# SOLID participatory research from Italy: Climate friendly organic milk production

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# Summary

This report presents the results of the case study "Climate friendly organic milk production" carried out in Italy as part of the "On-farm participatory research" in the SOLID project (Task 1.4 of WP1). The report describes the execution and findings of the trial and the LCA study performed at the Hombre organic farm.

The main goal was to evaluate the environmental performance of two different diets administered to a dairy herd (one consisting of almost all feed ingredients produced on the farm and the other composed of both feedstuff produced on the farm and purchased raw materials) to reduce environmental impact.

The feeding trial was carried out with 136 dairy cows (Italian Friesians) between January and March 2014. An attributional and cradle-to-farm-gate LCA approach was used to estimate the carbon footprint of the diets. Furthermore, the diets were assessed for their economic sustainability.

The results of this study indicate that the cows fed with a home-grown ingredient diet had a lower milk yield compared to those fed with a standard diet. The qualitative characteristics of milk were not affected by the diets. The impact of the experimental diet) on global warming, calculated in terms of kg of CO2-eq, is higher than the control diet (1.16 kg CO2-eq compare with 1.05 kg CO2-eq).This is mainly due to a reduction of milk production in the experimental system.

The protein content of feeds crucially affects the milk yield of cows. The ingredients of the experimental diet were limited to currently home-grown feeds, their protein content was mainly derived from alfalfa hay, while the protein content in the control diet was derived from soybean meal. Therefore, it has been suggested to integrate other home-grown crops. For example, faba-beans or peas are both suitable crops for improving home-grown protein supply to low input dairy systems and could be viable alternatives to soy with lower impact on the milk yield.

With regards to the economic evaluation, the overall impact on income of the experimental diet – at current milk prices – is negative, but the financial loss from the lower milk yield can be partially recovered through the lower cost of the home-grown ration.

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# 1 Aims and Research question

The present study aimed at evaluating the carbon footprint of organic milk obtained from two different diets. The main goal was to evaluate the environmental performance of two different diets administered to a dairy herd (one consisting of almost all feed ingredients produced on the farm and the other composed of both feedstuff produced on the farm and purchased raw materials) to reduce environmental impact. An on-farm trial was implemented in order to evaluate the effect of a diet based on home-grown feed ingredients on milk production. This was followed by an attributional and cradle-to-farm-gate LCA approach to estimate the carbon footprint of the diet. Therefore, the possibility of substituting the purchased protein ingredients, which have a negative environmental impact, with other on-farm-grown ingredients was also evaluated. Furthermore, in addition to the trial and LCA results, some general economic evaluations were carried out in order to assess the impact of the alternative diet on milk production costs.

# 2 Background

## 2.1 Farm Background

Hombre is an organic farm that makes Parmigiano Reggiano cheese. The farm has almost 300 hectares of flatlands and the herd is composed of 500 Italian Friesians, 240 of which are lactating. The farm is certified by CSQA and ICEA institutes under the new “Organically Farmed” standard. In 2003, Hombre obtained U.S. organic certification in compliance with the stringent NOP (Natural Organic Program) standard. Hombre decided to take part in the study in order to lower its emissions by using feed ingredients produced on site. The expectation is to introduce a successful and optimizing method that will give results in the long term and to obtain possible environmental certifications. The research group of UPM, in collaboration with ICEA, proposed the farm for the on-farm project. The protocol of the trial has been defined by researchers and Hombre staff in participatory approach.

## 2.2 Research Background

Agriculture is one of the main sources of global emissions of greenhouse gases (GHGs) it accounts for 10–12% of total global anthropogenic emissions of GHGs (IPCC, 2007). The livestock products are GHGs intensive (Garnett, 2009), roughly 80% of global agricultural GHG emissions are due to livestock (FAO, 2006). In particular, the most relevant GHGs are methane (CH4) and nitrous oxide (N2O) (Kristensen et al., 2011). The CH4 emissions come from both enteric fermentation in ruminants and manure handling, while direct and indirect N2O emissions are due to the intensive nitrogen (N) cycle on livestock farms (Olesen et al., 2006).

The farming step is essential to determine the carbon footprint, since 70 to 90% of the emissions of the entire supply-chain occur before the products leave the farm gate (Hermansen et al., 2011).

In the case of dairy products, several factors contribute to the carbon footprint, for example: emissions from enteric fermentation, feed production, manure and farm management. The environmental impact can be reduced mainly on the farm. This can be obtained by selecting particular diets to reduce the enteric emissions, by introducing energy recovering from anaerobic digestion of manure, and by optimizing the use of fertilizers (Fantin et al., 2012).

In our case, it is not possible to evaluate a proper diet to reduce the enteric emissions because we cannot change the relationship between forage and concentrates (60 forage: 40 concentrates) because of the rules on organic production and the Parmigiano Reggiano specification. Therefore, we want to evaluate the possibility of reducing GHGs by feeding the cows with almost only ingredients produced on the farm to reduce the impact due to transport of feed (Knudsen et al., 2010). Since milk yield per cow is one of the main factors that modify the carbon footprint analysis (Rotz et al., 2010; Hermansen et al., 2011; Opio et al., 2011), we wanted to monitor and compare the overall milk production using different diets. Over the last years, the LCA method has been widely used to assess the environmental impact of different milk production systems across Europe (Guerci et al., 2013; Yan et al., 2011).LCA is an internationally computational method for estimating and assessing environmental life cycle impacts of a product or process (Rebitzer et al., 2004). The ISO 14000-series (ISO, 2006a,b) defines the standards for LCA studies. The ISO defines the principles and the framework of a LCA study, which is divided in to four steps:

- *goal definition and scoping*: definition of the production system, functional unit, approach to co-product allocation, environmental impact categories, detail level of study;
- *life cycle inventory*: collection and analysis of input and output data;
- *life cycle impact assessment*: the emissions in air, soil, water, as well as raw materials and energy consumptions, are standardized and translated into environmental effects;
- *life cycle interpretation and improvement*: identification of weaknesses and possible improvements of the processes.

# 3 Methodology and Data Collection

## 3.1 Location of the Farm

The Hombre farm (Figure 1) is located in Via Corletto sud, 320 41100 Modena Italy Tel. +39 059 510 660 info@hombre.it

## 3.2 Monitoring of farm records and data collection

This section is divided into two parts: the first (subparagraph 3.2.1) is about the materials and methods used for the trial; the second (subparagraph 3.2.2) deals with the materials and methods of the LCA study used to evaluate the carbon footprint of organic milk obtained from two different diets.

### 3.2.1 On-farm trial: Materials and methods used

The feeding trial was carried out with 136 dairy cows (Italian Friesians) between January and March 2014 at the Hombre farm. After an adaptation period of two weeks, two homogeneous groups (in terms of parity-multiparous and day of lactation) of Holstein-Friesian lactating cows were fed with two different diets for 3 months. One diet (Diet 1; control) was based on purchased and farm produced ingredients and the other (Diet 2; experimental) was based almost solely on farm produced feed ingredients. The two diets are conformed to the EU Reg. 834/07 for concentrate/forage ratio, and are comparable in terms of both crude protein and energy content (see Table 2). In order to determine the chemical composition of the two rations, all the feed samples were subjected to analysis of dry matter (DM), crude protein (CP), ether extract (EE), fibrous fraction (CF- crude fibre; NDF- neutral detergent fibre; ADF- acid detergent fibre; ADL – acid detergent lignin ) and ash according to Martilotti et al., (1987). The chemical composition of the feeds is reported in Table 1 and the composition of the diets is summarized in Table 2.

**Table 1** - Chemical composition (%DM) of feeds.

| Chemical composition | Alfalfa Hay* | Crushed Barley | Crushed Sorghum | Crushed Maize | Protein meal** | ~~Mix of concentrate***~~ |
|---|---|---|---|---|---|---|
| Dry matter | 90.6 | 86.7 | 86.5 | 86.4 | 88.0 | ~~87.3~~ |
| Ether extract | 1.0 | 1.8 | 2.9 | 3.7 | 8.7 | ~~4.6~~ |
| Crude protein | 12.0 | 10.1 | 9.4 | 8.1 | 21.2 | ~~15.4~~ |
| Ash | 6.7 | 2.2 | 1.4 | 1.2 | 14.6 | ~~5.9~~ |
| Crude fibre | | 4.6 | 2.4 | 2.2 | 11.0 | ~~7.1~~ |
| NDF | 48.9 | 18.7 | 9.4 | 10.4 | | ~~14.5~~ |
| ADF | 39.9 | 5.5 | 3.8 | 2.6 | | ~~5.3~~ |
| ADL | 8.1 | 1.0 | 1.1 | 0.5 | | ~~1.6~~ |

*Average values between first and second cutting of alfalfa hay
**Protein meal composed of: sunflower meal, wheat bran, extruded soybean, extruded corn, wheat bran, calcium carbonate, sodium chloride, sodium bicarbonate, magnesium oxide.

**Table 2** - Composition of the two diets (kg of DM and % of DM) and principal nutrients value.

| Formulation | Diet 1- Control | | Diet 2 – Home-grown protein | |
|---|---|---|---|---|
| | kg | % | kg | % |
| Alfalfa Hay (1st and 2nd cut); farm produced | 13.6 | 60 | 14.5 | 64 |
| Crushed barley; farm produced | 3.0 | 13 | 3.7 | 16 |
| Crushed sorghum; farm produced | 2.2 | 10 | 4.2 | 19 |
| Crushed maize; purchased | 1.7 | 7 | - | - |
| Protein meal; purchased | 2.2 | 10 | 0.3 | 1 |
| Dry matter kg/day | 22.7 | | 22.7 | |
| Dry matter concentrate | 9.1 | | 8.2 | |
| Crude protein kg/day* | 2.7 | 12,0 | 2.6 | 11,4 |
| UFL (forage unit for milk production)** | 15.6 | | 15.8 | |
| Net energy (MJ)** | 113.0 | | 114.3 | |

*Diet 1 (control group) and Diet 2 (experimental group) were offered to 74 and 62 lactating cows, respectively.*
** real chemical composition.*
***estimated according to INRA (1988).*

Protein meal was fed to the animals by an automated system, while the rest of the ingredients were fed to the animals as total mixed ration. During the case study, the milk yield of each group of cows was obtained from monthly averages of total milk production per day per cow. At each milking, records based on automated milk weight measurements were taken. Milk yields were provided by APA (Associazione Provinciale Allevatori). In particular, milk samples were analysed for the following parameters: protein, lactose, lipids and somatic cells. The milk samples were analysed at the APA Laboratory in Modena, which operates in compliance with the UNI EN ISO 9001:2000. Milk protein, sugars and lipids were measured by the Milkoscan 13K (Foss Electric), while the somatic cells were measured with the Foss-o-Matic (Foss Electric). An unpaired or two-sample t-test was used to compare the means of the various quantitative characteristics of milk in the two groups. The statistical analysis was carried out using STATA software, ver. 12. Furthermore, basic cost-revenue assessment of the two diets were performed.

### 3.2.2 LCA modelling study

Two different systems have been modelled to build the LCA study, both with the same number of animals (see Table 10). The two systems - respectively named "control" and "experimental" - differ for the type of diet that have been administered to the lactation cows (see Table 2).

*Goal and scope definition, inventory analysis, impact assessment method*

The main goal of this study was to build an efficiency analysis of an organic dairy farm in order to decrease its carbon footprint and to improve the environmental performance. The study evaluated the carbon footprint of the organic milk for which two different animal diets (see Table 2) were set.

The functional unit is 1 kg of fat and protein corrected milk (FPCM) obtained through the equation 1:

***Equation 1 (FIL IDF, 2010):***

$$FPCM\ (kg/yr) = Production\ (kg/yr) \times [0.1226 \times Fat\% + 0.0776 \times True\ Protein\% + 0.2534]$$

The attributional and cradle-to-farm-gate LCA approach was used to estimate the carbon footprint. All the on-farm processes (forages and crop production, manure and livestock management) and its emissions were included. Furthermore, processes related to the purchased feed were included (maize, soy, protein meal). Milk transportation and transformation phases have not been taken into account after milk production.

The system output was:

- Milk (kg FPCM)
- Meat derived from slaughtered dairy cows (kg of live weight of animals)

The allocation for milk and meat has been calculated using the following equation:

***Equation 2 (FIL IDF, 2010):***

$$\mathbf{AF = 1 - 5.7717 \times R}$$

Where: **AF** = allocation factor for milk; **R** = $M_{meat}/M_{milk}$; $\mathbf{M_{meat}}$ = sum of live weight of all animals sold; $\mathbf{M_{milk}}$ = sum of milk sold corrected using equation 1

In our study, we did not consider the newborn calves because they were sold immediately after birth. The primary data have been collected using a specific questionnaire while the secondary data were derived from Ecoinvent, Agrofootprint database and literature. Table 3 shows the equations applied and the emissions factors used to estimate the emissions.

For the carbon dioxide fossil emission related to crop processing, the Ecoinvent processes suitably modified have been employed.

With regards to the impact assessment method, we used the IPCC 2013 method (over a period of 100 years) implemented in Simapro 8.04.

The GWP factors have changed during the years (see Table 4). We used the 2013 GWP factors.

**Table 3** - Equations and emissions factor to assess the different emissions

| Pollutant | Source | Equation | Emission factor | Reference |
|---|---|---|---|---|
| kg $CH_4$ | Enteric | $CH_4$ = kg DMI herd$^{-1}$*18,93 (Gross Energy MJ kg$^{-1}$ DMI)*Ym%/55,65[a] | Ym = 6.5% | IPCC, 2006a |
| | Storage | $CH_4$ = VS*$B_0$*0,67*MCF/100*MS | MCF: solid fraction = 2; liquid fraction = 25 | IPCC, 2006a |
| kg $N_2O$ *direct* | Storage | $N_2O = N_{(T)}$*$Nex_{(conf.\ system)}$*MS*EF*44/28 | EF = 0.005 | IPCC, 2006a |
| | Field | $N_2O = N_2O_{inputs}$*EF*44/28 | EF = 0.01 | IPCC, 2006b |
| kg $N_2O$ *indirect* | Storage | $N_2O = N_{volatilization}$*EF*44/28 | EF = 0.01 | IPCC, 2006a |
| | Field | $N_2O_{ATD} = \{(N_{SN}*Frac_{GASFi})+[(N_{ON}+N_{PRP})*Frac_{GASM}]\}*EF*44/28$<br>$N_2O_L = (N_{SN}+N_{ON}+N_{PRP}+N_{CR}+N_{SOM})*Frac_{LEACH}*EF*44/28$ | EF = 0.01<br>EF = 0.0075 | IPCC, 2006b |
| kg $NH_3$ | Storage | $N_{volatilization} = Nex_{(conf.\ system)}$*MS* Frac_GasMS/100 * 17/14 | Frac_GasMS = 40 | IPCC, 2006a |
| | Field | $NH_3 = (N_{SN}+N_{ON}+N_{PRP})$ * EF | EF = 0.084 | EEA, 2009 |

*Source: Guerci et al., 2013; Kristensen et al., 2011 (Emission factors adapted to our system)*
[a]18,93 = GE per kg of dry matter (MJkg$^{-1}$) for diet administered

**Table 4** - GWP factors

| Substance | AR1, 1990 | AR2, 1995 | AR3, 2001 | AR4, 2007 | AR5, 2013 |
|---|---|---|---|---|---|
| **Carbon dioxide ($CO_2$)** | 1 | 1 | 1 | 1 | 1 |
| **Methane, biogenic ($CH_4$)** | 18.25 | 18.25 | 20.25 | 22.25 | 25.25 |
| **Nitrous oxide ($N_2O$)** | 290 | 310 | 296 | 298 | 265 |

*AR: Assessment Report published by the Intergovernmental Panel for Climate Change of the United Nations (IPCC).
*Source: http://www.pre-sustainability.com/updated-carbon-footprint-calculation-factors*

## 3.3 Further analysis and calculations

### 3.3.1 Economic evaluations

During the study cows fed on the experimental diet (Diet 2) produced on average 3.86 kg less milk per day compared to those in the control diet (see table 6). This means that the farm produced about 810 kg/day less of milk from the total herd. Considering 0.49 euro/kg[1] of milk the loss of income per year is around Euro 145,000.00. This loss of revenue could be partially remedied by a lower cost of the ratio used for the lactating cows (see Table 5). According to Table 5, the switching

[1] According to ISMEA (www.ismea.it) the average price of 1 litre of organic milk is 0.49 (2013 average price)

towards the experimental diet, made by substituting maize and part of the protein meal by currently feeds grown on the farm, can lead to a decrease of the ratio cost of about 15%. The overall impact on income of the experimental diet – at current milk prices – is negative.

**Table 5** - Cost/year of the diets for the lactating cows

| | **Ton/ year for the lactating cows** | | **Cost/ year of the diets** | | |
|---|---|---|---|---|---|
| | **Control diet** | **Experimental diet** | **€/ton*** ** | **Control diet** | **Experimental diet** |
| Maize | 153.3 | 0 | 271.13 | € 41,564.23 | € 0.00 |
| Protein meal | 191.6 | 23.0 | 510.00 | € 97,728.75 | € 11,727.45 |
| Sorghum | 191.6 | 367.9 | 229.53 | € 43,983.69 | € 84,448.68 |
| Barley | 268.3 | 329.6 | 250.39 | € 67,173.38 | € 82,527.29 |
| Hay | 1,149.8 | 1,226.4 | 137.75 | € 158,378.06 | € 168,936.60 |
| Total | | | | **€ 408,828.11** | **€ 347,640.02** |
| Saving | | | | | **€ 61,188.09** |

*** *Prices data has been collected from the Bologna agricultural stock exchanges (2013 average price).*

## 3.4 Time Scale

A draft protocol started in May 2013 and a dairy farm willing to be studied was identified in June 2013. The detailed LCA questionnaire and protocol trial was developed by Dec 2013. The on-farm trial started in January 2014 and lasted for three months (until March 2014). The first data analysis was carried out in April 2014.The final data analysis was completed by February 2014, and the final report was available by July 2015 A farmer meeting to disseminate the project results was carried out, in collaboration with ICEA, in October 2015 at the BioGold farm.

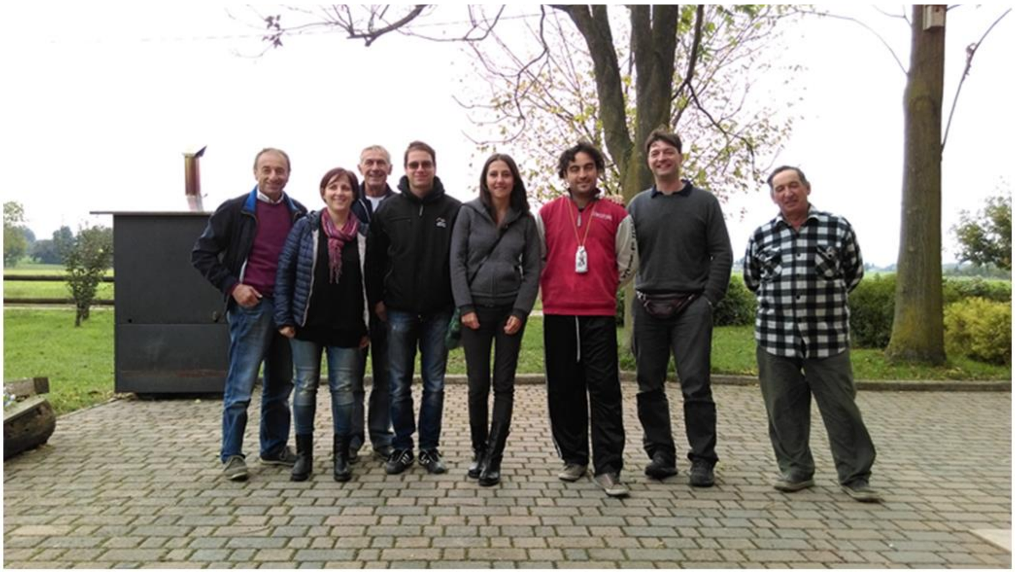

**Figure 1- Farmer meeting**

# 4 Results and Discussion

This section is divided into two parts: the first (paragraph 4.1) is about the results of the trial; the second (paragraph4.2) deals with the results of the LCA study.

## 4.1 Trial

The results of the milking production of the two groups fed with different diets are shown in Table 6. The milk yield obtained from the experimental group, fed with the home-grown ratio (diet 2), was statistically significantly lower than the milk yield obtained from the control group fed with farm produced and purchased raw materials (diet 1). Table 6 shows that the average daily milk production of the experimental group decreased by 3.86 kg compared to that of the control group. Milk quality in terms of fat, protein and somatic cells was not influenced by diet but a significant statistical decrease was reported for the lactose content in the experimental group compared to the control group. The milk yield and the bulk milk quality between diet 1 and diet 2 were also tested separately for the two lactation periods (0-100 days; 101-300 days) (Tables 7 and 8).

The results are consistent with the previous findings, which have shown a significant statistical decrease of both milk yield and milk lactose content (only in the second period of lactation) in the experimental diet. The results we obtained for the milk yield has been confirmed by other authors that studied the substitution of soybean with alternative protein plants on a dairy cow ration (Martini et al., 2008; Mordenti et al., 2007)

As far as the lactose content is concerned, in compliance with the literature, the reduction between the two groups is not imputable to the diet; however, the lactose content in both groups is comparable with the values that are found in the literature.

**Table 6** - Effects of dietary change on milk production and milk characteristics of dairy cows during the total lactation period (group 1 control and group 2 experimental).

| | *Diet* | *Mean* | *Std. Err.* | *P* |
|---|---|---|---|---|
| Production (*Kg/day*) | 1 | 31.28 | 0.7995 | 0.0006 |
| | 2 | 27.42 | 0.7269 | |
| Fat (*gr/100 ml*) | 1 | 3.51 | 0.0944 | 0.7239 |
| | 2 | 3.46 | 0.0804 | |
| Protein (*gr/100 ml*) | 1 | 3.49 | 0.0399 | 0.6681 |
| | 2 | 3.46 | 0.0440 | |
| Lactose (*gr/100 ml*) | 1 | 4.92 | 0.0223 | 0.0018 |
| | 2 | 4.82 | 0.0236 | |
| Somatic cell (*ccs/ml*) | 1 | 139.30 | 12.5925 | 0.9838 |
| | 2 | 138.93 | 12.2647 | |

**Table 7** - Effects of dietary change on milk production and milk characteristics of dairy cows during the first lactation period (from 0 to 100 days) (group 1 control and group 2 experimental).

| | *Diet* | *Mean* | *Std. Err.* | *P* |
|---|---|---|---|---|
| Production (*Kg/day)* | 1 | 32.19 | 1.1611 | 0.0242 |
| | 2 | 28.18 | 1.2527 | |
| Fat (*gr/100 ml)* | 1 | 3.57 | 0.1834 | 0.7736 |
| | 2 | 3.51 | 0.1129 | |
| Protein (*gr/100 ml)* | 1 | 3.40 | 0.7239 | 0.8268 |
| | 2 | 3.42 | 0.6386 | |
| Lactose (*gr/100 ml)* | 1 | 4.93 | 0.0297 | 0.0902 |
| | 2 | 4.85 | 0.0376 | |
| Somatic cell (*ccs/ml)* | 1 | 132.24 | 20.30 | 0.8919 |
| | 2 | 128.57 | 17.31 | |

**Table 8** - Effects of dietary change on milk production and milk characteristics of dairy cows during the second lactation period (from 101 to 300 days) (group 1 control and group 2 experimental).

| | *Diet* | *Mean* | *Std. Err.* | *P* |
|---|---|---|---|---|
| Production (*Kg/day)* | 1 | 30.60 | 1.1010 | 0.0078 |
| | 2 | 26.71 | 0.7777 | |
| Fat (*gr/100 ml)* | 1 | 3.46 | 0.0869 | 0.8049 |
| | 2 | 3.42 | 0.1156 | |
| Protein (*gr/100 ml)* | 1 | 3.56 | 0.0396 | 0.4136 |
| | 2 | 3.50 | 0.0608 | |
| Lactose (*gr/100 ml)* | 1 | 4.91 | 0.0327 | 0.0066 |
| | 2 | 4.79 | 0.0286 | |
| Somatic cell (*ccs/ml)* | 1 | 144.97 | 15.9769 | 0.8773 |
| | 2 | 148.66 | 17.4424 | |

## 4.2 LCA model - Characteristics of control and experimental farm systems

For the LCA modelling study it was assumed that whole herd of 210 cows would receive both diet that were studied. Table 9, 10, 11 show the main features of the two modelled systems (control and experimental). In particular, we have decided to keep the same number of cows in both systems because, with appropriate crop management, the farm was able to sustain the same herd. The farm, indeed, has a sufficient number of hectares to produce the feed required by the experimental diet (Table 9).The calculation of the necessary hectares has been made on the basis of the dry matter consumed per animal and the crop yield (Table 10). Finally, Table 11 shows the production of milk (Kg FPCM per cow) per year considering the dry period of the cows. The experimental system efficiency is lower because it is affected by a decrease in milk quantity of 3.86 kg compared to the control system’s milk.

**Table 9** - Number of hectares required to conventional and experimental systems

| *Land* | | ha farm (APP*) | Control | Experimental |
|---|---|---|---|---|
| *Total* | *ha* | *294.17* | *226.90* | *262.80* |
| Hay | ha | 175.34 | 117.3 | 122.8 |
| Barley | ha | 80.91 | 74.2 | 82.7 |
| Sorghum | ha | 32.62 | 30.1 | 52 |
| Wood/ set-aside | ha | 5.3 | 5.3 | 5.3 |
| Hay | % of area | 59.60 | 51.70 | 46.73 |
| Barley | % of area | 27.50 | 32.70 | 31.47 |
| Sorghum | % of area | 11.09 | 13.27 | 19.79 |
| Wood/set-aside | % of area | 1.80 | 2.34 | 2.02 |

* APP: annual production plan

**Table 10** - Number of cows and dry mass per cow category in control and experimental systems

| | Control | | Experimental | |
|---|---|---|---|---|
| *Herd* | N° of cows | DM (kg/day) | N° of cows | DM (kg/day) |
| Cows - lactation | 210 | 22.7 | 210 | 22.7 |
| Cows - dry period | 50 | 12.4 | 50 | 12.4 |
| Heifers (12-24 months) | 65 | 16.9 | 65 | 16.9 |
| Heifers (0-12 months) | 65 | 6 | 65 | 6 |
| Cows - slaughtered | 88 | | 88 | |

**Table 11** - Annual number of animals, feeding, milk production and efficiency in both systems

| *Herd* | *Control* | *Experimental* |
|---|---|---|
| Production cows and heifers (number) | 390 | 390 |
| Milk ( kg FPCM per cow) | 7086.67 | 5690.93 |
| Feed intake (kg DM per production cows) | 7559.15 | 7559.15 |
| Feed intake (kg DM per herd) | 9646.95 | 9646.95 |
| Efficiency (kg FPCM per kg DMI per cow) | 0.93 | 0.75 |
| Efficiency (kg FPCM per kg DMI per herd) | 0.73 | 0.59 |

The total GHG emissions per kg of FPCM milk from the control and experimental systems are respectively equal to 1.05 kg $CO_2$-eq and 1.16 kg $CO_2$-eq. (Fig. 2). Figure 3 shows that, for both systems (control and experimental diet), among the three greenhouse gases considered, methane has the highest impact followed by nitrous oxide and $CO_2$ fossil.

The impact of the experimental system on global warming, calculated in terms of kg of $CO_2$-eq, is higher than the control system. This is because the analysis accounted for the effect of the reduction in milk production in the experimental system. Those results show, in agreement with literature, that the milk yield per cow, in fact, is one of the main factors that modifies the carbon footprint analysis (Rotz et al., 2010; Hermansen et al., 2011; Opio et al., 2011).

If we consider only the feed items, without considering the milk production, the experimental diet shows a lower impact, since the experimental diet employs almost only feeds produced on the farm, whose impact per kg of product is lower (Fig. 4). By using the experimental diet, a calculated 127859.86 kg of CO2-eq. would have been saved from the total emissions (Table 12).

**Table 12** – CO2-eq emissions for the different feeds within the two different diets

| | *Control diet* *total of kg $CO_2$-eq per kg DM* | *Experimental diet* *total of kg $CO_2$-eq per kg DM* |
|---|---|---|
| Hay organic (farm produced) | 209530 | 223396 |
| Barley organic (farm produced) | 44840 | 55303 |
| Sorghum organic (farm produced) | 38110 | 72756 |
| Maize organic (purchased) | 66977 | 0 |
| Protein meal (purchased) | 138783 | 18925 |
| Total | 498240 | 370380 |
| Saving | | 127860 |

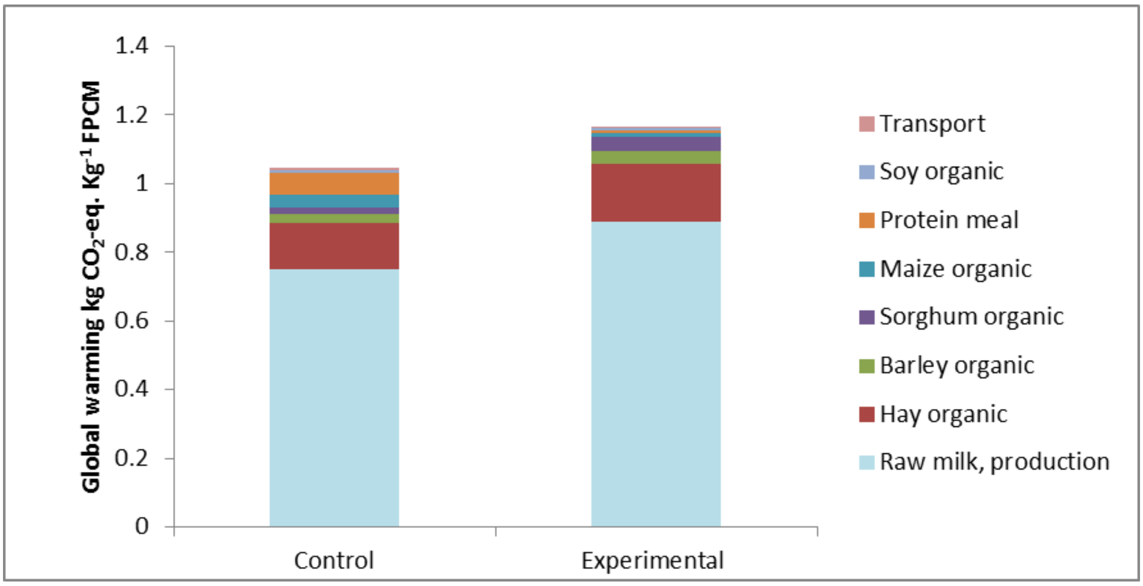


**Figure 2 -** Global warming potential of control and experimental systems and the contribution from different processes

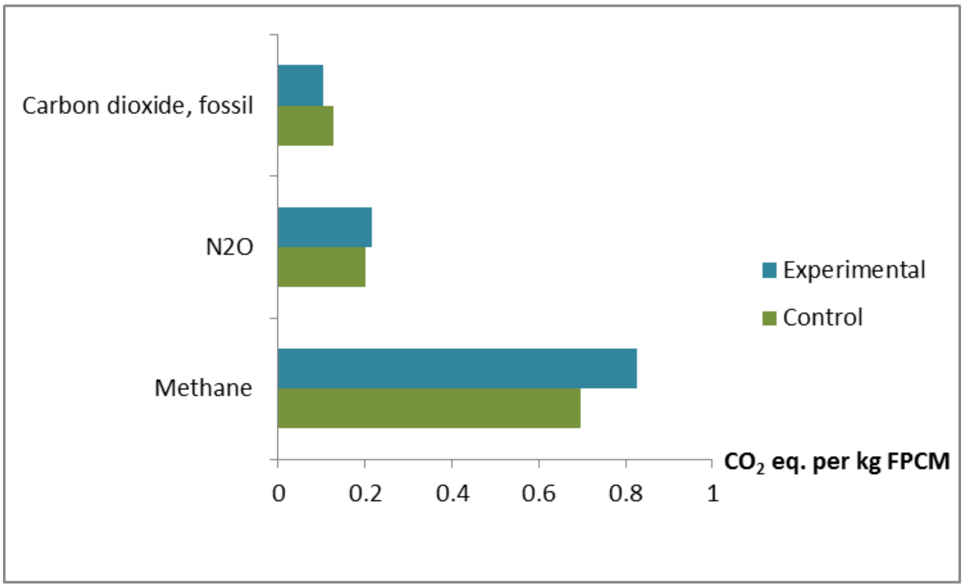


**Figure 3 -** Contribution of different greenhouse gases in control and experimental systems

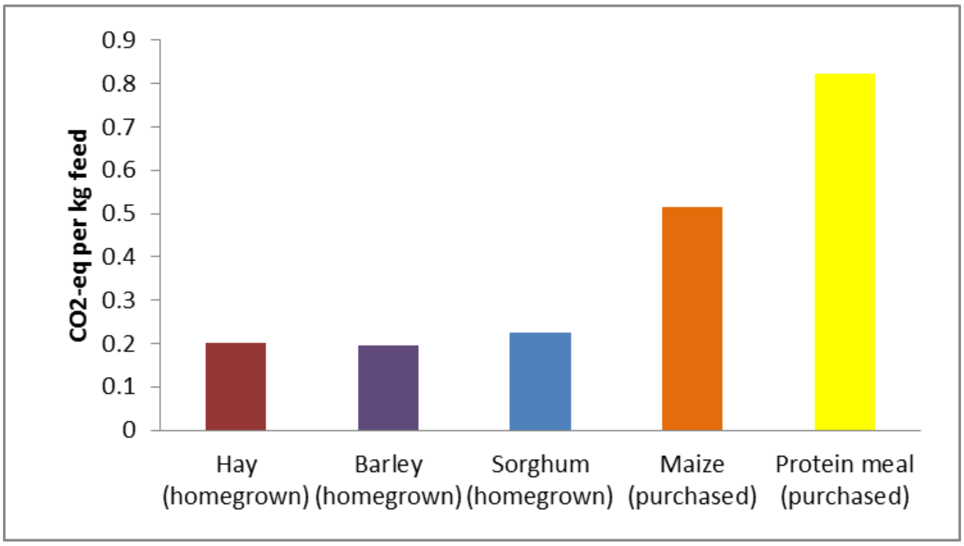


**Figure 4 –** Comparison between different feeds

# 5 Conclusions/Recommendations

The results of this study indicate that the cows fed with a home-grown ingredient diet had lower milk yield compared to those fed a standard) diet. However the economic loss from lower milk yield can be partially recovered by the lower cost of the home-grown ratio. Milk qualitative characteristics were not affected by the diets.

Should consumers perceive the milk produced by home-grown feeds is a superior quality product, and exhibits a higher willingness to pay the change in the diet could be economically sustainable: results from other work in the SOLID project (task 5.3) may or may not confirm this hypothesis.

The ingredients of the experimental diet were limited to home grown feeds currently grown on the farm. The protein content of the experimental diets was mainly derived from alfalfa hay, while protein content in the control diet was derived from soybean meal. It has been suggested that faba-beans or peas are both suitable approaches for improving the home-grown protein supply to low input dairy systems and could be viable alternatives to soy with lower impact on milk yield. A change in what protein rich crops are grown is therefore needed to totally eliminate soybean from the ration without impact on income at current prices.

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