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Further effects of forage on greenhouse gases estimated by DairyCant for dairy farms

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Introduction

Silage corn is a fodder with high starch content, organic matter and digestible fibre, and low nitrogen. From an environmental perspective, its use helps to reduce the volume of manure and N (Salcedo, 2011), emissions of NH_3 (Merino *et al.*, 2008), N_2O (Arriaga *et al.*, 2010), enteric CH_4 (Vellinga and Hovingy, 2010), carbon footprint (Nguyen *et al.*, 2013) and increases nitrogen recovered in milk with respect to intake (Arriaga *et al.*, 2009; Dewhurst, 2013). The aim of this study was to estimate whether the partial substitution of pasture (surface) and grass (feed) by forages with known production and nutritive potential (maize or maize and *Lolium multiflorum*) and higher input needs (seeds, fertilizers, etc.) can contribute to reducing emissions of CO_2-eq/kg of milk, using the simulation model DairyCant 1.0 (Salcedo and Perez, 2014).

Material and methods

This study was based on information from 49 dairy farms in Cantabria (Spain) derived from the research projects RTA2006-00132-C02-1 and 2012-0006512-05, funded by the National Institute for Agricultural Research (Spain) and project 05-640.02-2174, funded by the Ministry of Environment of the Government of Cantabria (Spain). Farms were classified according to their dedication to forage: 100% grassland (G), 20 farms; between 65% min to 89% max pasture and 10% to 35% maize (GM), seven farms; 19% to 88% pasture, 11% to 80%, 7% to 80% of maize and winter forage crops (GMWf), 22 farms. The information from each farm was obtained by individual survey, extrapolating the surface (total and dedication to forage); milk (quota year/kg cow, fat and protein); animals (dairy cows, dry heifers < or > 1 year); feed (kg/head and day); forage production and chemical composition of food (Salcedo, 2006 and 2011); and purchases (fertilizers, chemicals, concentrates, fodder, fuel, animals, seeds). The information collected was introduced into the dairy cattle simulation model DairyCant 1.0 (Salcedo and Perez, 2014) to estimate the CO2-eq kg milk, corrected for fat. The functional units used in this work are 1 kg energy corrected milk (ECM). The results were subjected to analysis of variance, including as fixed value the percentage of maize grown on the farm.

Results and discussion

The most relevant characteristics of the farms of different forage dedication are indicated in Table 1. The supply of dry matter (DM) per hectare, cow milk production per year and nitrogen use efficiency (NUE) increased 70.3 kg milk solid ($r^2 = 0.46$, $P < 0.001$); 63.7 kg milk production/cow per year ($r^2 = 0.34$, $P < 0.001$) and 0.094 percentage units NUE ($r^2 = 0.26$, $P < 0.001$), respectively, with increasing corn acreage. The percentages of CH_4 (enteric and manure) by kg ECM estimated by DairyCant 1.0 are 50%, 48.2% and 49.6% for G, GM and GMWf, respectively, similar to the 50% indicated by Nguyen *et al.* (2013) for French dairy farmers who grow maize for silage. The CO_2-eq/kg of DM forage produced did not differ between farms growing maize or not (Table 2), with mean values of 0.27 ± 0.11 kg for a variable range from 0.09 to 0.52 kg. van Middelaar *et al.* (2013) report emissions of 0.21 kg CO_2-eq kg DM for maize silage, up slightly from 0.32 ± 0.09 in GM and 0.28 ± 0.09 in GMWf in the conditions of Cantabria. Fodder production represents $25.0 \pm 17\%$ in G, $37.9 \pm 13\%$ in GM and $31.3 \pm 12\%$ in GMWf per kg ECM, less than the values of 40% and 58% in GM and G reported by Nguyen *et al.* (2013), attributed to increased milk production (16.4 ± 10.7 *v.* 1.86 tonnes/ha), more cows per hectare (1.91 ± 0.95 *v.* 0.64) and not to the production of milk per cow year (8.2 ± 2.1 *v.* 7.8 tonnes).

The average proportion of forage and concentrate included in the diet is similar between farms in Table 1, but not the CH_4/kg ECM (Table 2), with a minimum of 0.31 and maximum of 1.05 kg CO_2 kg ECM observed in 100% G.

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Table 1 *Farm characteristics (means (minimum to maximum in parentheses))*

	G	GM	GMWf	s.d.	*P*
Total area (ha)	22.7 (4 to 46)	21.7 (8 to 48)	33.2 (8 to 70)	16	ns
Meadow (ha)	22.7 (4 to 46)	16.7 (7 to 38)	20.1 (7 to 47)	11	ns
Maize (%)	0 (0 to 0)	20.1 (10 to 35)	33.5 (11 to 88)	19.4	***
Wf (%)	0 (0 to 0)	0 (0 to 0)	31.4 (7.5 to 80.7)	19.5	***
DM (tonnes/ha)[1]	8.8 (6.1 to 11.7)	9.2 (8.1 to 10.7)	11.1 (8.3 to 10.7)	1.9	***
Inorganic N (kg/ha)	17.6 (0 to 202)	42.5 (0 to 202)	38 (0 to 202)	49	ns
Cows milk (ha)	1.78 (0.56 to 4.4)	2.4 (0.85 to 3.8)	1.88 (1.1 to 4.1)	0.95	ns
LU (ha)	3.01 (0.92 to 7.5)	3.4 (1.48 to 5.5)	3.14 (1.7 to 7.0)	1.56	ns
Quote milk (tonnes)	263 (66 to 1052)	388 (70 to 622)	630 (71 to 2022)	422	**
Milk, ECM (tonnes/ha)	13.5 (3.2 to 52.9)	19.8 (7.1 to 35.8)	17.9 (6.6 to 50.7)	10.7	ns
Milk, cow ECM year (tonnes)	7.2 (3.5 to 12.0)	8.0 (6.3 to 9.9)	9.3 (6.2 to 12.9)	2.1	***
NUE (%)	25.3 (21.2 to 34)	26.3 (23.4 to 28.5)	28.4 (21.9 to 36)	3.54	**
Forage in the diet (%)	55.8 (34.7 to 83.2)	60.1 (37.8 to 84.1)	55.3 (44.8 to 84.3)	11.7	ns
Concentrate in the diet (%)	42.6 (16.7 to 65)	39.3 (15.8 to 62.2)	44.1 (15.7 to 55.2)	11.9	ns
Maize silage diet (%)	0 (0 to 0)	14.1 (8.4 to 20.7)	17.0 (6.5 to 36.7)	9.7	***
Concentrate (tonnes DM/ha)	7.6 (1.4 to 32.2)	7.3 (1.9 to 13.7)	8.2 (1.9 to 26.4)	6.2	ns
Concentrate (tonnes DM cow year)	3.1 (0.78 to 5.2)	2.7 (0.78 to 3.8)	3.6 (0.78 to 5.1)	1.0	ns

DM = dry matter; ECM = energy corrected milk; NUE = nitrogen use efficiency.
[1]Includes grass, maize and winter crops.
**$P < 0.01$; ***$P < 0.001$.

Table 2 *Contribution of different gases per hectare per litre ECM*

	CH_4		N_2O		CO_2		CO_2-eq		
Farm	CO_2 (kg ha)	kg CO_2-eq (kg ECM)	CO_2 (kg ha)	Kg CO_2-eq (kg ECM)	CO_2 (kg ha)	Kg CO_2 (kg ECM)	CO_2-eq (kg ha)	kg CO_2-eq (kg ECM)	kg CO_2-eq (kg DM)
G	6587	0.56b	2151	0.211	4224	0.34	11 965	1.12	0.24
GM	7700	0.42a	3183	0.167	5554	0.28	16 440	0.87	0.32
GMWf	7597	0.46ab	3007	0.170	5568	0.31	16 172	0.93	0.28
s.d.	3381	0.15	1547	0.16	3173	0.15	7615	0.33	0.11
Significance	ns	**	ns	ns	ns	ns	ns	ns	ns

ECM = energy corrected milk; DM = dry matter.
**$P < 0.01$.

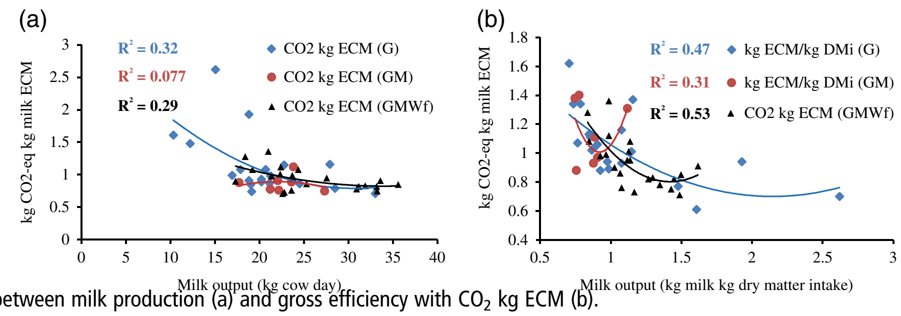

Figure 1 Relationship between milk production (a) and gross efficiency with CO_2 kg ECM (b).

For all systems, the mean value is 0.49 ± 0.14, slightly <0.54 kg reported by del Prado and Scholefield (2008) on dairy farms in the United Kingdom. Individual milk production per cow ($r = -0.69$, $P < 0.01$), the percentage of maize grown ($r = -0.38$, $P < 0.01$) and included in the diet ($r = -0.29$, $P < 0.05$) were negatively related to CH_4/kg ECM in this study; with no significant relationship with the concentration of starch in the diet. The high starch content of corn silage promotes increased production of propionate at the expense of acetate, thus reducing the formation of CH_4 per unit of fermented substrate (Beauchemin *et al.*, 2008). Bypass starch fermentation does not produce CH_4, whereas the digestion of fibre in the rumen does (Dijkstra *et al.*, 2011). In this work the percentage of neutral fibre in diet was positively related to the CH_4/kg ECM ($r = 0.29$, $P < 0.05$).

N_2O production in kg CO_2-eq per hectare and per kg ECM (Table 2), represented for the latter parameter 18.7%, 20.6% and 18.2% of the total CO_2-eq for G, GM and GMWf, respectively, without differences between farms of different forage dedication. Most emissions were observed in G, agreeing with Nguyen *et al.* (2013), but the percentage difference relative to G is 14.2% and 19.0% for GM and GMWf, far below the 36.2%, possibly owing to the lower contribution inorganic nitrogen fertilizer on the farms in Cantabria (Table 2).

The kilos of CO_2-eq/kg ECM vary from 0.71 to 2.62, with an average value of 1.0 ± 0.3 kg/kg, the largest values seen in G (Table 2), attributable partly to production factors (Figure 1a) and gross efficiency (kg milk/kg DM intake, Figure 1b). The values obtained here are similar to the 1.03 ± 0.14 kg CO_2/kg ECM indicated by de Vries and de Boer (2010). As estimated by DairyCant 1.0 emissions fell by 22.3% and 16.9% in GM and GMWf with respect to G, higher than the 11.1% reported by Nguyen *et al.* (2013).

Conclusions

The highest values of CO_2-eq/kg ECM were observed in the pasture-based systems. The culture of maize crop has an interesting potential for mitigating CH_4/kg ECM. From an environmental perspective, the planting of winter forage crops does not improve CO_2-eq. Information that defines the minimum percentage of maize cultivation that maximizes the mitigation of greenhouse gases in the soil and climate of Cantabria (Spain) is required.

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Further information

The LiveM International Livestock Modelling and Research Colloquium was hosted by the Basque Centre for Climate Change (BC3) at the Maritime Museum in Bilbao, Spain between 14 and 16 October 2014. LiveM is the livestock and grassland modelling theme of the EU knowledge hub Modelling European Agriculture with Climate Change for Food Security (MACSUR). The MACSUR project is a pilot knowledge hub started by FACCE-JPI in 2012. It provides an opportunity to explore the role and potential of multi-disciplinary networking structures to address complex regional and global issues. More information on MACSUR and the LiveM theme can be found at www.macsur.eu, with PDFs of slides from conference presentations available through the conference website (http://www.livem2014bilbao.com/).

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