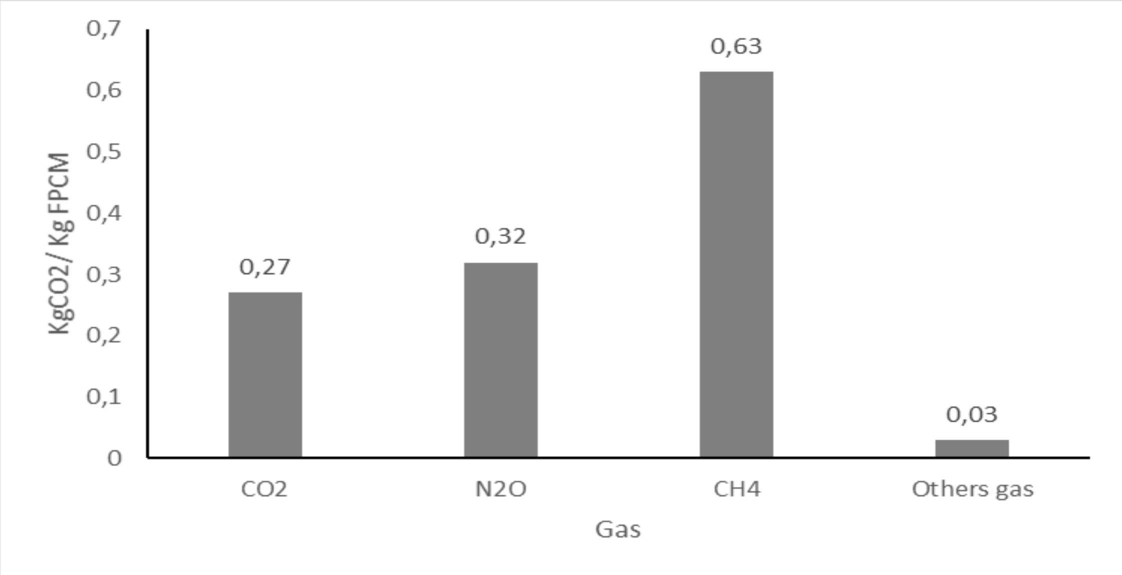

Figure 2. Potential greenhouse effect of visited farms.

Carbon footprint of milk production

The carbon footprint of milk production is 877 g, identified as the main source of the carbon footprint in the milk life cycle. More precisely, forage such as corn and silage are the main contributors (534 g) which represents 60.8% of the total carbon footprint. CH_4 emissions of dairy cows are the second highest, with a carbon footprint of 283 g representing 32.27% of the total carbon footprint (Figure 3). This may be due to rumination and rumen fermentation of the cow that emits a significant amount of enteric methane. Our results are in the ranges reported by Zhao et al. (2017) and Wang et al. (2016).

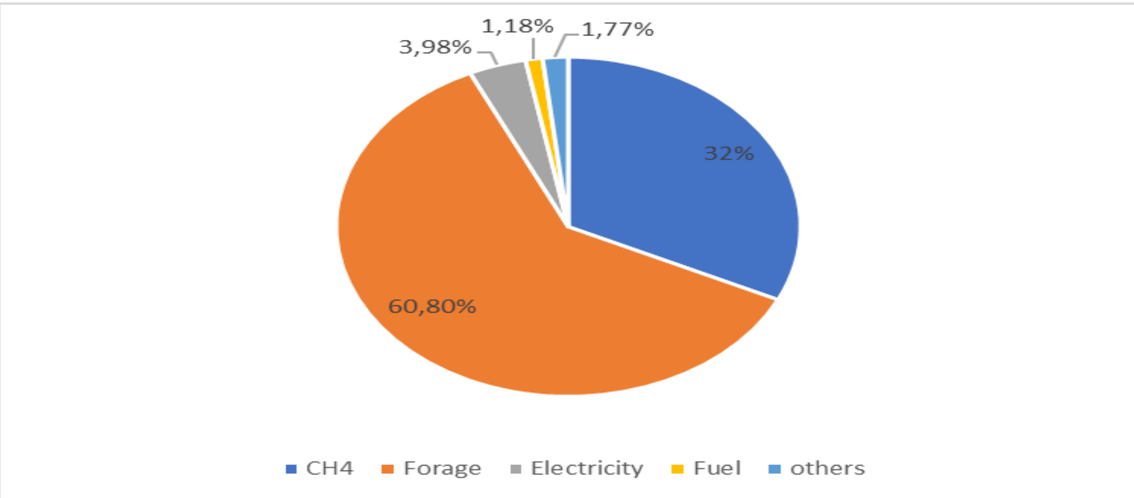

Figure 3. Carbon footprint of milk production.

Carbon footprint of forage production

Figure 4 shows the Carbon footprint of forage crops. Indeed, the highest kg CO_2eq/kg DM is attributed to Sorghum with an average of 0.54 kg CO_2eq/kg DM produced. while the lowest value is recorded for cereals. The CO_2eq/kg DM of all kind of silage is of the order of 0.35. This is considered low in relation to several results which can be explained by the fact that the majority of breeders do not use fertilizers and heavy machinery for tillage.

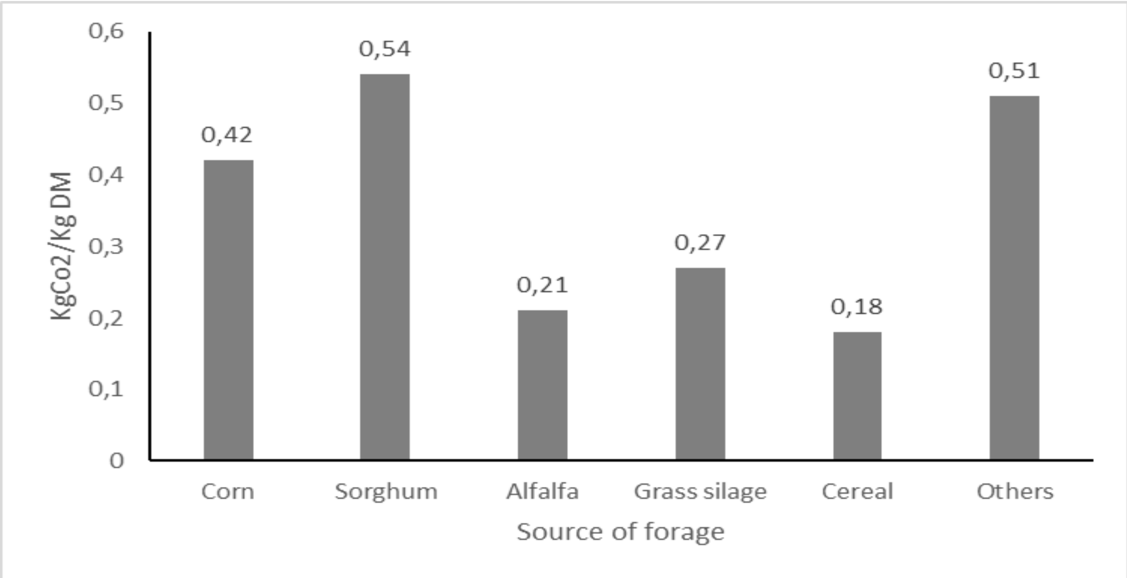

Figure 4. Carbon footprint of forage production.

Correlation between milk production and GHG emissions

The study of the relationship between milk production and GHG emissions has shown that with increasing yields, GHG emissions per cow have increased but decreased per kg of production (FPCM) with a significant relationship between productivity and GHG emissions per kg of milk produced. As shown in Figure 5, the main reductions in GHG emissions per kg of FPCM started from 2,347 kg per cow per year and then the reduction slows down to stabilize at around 6,127 kg FPCM per cow per year. Our results agree with those of Gerber et al. (2013) who recorded a remarkable reduction at 2,000 kg FPCM and a stabilization from 6,000 kg FPCM/cow/year. In the same context, Weidema et al. (2008) analyzed the potential for improving the environmental impact of milk production and meat products. They modeled with data from different cattle production systems in Europe an increased milk yield of 5,900 kg to 8,500 kg/cow and year and their effects

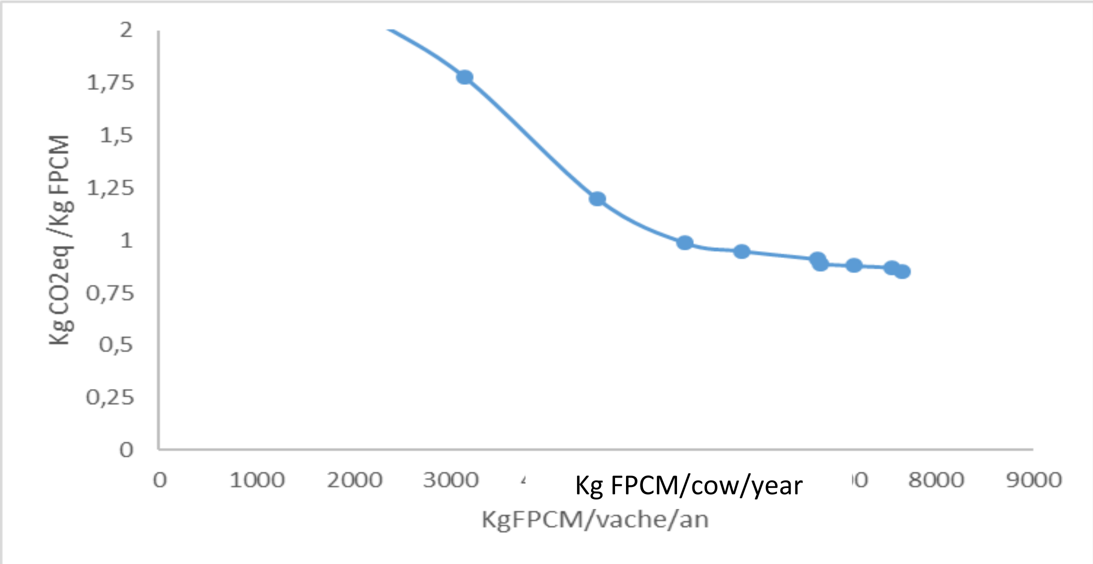

Figure 5. Correlation between milk production and GHG emissions.

Conclusions

Life Cycle Assessment (LCA) allows the assessment of a product or a production system. It is a conceptual framework that can lead to Life Cycle Sustainability Analysis (LCA) considering the other two pillars of sustainability, social and economic. The environmental performance assessment of dairy farms and GHG mitigation are broadly like studies in several countries.

Since this study is the first in Tunisia, it will be a tool to know the environmental performance of dairy farms. Indeed, improving productive efficiency is the most important factor that breeders need to consider when adopting environmentally friendly farming practices. This study is an example of measurements based on real farm data and what might be expected in specific scenarios. It also largely illustrates that reductions in greenhouse gas emissions are achievable and consistent with maximizing farm profits.

Conflict of interest

The authors declare that they have no conflict of interest in the publication.

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