Estimation of methane emissions by dairy cows feeding on diets based on Italian ryegrass or legume silages in two grazing seasons

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Abstract

The dairy sector plays an important role in the emission of greenhouse gases (GHG). Dairy cows are a significant contributor to total livestock GHG emissions, being the main sources carbon loss from land use change, methane emissions from enteric fermentation, soil nitrous oxide emissions and manure management. For this reason, the objective of this study was to estimate methane emissions using the IPCC model in lactating Holstein cows with feeding rations based on Italian ryegrass silage grown conventionally or fava bean-rapeseed silage fertilized with manure and slurry in two grazing seasons, and to compare the results obtained with other models tested. Two trials were carried out in spring and autumn 2013, each with ten lactating Holstein cows. Both trials were performed using a crossover design. Considering the IPCC Tier 2 as an international reference to estimate enteric methane emissions, the estimations were similar considering both seasons and diets. When the IPCC predictions were compared to other models, the results showed the same variation of methane production, but with higher values for Mills and Yates models and lower estimations based on Ellis equations.

Keywords: methane emission estimation, organic fertilization, Italian ryegrass, fava bean-rapeseed

Introduction

The dairy sector plays a major role in livestock production, however, it is a source of greenhouse gases (GHGs) and contributes 3% of the total anthropogenic emissions. In addition, the feedstuffs industry accounts about 10% of emissions, and storage of animal manure can reach up to 9% (Gerber *et al.*, 2010). The highest percentage of methane emissions in livestock is due to enteric fermentation in ruminants, which has increased by about 11% from 2001 to 2011 (Tubiello *et al.*, 2014). Different equations have been proposed to estimate the production of GHGs that are based on the type of feed, the amount of dry matter intake (Kebreab *et al.*, 2008) and also in the animal itself (Yan *et al.*, 2002). The objective of this study was to estimate methane emissions using the IPCC model in lactating Holstein cows with feeding rations based on Italian ryegrass silage grown conventionally (conventional) or fava bean-rapeseed silage fertilized with manure and slurry (organic) in two grazing seasons, and to compare the results with other models tested.

Materials and methods

Two trials, each with ten lactating Holstein cows, were conducted during the spring and autumn of 2013 in the SERIDA experimental farm. The animals, at the beginning of the trials, were 100±8.2 days in milk (average ± standard error), 2.3±0.22 lactations, 614±16.5 kg live weight and a production of 28.0±1.26 l d^{-1}. The animals were randomly divided into 2 groups and in both trials were fed with two total mixed rations (TMR) using a crossover design. The details of all TMR are shown in Table 1. The TMRs were supplemented by grazing in meadows for 12 hours daily in spring and 8 hours in autumn. The TMR intakes of each cow were daily and automatically recorded by an electric weighing system integrated to the scale pens using a computerized system. The grass intake at grazing was estimated by the animal performance method suggested by Macoon *et al.* (2003).

Table 1. Composition and nutritional value of the total mixed rations in spring and autumn.

	Spring		Autumn	
	Organic	Conventional	Organic	Conventional
Ingredient (%dry matter)				
Maize silage	32.56	35.30	-	-
Ryegrass silage	-	36.85	-	32.38
Fava bean-rapeseed silage	43.53	-	37.92	-
Alfalfa hay	-	-	23.35	25.44
Cereal straw	15.62	16.16	6.58	7.16
Concentrate	8.29	11.69	32.15	35.02
Nutritional value (g kg^{-1} dry matter)				
Dry matter	387.9	329.5	408.1	416.0
Crude protein	103.8	971.0	133.3	127.4

The IPCC Tier 2 equation (IPCC, 2006) was used as reference model to estimate the methane production for each cow. This model incorporates CH_4 conversion factors for milking cows, animal production and gross energy intake without considering the forage proportion in the diet. The results of the IPCC methane emission estimations, as MJ d^{-1}, were compared using a paired t-test with different models based on many factors such as dry matter intake (DMI) and forage proportion (Yates *et al.,* 2000; Mills *et al.,* 2003 and Ellis *et al.,* 2007). The dry matter intake, the forage proportion and CH_4 emissions were analysed using a lineal model considering the type of TMR and season as main factors (R Core team, 2014).

Results and discussion

Based on the IPCC model as reference, the enteric methane emissions did not show any significant difference, either for seasons or for the TMR used (Table 2). Nevertheless, according to the results obtained the ryegrass diet (conventional) presented higher methane emissions than the fava bean-rapeseed diet (organic) (28.71 vs 22.56 MJ d^{-1}, respectively, $P>0.05$). In comparison with IPCC prediction, both Ellis' models underestimated the CH_4 emissions (24.80 vs 22.14 and 19.36 MJ d^{-1} for IPCC; Ellis based on DMI and Ellis based on forage proportion, respectively, $P<0.001$). However, when the Mills' models based on DMI and forage proportion were used, the CH_4 emissions estimated were

Table 2. Methane emissions estimated as MJ d^{-1} according to season (S) and type of total mixed ration (TMR).

	Season		TMR		RSD	Significance[1]		
	Spring	Autumn	Conventional	Organic		S	TMR	S × TMR
IPCC	24.25	25.33	28.71	22.56	10.240	NS	NS	NS
Mills 1 [2]	27.76	28.27	29.38	25.65	8.742	NS	NS	NS
Mills 2 [3]	29.50	29.43	31.22	27.72	9.165	NS	NS	NS
Ellis 1 [4]	21.55	22.73	23.58	20.70	7.688	NS	NS	NS
Ellis 2 [5]	20.39	18.34	19.32	19.14	1.460	***	NS	NS
Yates [6]	33.06	31.38	34.30	30.14	11.830	NS	NS	NS

[1] Statistical significance *** $P<0.001$. RSD = relative standard deviation. NS = not significant.

[2] CH_4 (MJ d^{-1}) = 5.93 + 0.920 dry matter intake (DMI) (kg d^{-1}).

[3] CH_4 (MJ d^{-1}) = 1.06 + 10.27 forage proportion + 0.87 DMI (kg d^{-1}).

[4] CH_4 (MJ d^{-1}) = 3.23 + 0.809 DMI (kg d^{-1}).

[5] CH_4 (MJ d^{-1}) = 8.56 + 0.139 forage proportion.

[6] CH_4 (MJ d^{-1}) = 1.36 + 1.21 DMI (kg d^{-1}) – 0.825 × g concentrate + 12.8 × g neutral detergent fibre.

higher than the estimated values by IPCC equations (24.80 vs 27.51 and 29.47 MJ d^{-1} for IPCC, Mills based on DMI and Mills based on forage proportion, respectively, *P*<0.001). In the same vein, the Yates' model, including both DMI and forage proportion estimated higher values than IPCC model (24.80 vs 32.22 MJ d^{-1} for IPCC and Yates models, respectively, *P*<0.001).

It should be noted that, whatever the model used, there were no significant differences between TMR for enteric methane, although the values were higher with the diet based on ryegrass silage. No differences were observed between seasons, except in the Ellis' model that includes the forage proportion (*P*<0.001), due to the higher forage proportion in spring than autumn (85 vs 71% of forage proportion, respectively).

Conclusions

If the IPCC model is considered as an international reference to estimate enteric methane emissions, these estimations were similar considering both seasons and diets. In comparison with the IPCC predictions, the other models showed the same variation of methane production, but with higher values for Mills and Yates models and lower estimations based on Ellis equations.

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