Acta Agraria Kaposváriensis (2014) Vol 18 Supplement 1, 75-80.
Kaposvári Egyetem, Agrár- és Környezettudományi Kar, Kaposvár
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Carbon footprint from dairy farming system: comparison between Holstein and Jersey cattle in Italian circumstances

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ABSTRACT

Aim of the present study was to estimate the carbon footprint (CF) of milk production at farm gate considering two dairy cattle breeds, Holstein Friesian (HF) and Jersey (JE). Using Italian inventory data the emissions of CO_2eq per kg ECM for dairy herds of HF and JE breed were estimated. The results show 0.80 kg CO_2eq/kg ECM in JE herd, while 0.96 kg CO_2eq/kg ECM in HF herd. The main differences were due to the level of dry matter intake, milk yield and fertility traits. Indeed, JE herd showed a lower milk yield than HF herd, a lower DMI and better fertility, determining less production and consumption of feed and less replacement animals in the herd.
(Keywords: carbon footprint, dairy cattle breed, milk production)

INTRODUCTION

Carbon footprint (CF) is the total amount of GHG emitted in production processes, expressing Global Warming Potential (GWP). According to *IPCC* (2006), GHG attributed to the agricultural activity are methane (CH_4) and nitrous oxide (N_2O). CH_4 is produced mainly with enteric fermentation (*Cassandro et al.*, 2013) and decomposition of manure, while N_2O derives from the N content of manure and from N of fertilizers once they are applied to the soil.

The major part of studies about CF on dairy milk production are lacking on variation of CF across different dairy breed. Indeed, *Cassandro* (2013) compared local and cosmopolitan cattle breeds on their predicted methane emissions showing that a reduction of 10% of daily methane emissions per kg of metabolic body weight is expected for local compared with cosmopolitan breeds. Moreover, *Capper and Cady* (2012) published CF results from comparison between Jersey (JE) and Holstein Friesian (HF) cattle breeds, where production of the same quantity of protein, milk-fat, and other solids, Jersey cows emitted 20% less CF.

Aim of this study was to investigate the difference of CF among HF and JE dairy herd in Italian circumstances, using an holistic approach.

MATERIAL AND METHODS

A life cycle assessment (LCA) in a farm gate perspective was performed to evaluate CF of HF and JE dairy breed in Italy. Using data from national inventories a standard dairy herd was performed and a linear model was developed, using *Excel Software (Microsoft,* 2010), and it were estimated and assumed inputs, outputs, herd turnover and GHG emissions. Reference time was one year.

The system included: (i) GHG emissions (defined as CO_2eq) derived from the production of one kg of dry matter of feed, and straw as bedding materials, used in the herd; (ii) emissions of CH_4 derived from enteric fermentation; (iii) emissions of CH_4 and N_2O (direct and indirect) associated with manure management. Emissions from other production inputs like pesticides, seeds, fossil energy consumption, liming and medicine were not included as well as the information of the construction of machinery and buildings or the potential emission from managed organic soil (*Kristensen et al.,* 2011).

One kg ECM (*Sjaunja et al.,* 1990) produced at farm gate was chosen as functional unit.

Biological allocation was applied, where allocation factors to milk and meat were calculated (AFmi and AFme, respectively), which are used to share GHG emissions between the amount of milk and meat according the energy required to produce the two outputs (Live Weight, LW) (*IDF,* 2010). The organization of herd system took into account a typical intensive farming system used in Northern Italy.

Two animal systems composed the herd: (i) cow (including dry and lactating dairy cows), (ii) heifer (including heifers destined to replacement, and exceed heifers used to fattening). Moreover (iii) calf system (male calves destined to fattening), reared as veal calves, a typical production of in the Italian cattle livestock (*Dall'Orto et al.,* 2010), was considered in HF herd. Calf system in JE herd was not considered because we assumed that they leave the herd system immediately after birth (*Capper and Cady,* 2012).

One hundred cows were the basis for the calculation of herd turnover. Two numbers of animals were estimated for herd turnover: animals annually feed (sum of feeding days/365days) and animals annually slaughtered. Both numbers were computed considering number of animals born in one year and the months spent inside the herd by each animal system. For heifer system this value was the months at first calving while in male calf system it was months at slaughtering.

Animals annually feed were calculated considering several parameters: calving interval, replacement rate, stillbirth rate and female rate. Artificial insemination was the only reproduction technique (no bulls were present). Animals annually slaughtering were computed after considering the mortality rate. LW (kg) obtained in the herd was calculated considering the animal weight before slaughtering for each of animal system. Heifers were assumed to be replacement animals, from birth to first calving. Surplus heifers, which exceed the replacement rate, were assumed to be slaughtered at the normal age of first calving. Buying and selling of animals were not taken into account.

Feed ration was calculated for each animal system. Daily dry matter intake (DMI), content of crude protein (CP), ash (Ash), daily gross energy (GE) assumption and digestibility of organic matter (DE) were identified. The feed ration for JE cow and heifer system was obtained using proportional data derived from the average LW ratio of the two breeds in the respective animal system. The feed rations were calculated using literature review (not show in this paper).

Information about stable system was modeled for cow and heifer (*CRPA*, 2012) and calf (*Mottaran*, 2011; *Dell'Orto*, 2010) system using literature data. The GWP was estimated for a 100-year time period by converting all GHG to CO_2 equivalents

(CO2eq), which on a weight basis gives 1 kg CH_4=25 and 1 kg N_2O-N=298 CO_2eq (*IPCC,* 2006). The GHG emissions, expressed as kg CO_2eq, were determined per herd, per kg ECM and kg meat (LW). The emission factor (EF) to CH_4 enteric emissions was calculated using equation for dairy cows by *Ellis et al.* (2007) (CH_4 (MJ/d) = 3.23 (± 1.12) + 0.809 (± 0.0862) × DMI (kg/d)) and considering an energy content of 55.65 MJ in 1 kg of CH_4 (*IPCC,* 2006). CH_4 and N_2O emissions from deep litter and slurry manure produced by herd was estimated using the IPCC Tier 2 method *IPCC* (2006) using specific country parameters (*INIR,* 2012), but international values (*IPCC,* 2006) were used in some cases, according the Italian national emissions inventory (*INIR*, 2012).
N excretion rate were derived from N intake, subtracting the N contained in milk and meat produced, and N in the bedding straw (*Kristensen et al.,* 2011). Emissions CO_2eq per kg dry matter of feed were derived from literature (*Guerci*, 2012).

RESULTS AND DISCUSSION

HF herd emitted 1,188,321 kg CO_2eq, while JE herd were 39% lower than HF herd. The main source of GHG was Total CH_4, which represented 59% and 63% of CF, for HF and JE herd, respectively. Enteric CH_4 represented 75% and 78% of Total CH_4 emissions. CF deriving from production and utilization of feed was the second source of GHG representing 37% in HF herd and 30% in JE herd of total GHG emissions. Thirdly emitter was N_2O emissions, 7.5% of the total GHG emissions in both herds.

Cow system was the first emitter of GHG in the herd, emitting 62% and 68% in HF and JE herd, respectively. Second emitter was heifer system, releasing 28% and 32% in HF and JE herd, respectively. While calf system, only present in HF herd, emitted 10% of total emissions. Milk production had the greatest part of the emissions in both herd system *(Table 1)*, recording 72% and 80%, as AFmi, of total GHG emissions, for HF and JE herd, respectively.

Emission of CO_2eq, associated to ECM production was greater for HF herd (0.96 kgCO_2eq/kg ECM) than JE herd, which had 17% less than HF herd (0.80 kgCO_2eq/kg ECM). Similar lower trend in JE herd (23% less than HF herd system) was recorded for kgCO_2eq/kg meat. The main differences are number of heads, milk production and level of DMI in the herd among the two breeds considered.

HF herd presented higher calving interval (HF: 432 days; JE: 385 days), replacement rate (HF: 34%; JE: 30%) and age at first calving (HF: 28.4 months; JE: 26.0 months) than JE herd, which increased heads in the herd (HF: 218; JE: 197), replacement heifers (HF: 81; JE: 65) and culled cows (HF: 32; JE: 29); having more heads, higher emissions are produces, obviously. This shows a general better fertility of JE breed than HF breed and according *Garnsworthy et al.* (2004) a better fertility traits in the herd determine a lower GHG emissions from herd. Moreover HF herd presented calf system, which increase meat produced but at the same time the emissions. Removing calf system, the emissions from HF herd are 0.94 kgCO_2eq/kg ECM and 14.44 kgCO_2eq/kg meat, remaining higher than JE herd values.

HF herd had a greater milk yield (8,853 kg ECM/cow/year) than JE herd (7,239 kg ECM/cow/year), while JE herd presented higher values of fat and protein (fat: 4.98%; protein: 4.01%) respect HF herd (fat: 3.73%; protein: 3.39%). *Capper and Cady* (2012) published CF results of the comparison between Jersey and Holstein breeds; they found that for the production of the same quantity of protein, milk-fat, and other solids, Jersey cows emitted 20% less CF. If HF milk yield is decreased to same amount of JE herd the emissions increase to 1.07 kg CO_2eq/kg ECM, and if JE herd system produce same amount of HF herd, the emissions per kg ECM decrease to 0.68 kg CO_2eq. According to *Capper and Cady* (2012), body weight, milk yield, and milk nutrient density differences between HF and JE breed have the greatest effect upon CF per unit of product. Level of feed intake and its composition are important factors influencing GHG losses (*Bell et al.*, 2012). JE breed, being a lightweight compared to HF breed (LW cow: 454kg and 700kg, respectively), and its DMI is lower of HF breed (DMI herd: 3,381 kg/year and 4,805 kg/year, respectively; where JE cow and heifer system consumed 65% of DMI of the respective HF animal system), corresponding to a lower GHG emissions, as noted by *Ferris* (2011).

The main impact category is represented by CH_4 from enteric fermentation, followed by emissions associated to feed production and thirdly CH_4 and N_2O emissions from manure. *Rotz et al.* (2010) determined as enteric CH_4 has the greatest effect on the overall CF, which principally depends upon milk production level and the feeding. The main differences between herd systems were level of DMI and milk yield, recognized from *Yan et al*. (2010) as the main drivers of enteric CH_4 emission.

Table 1

Emissions per head (kg CO_2eq/head), per animal system(kg CO_2eq/heads), per herd (kg CO_2eq/herd), per kg ECM and kg meat(kg CO_2eq/kg ECM and kg meat) and allocation factor (AF, %) for Italian Holstein Friesian (HF) and Jersey (JE) herd. Data concerning one year

	HF				JE			
	Cow	**Heifer**	**Calf**	**Herd**	**Cow**	**Heifer**	**Calf**	**Herd**
Feed[1]	2,197	1,120	5,382	1,984	1,425	727	0	1,080
Bedding straw[2]	0	27	35	15	0	21	0	10
CH_4								
Enteric CH_4	3,315	1,509	795	2,276	2,336	1,165	0	1,758
Manure CH_4	1,340	320	114	770	869	212	0	545
Total CH_4[a]	4,656	1,828	908	3,046	3,206	1,377	0	2,303
N_2O								
Direct N_2O	74	231	95	147	45	161	0	102
Indirect N_2O	443	127	11	262	267	79	0	174
Total N_2O[b]	517	358	106	409	312	240	0	276
Tot GHG/head[3]	7,370	3,333	6,431	5,455	4,942	2,364	0	3,670
Allocation Factor milk, %	72				80			
Allocation Factor meat, %	28				20			
kg CO_2eq/kg ECM	0.96				0.80			
kg CO_2eq/kg meat	15.43				11.88			

[1](kg CO_2eq/kg DM)*(kg DMI/head/year); [2] (kg CO_2eq/kg DM)*(kg straw/head/year).
[a]Kg CO_2eq derived from CH_4 emissions; [b] Kg CO_2eq derived from N_2O emissions.
[3]sum of emissions from Feed, Bedding straw, Total CH_4 and Total N_2O, per head of animal system in the herd (Cow, Heifer, Calf), and in the herd (Herd).

CONCLUSIONS

Asserting CF in milk production at farm gate several parameters affect the results: enteric CH_4 and CO_2eq from production and utilization of feed represent the main source of GHG emissions from dairy herd.

An important aspect to reduce the CF of milk production could be considered dairy cattle breeds inside the valuation. In this preliminary study JE herd system showed a lower CF per kg ECM than HF herd. Dairy cows were the first emitter in both herd. JE herd had lighter animals than HF breed, contributing a lower DMI in JE herd than HF herd. Moreover better fertility traits and higher values of fat and protein in milk was recognized in JE herd than HF herd. These parameters are the main contributors to lower CF in JE herd than HF herd.

As conclusions, a LCA could be applied to compare two dairy cattle herd, and other researches are suggested to show the deeply difference between the two dairy breeds and also including the followed staged of cheese production, an important Italian agricultural sector.

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