Effect of organic fertilization of maize forage on greenhouse gas emissions by dairy cows

Velarde-Guillén J., Jiménez-Calderón J.D., Martínez-Fernández A. and Vicente F.
Servicio Regional de Investigación y Desarrollo Agroalimentario (SERIDA), P.O. Box 13, 33300 Villaviciosa (Asturias), Spain

Abstract

The emission of methane by dairy cows, as enteric and manure fermentation, is the main source of greenhouse gas (GHG) emission in the dairy sector. The second most important GHG is the N_2O emission as a result of nitrogen addition to the soil. An empirical model was used to predict the methane production by dairy cows feeding on two diets based on maize silage grown with organic (MSF) or conventional (ChF) fertilization (IPCC Tier 2) and the emission of N_2O by both types of fertilization (IPCC Tier 1). The results were converted to carbon dioxide equivalent (CO_2eq) using the Global Warming Potential of 25 and 296 for CH_4 and N_2O respectively. More than 70% of GHG emissions were due to enteric fermentation. Milk production did not show differences between treatments; however, a 10% higher production of CO_2eq kg^{-1} of milk was observed in ChF than MSF. The difference observed was due to the diet and not to the type of fertilization, because there were no differences between both soil managements. The results demonstrate that it is possible to reduce GHG emissions with the use of manure and slurry as fertilizers, without affecting milk production.

Keywords: greenhouse gas, dairy cows, manure, fertilizers

Introduction

Nowadays there is a growing interest in steering agricultural production towards more sustainable systems, because agricultural livestock account for about 9% of total anthropogenic greenhouse gas (GHG) emissions (IPCC, 2007). In most dairy farms, the crop rotation of maize-Italian ryegrass is repeated continuously, demanding high amounts of nitrogen fertilization and causing negative effects on the soil (Heinze *et al.*, 2011). Therefore, the production of forages must be environmentally and ecologically sound and aligned with public values. The efficiency of chemical fertilizer used in maize cropping has become a major issue of concern, as the crop often has negative connotations with N-aspects of surface and groundwater quality (Schröder *et al.*, 2000). On another note, manure and slurry applications can recycle animal wastes and be a valuable soil nutrient resource. The benefit of dairy manure application on maize silage production has been reported (Butler *et al.*, 2008) and has been attributed to the improvement of physical and chemical edaphic properties. The objective of this study was to evaluate the effects of organic (manure and slurry) or chemical fertilization applied to maize forage crop on the emissions of nitrous oxide and enteric methane.

Materials and methods

Two adjacent plots of 1.7 ha each were sown with maize as summer crop, using chemical (ChF) or organic (MSF) fertilization respectively. The annual fertilization of the ChF plot was as follows: a basal dressing fertilization of 60 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 120 kg K_2O ha^{-1} before the sowing of the previous winter crop (Italian ryegrass); 60 kg N ha^{-1} applied as topdressing after the first Italian ryegrass cut for silage; 125 kg N ha^{-1}, 150 kg P_2O_5 ha^{-1} and 250 kg K_2O ha^{-1} after the second silage cut, before sowing the maize; and finally, 75 kg N ha^{-1} as topdressing when the maize plants were 20 cm high. The MSF plot was fertilized with 50 m^3 ha^{-1} of slurry distributed in three applications: the first in the previous autumn before the sowing of the winter crop, and the remaining two applications after each of the spring Italian ryegrass silage cuts. Before sowing the maize, 45 Mg ha^{-1} of manure were also applied. The slurry supplied 0.52 kg N m^{-3}, 0.28 kg P_2O_5 m^{-3}, 0.72 kg K_2O m^{-3} and 0.20 kg MgO m^{-3}, and the manure had 3.24 kg N Mg^{-1}, 1.93 kg P_2O_5 Mg^{-1}, 6.23 kg K_2O Mg^{-1} and 1.34 kg MgO Mg^{-1}. Both types of maize were harvested in autumn 2011, when the maize grain was doughy-vitreous, and ensiled in trench silos that were opened in January 2012 to make two isoenergetic and isoproteic partial mixed rations (ChF PMR and MSF PMR). The PMRs consisted of ChF or MSF silage, grass silage, barley straw and concentrate.

Eighteen dairy cows in the second third lactation were allocated into two groups, and assigned to one of the PMRs throughout 4 months between February and May 2012. Cows were milked twice daily, remained indoors until 11:30 a.m., and then moved to the grazing area, where they stayed until the evening milking.

The model used to predict CH_4 emission was IPCC Tier 2 and IPCC Tier 1 was used to predict N_2O emission (IPCC, 2006). The first model incorporates the CH_4 conversion factor for milking cows, animal production and gross energy intake. The second one uses the source of N added to soil (inorganic, organic, urine and manure of grazing animals, crop residues). The results were converted to carbon dioxide equivalent (CO_2eq) using the Global Warming Potential of 25 and 296 for CH_4 and N_2O respectively. GHG emissions were analysed using the MIXED procedure of the SAS (1999) for repeated measurements, with a model considering the treatment effect (ChF or MSF). When the ANOVA was significant (P<0.05), means were separated by Tukey's test pairwise comparison.

Results and discussion

The MSF diet had 10% less total dry matter intake than the ChF, with 17.7 and 19.8 kg DM day^{-1} respectively, and the concentrate intake included on PMR was lower in the treatment based on MSF silage than ChF silage (2.8 vs 3.2 kg d^{-1} resp.; P<0.05). No differences were seen between treatments with respect to milk production per cow (25.4 kg d^{-1}).

The values for greenhouse gas emissions per cow, per dry matter intake and per milk production are given in Table 1. More than 70% of GHG total emissions are due to enteric fermentation, being higher in ChF than in MSF diet (13.46 vs 11.76 kg CO_2eq kg^{-1} respectively, P<0.05). The prediction of total CO_2eq emission in ChF treatment was higher than in MSF (up to 13%; P<0.05). The difference observed in this study was due to the diet and not to the kind of fertilization, because there were no differences in either soil management or in manure excretion between treatments. There were no differences when GHG emissions were related to dry matter intake; however, a 10% higher production of CO_2eq per kg of milk was observed in ChF than in MSF (0.74 vs 0.67 kg CO_2eq kg^{-1} respectively, P<0.05). The estimated enteric CH_4 emissions in this study were higher than those calculated by Legesse *et al.*, (2011) or measured values in a respiratory chamber (Brask *et al.*, 2013). However, the proportion of forage in

Table 1. Estimated emissions of carbon dioxide equivalent related to cow, dry matter intake and milk yield for the two treatments: diets based on maize silage fertilized with organic (MSF) and chemical (ChF) fertilization.[1]

	MSF	ChF	Standard error	P-value[2]
Enteric fermentation (kg CO_2eq cow^{-1} d^{-1})	11.76	13.46	2.049	*
Manure (kg CO_2eq cow^{-1} d^{-1})	1.23	1.55	0.228	NS
Soil management (kg CO_2eq cow^{-1} d^{-1})	3.78	3.95	0.122	NS
Total (kg CO_2eq cow^{-1} d^{-1})	16.77	18.97	1.553	*
kg CO_2eq kg^{-1} dry matter intake	0.95	0.96	0.008	NS
kg CO_2eq kg^{-1} milk	0.67	0.74	0.050	*

[1] CO_2eq calculated from the values of the Global Warming Potential: 25 for methane and 296 for nitrous oxide (IPCC, 2006). Values are means for n=9.

[2] Statistical significance: * P<0.05; NS = not significant.

all these studies was 60% or less. Aguerre *et al.* (2011) studied the effect of forage-to-concentrate ratio in dairy cow diets on GHG emission, and noted that increasing the forage proportion in the diet from 47% to 68%, the CH_4 emission was increased from 0.538 to 0.648 per cow and day. In our study, the diets had 79% of forage, and therefore, this could explain our higher estimated GHG emissions.

Conclusions

On the basis of the results obtained, it could be concluded that it is possible to reduce the GHG emissions using maize forage with manure and slurry as own fertilization sources for a sustainable soil management, with a good management of the diets and without lowering the milk production.

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