Animal Feed Science and Technology 194 (2014) 145–150

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

Short communication

Strong differences in the CH_4 emission from feces of grazing steers submitted to different feeding schedules

M.E. Priano[a,b], V.S. Fusé[a,b], J.I. Gere[b], A.M. Berkovic[a,b], K.E. Williams[c], S.A. Guzmán[c], R. Gratton[b,c], M.P. Juliarena[a,b,c,*]

[a] CIFICEN-CONICET – Consejo Nacional de Investigaciones Científicas y Tecnológicas, Pinto 399, C.P. 7000, Tandil, Provincia de Buenos Aires, Argentina
[b] IFAS – Instituto de Física Arroyo Seco, Pinto 399, C.P. 7000, Tandil, Provincia de Buenos Aires, Argentina
[c] UNCPBA – Universidad Nacional del Centro de la Provincia de Buenos Aires, Pinto 399, C.P. 7000, Tandil, Provincia de Buenos Aires, Argentina

ARTICLE INFO

Article history:
Received 18 April 2013
Received in revised form 10 March 2014
Accepted 21 April 2014

Keywords:
Fecal matter
Methane emission
Oat pasture
Grazing steers
Grazing schedules

ABSTRACT

When studying the effects of changing the feeding schedule of Holstein steers grazing in a pure oat field, it was observed that the fecal matter of animals grazing in the morning emitted much more methane than that of steers grazing in the afternoon. Feces from two groups of 10 steers with different feeding schedules were collected on the same day and separately mixed to form two composite samples. Then, five sub-samples of each composite sample were randomly placed on the oat field and CH_4 emissions were measured after deposition for 27 days. The difference in the emissions was in qualitative agreement with the pronounced loss of organic matter from the morning samples during the experimental period.

1. Introduction

The livestock sector represents approximately 12–18% of the total anthropogenic greenhouse gases emission (GHG) (Steinfeld et al., 2006). However, according to inventory data, in Argentina this sector is responsible for 44.3% of the total anthropogenic emission (República Argentina, 2007); 72% of this fraction corresponds to CH_4 and 28% to N_2O. Most of the CH_4 emission is due to enteric fermentation and only 1% to anaerobic fermentation of animal feces. It should be noted that GHC anthropogenic emissions in Argentina are estimated at 0.9% of the total world GHC emissions, but the country population is only 0.56% of the total world one.

The National Inventory assumes an average emission factor of 1 kg CH_4/head/year for the contribution of fecal matter (FM) deposited by freely grazing cattle, the most important feeding system in Argentina. However values in this country had not been measured before the present work. Other authors elsewhere have published values of the above order: *e.g.*, Flessa et al. (2002) mentioned that the total CH_4 emission from patches of grazing cattle manure would be in the order of 0.5 g/kg dry matter of feces; Jarvis et al. (1995) found values of 0.14–1.10 g CH_4/kg dry matter of feces for cows fed with forage diets with a low ratio C/N. Anyway, the CH_4 emission depends on the physical form of the feces (shape, size, density,

Abbreviations: GHG, greenhouse gases; FM, fecal matter; M, morning group; A, afternoon group.

* Corresponding author at: UNCPBA – Universidad Nacional del Centro de la Provincia de Buenos Aires, Pinto 399, C.P. 7000, Tandil, Provincia de Buenos Aires, Argentina. Tel.: +54 0249 4439660/61; fax: +54 0249 4439669.
E-mail addresses: pjuliarena@exa.unicen.edu.ar, paula.juliarena@gmail.com (M.P. Juliarena).

http://dx.doi.org/10.1016/j.anifeedsci.2014.04.011
0377-8401/

humidity), the amount of digestible material, the climate (temperature and humidity) and the time they remained intact (González-Avalos and Ruiz-Suárez, 2001; Saggar et al., 2004; De Klein and Eckard, 2008).

In Argentina, there is emerging concern over environmental issues related to livestock and there are local initiatives to evaluate GHG emissions from this sector (Bárbaro et al., 2008; Huarte et al., 2010; Williams et al., 2010). These initiatives will enable us to contribute to the understanding of the current risks and the specific vulnerability of different regions. This understanding would be useful to predict the future scenarios to which a production system should be adapted in a particular geographical area in the short, medium and long term.

In order to provide information on emissions from feces of grazing cattle under Argentinian conditions, we have carried out an experiment to evaluate differences in CH_4 emissions from steers with different feeding schedules grazing on an oat field. Here we present the values of CH_4 emission from the FM deposited by the animals involved in the experiment. We finally discuss the potential interest of these results.

2. Materials and methods

2.1. Experimental design

Methane emissions from patches of feces in oat pastures (37.32 S, 59.08 W) were measured within the context of an experiment designed to compare morning and afternoon feeding of steers on identically sown oat plots.

During September 2012 (spring in the Southern Hemisphere), a herd of 20 Holstein steers weighing 210–220 kg was divided in two groups of 10, and allowed to graze in two adjacent but separated paddocks. The pasture was in the vegetative stage and it was the only nutritional source provided. The access to the pasture was between 8:00 and 13:00 h for the morning group (M), and between 14:00 and 19:00 h for the afternoon group (A).

The average temperature during the measurements was 14.6 °C, with an average daily maximum of 20.2 °C and an average daily minimum of 9.0 °C.

On October 2nd, after a 20-day adaptation period, fresh FM deposited by all animals from the M lot were collected at 13:00 h, and mixed to form a composite sample, M sample. Immediately after that, the M sample was divided in five 1 kg sub-samples. Each sub-sample was deposited on the soil within the same oat field, inside cylindrical PVC tubes (16 cm diameter and 25 cm length) open at both ends; the tubes were driven into the soil to a depth of around 5 cm in locations randomly selected. In each cylinder, FM formed a homogeneous layer of approximately 7 cm of height simulating a natural deposition.

The same procedure was conducted for lot A, but the A sample was collected and mixed at 19:00 on the same day. Furthermore, another cylinder (control chamber) was driven nearby into the oat field, containing a composite sample of FM from all animals to monitor the temperature of FM during the measurements.

The cylinders were kept open at the top and they were closed only during the measurement periods. The first measurements were between 10:00 and 12:00 h on October 3rd, for both A and M samples.

Finally, five stainless steel cylinders were driven 5 cm into the soil of the same oat field near the PVC cylinders to measure CH_4 fluxes at the soil surface during the experimental period.

2.2. Methane fluxes measurements

During the entire month of October, and every 2–3 days, CH_4 emission from the 10 sub-samples was measured.

Cylinders were closed only during measurements to accumulate the emitted methane in the head-space limited by the soil and a lid fitted with a valve for air sample extraction. A fan attached to the lid ensured air mixing. In other words, the closed cylinder worked as an accumulation chamber.

After chamber closure, four air samples of 20 ml were sequentially withdrawn at regular time intervals. The time interval in the first day of the experiment was 5 min, however when the emission rate began to fall down after some days, the time interval was extended up to 20 min. These samples were stored in 20-ml syringes with a three-way stopcock, at a pressure slightly higher than the atmospheric. The syringes had been previously cleaned with pure N_2.

In this way, from the 10 FM sub-samples, a total of 40 air samples were obtained in each measurement. This procedure was always carried out between 10:00 and 11:00 h; the emission rate in this time interval is currently considered as a daily average in measurements of fluxes from soil to atmosphere (Parkin and Venterea, 2010).

Methane fluxes at feces–atmosphere interface were calculated from the linear regression of the varying CH_4 concentration versus time in the chambers.

The FM temperature was measured by using a temperature data logger *ibutton DS1921G* in the control chamber which remained closed for the same period as that of the other 10 chambers. Besides, soil and air temperature were also measured during the same period and their values were used to calculate mass fluxes.

A similar procedure was used to measure CH_4 flux at soil–atmosphere interface by using the stainless steel chambers. In this case the chambers remained closed during 60 min.

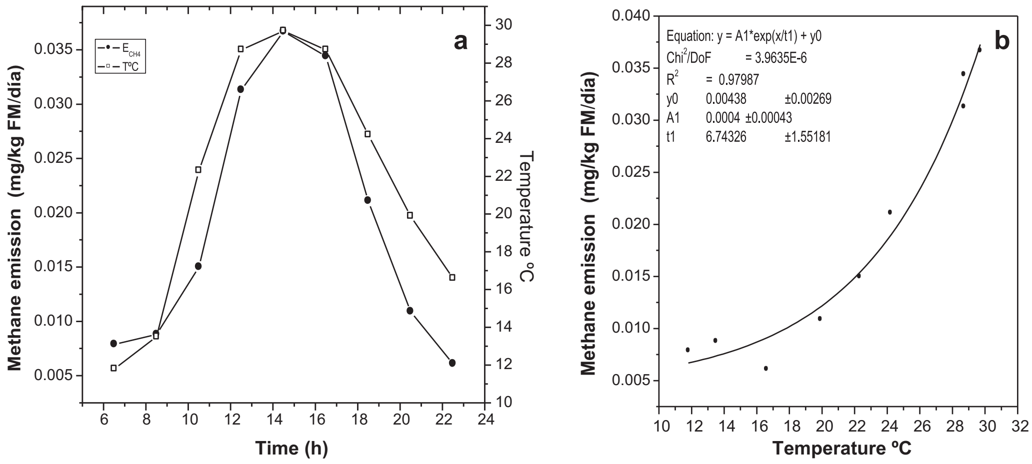

Fig. 1. (a) Variation of methane emission and temperature of fecal matter (FM) from grazing steers during the daytime. (b) Emission rate CH_4 as a function of temperature, and the corresponding logarithmic regression.

2.3. Chromatographic analysis

Analyses were carried out within 2 or 3 h after collection, by using a gas chromatograph (GC, Agilent, 7890A) equipped with an FID and a 1.8-m Porapak Q (80/100 mesh) column. The oven, injector and detector temperatures were 50 °C, 250 °C and 250 °C, respectively. The flow rate of the carrier gas (He) was 30 ml min^{-1}. Flame gases (H_2 and O_2) were set at 30 and 400 ml min^{-1}. The detection limit was below 1 ppm and concentrations were determined with an accuracy of 0.02 ppm. All samples were analyzed in duplicate.

2.4. Chemical analyses of fecal matter

Samples M and A were analyzed at the beginning and at the end of the experiment.

We carried out analyses of pH (with pH Test Strips), moisture (by drying at 60–65 °C during 3 days until constant weight), crude protein (by micro-Kjeldahl), and ash (by heating at 550 °C during 24 h until constant weight).

2.5. Variation of methane emission from FM during the daytime

By using the same procedure as above, we measured the methane emission from a layer of FM from a single chamber every 2 h between 6:00 till 22:00 h. In order to minimize errors in the determinations, the chamber with higher emission rate was chosen for the experiment.

To ensure a reasonable time resolution, the four air samples corresponding to each emission rate determination were extracted along 15 min after the chamber closure. The FM temperature was recorded throughout the experiment by means of a temperature data logger *ibutton DS1921G* placed in the control chamber.

2.6. Statistical calculations

Origin Lab 6.0 software was used to calculate the slopes of the linear regressions for all sets of CH_4 concentrations in the air samples sequentially extracted from each chamber. This provided five values for the flux on each lot per day, corresponding to different sub-samples. These flux values were treated as single experimental results. Then average fluxes for each lot were computed together with the corresponding dispersion. The differences of the fluxes between lots were investigated with a test of variance (*Test LSD Fisher*, *Infostat statistical* software).

3. Results and discussion

The variation of the methane emission and the feces temperature over time can be seen in Fig. 1a. The maximum of the emission rate was obtained at the highest day temperature. During the experiment, the temperature varied between 12 and 31 °C, while it remained constant across the remaining time interval, from 22:00 to 6:00 h. By assuming that the methane emission rate was also constant in this interval, a calculation of the daily average rate shows that the rate between 10:00 and 12:00 h is close to the day average. Therefore, as it occurs in the case of methane flux measurements at soil–atmosphere interface, this is the best choice when only one measurement per day is planned (Parkin and Venterea, 2010).

Fig. 1b shows the emission rate as a function of temperature and the corresponding logarithmic regression. The results are consistent with the findings of Williams (1993) on the influence of temperature on methanogenesis in feces. In the present

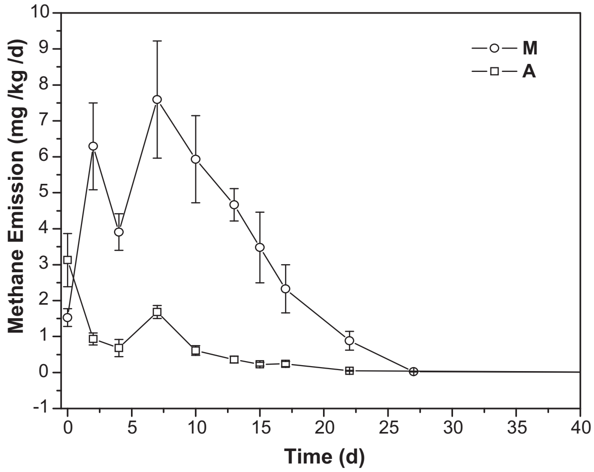

Fig. 2. CH_4 emissions from fecal matter (FM) from steers grazing in the morning (M) and in the afternoon (A) after deposition in the field (October 2012). Standard errors are shown as vertical bars.

assay, the value of Q_{10} was 2.70, slightly larger than the value given in his work, but the temperature range was also wider (18 °C).

Fig. 2 shows the average emission rate and the dispersion between the five chambers of each group across 27 days. The striking result is the 6-fold difference between methane emission rates from feces deposited by animals grazing in the morning (lot M) and animals grazing in the afternoon (lot A). The magnitude of this difference makes it difficult to be attributed to interanimal variations. However, individual samples should be used in future studies. Except for the first day, the time evolution is similar, with a peak around 7–8 days after deposition, but the rates corresponding to lot M are much larger than those of lot A. We attribute the inverse methane emission results of the first day to the time lapsed between deposition and measurements, which became negligible in the following days.

Table 1 gives the total methane emissions calculated from the rates measured in each group of chambers and shows also the dispersion for both lots. The FM samples from animals fed in the morning emitted on average, 6 times more methane than the FM samples from the animals fed in the afternoon. The difference is very remarkable taking into account that the animals and the environment (including the soil) are the same, and so is the plant grazed (oat).

It is well documented that, due to the balance between photosynthesis and respiration, the composition of the herbage changes along a day with the content of soluble carbohydrates increasing from sunrise to sunset (Delagarde et al., 2000). Therefore, it would be expected that if animals are given access to a new strip of pasture in the morning rather than in the afternoon they would consume diets with different chemical composition which would affect the chemical composition of the feces and, in turn, the methane emission. Nevertheless, to our knowledge, similar large differences have not been previously reported.

To compare the above results with the emission factor from feces used in the Argentine National Inventory (1 kg CH_4/head/year) it is necessary to have an estimation of fresh feces deposited by each animal per day. Based on previous studies performed in similar conditions (Sánchez Chopa et al., 2009), expected amount for steers may be around 1.5–2.2 kg dry matter/day, so the measured values must be multiplied by 2*365 = 730 kg/year. Consequently, the total CH_4 emission can be estimated to be 0.067 kg CH_4/head/year for lot M and 0.012 kg CH_4/head/year for lot A. These results agree with the published data quoted in Section 1 (see Table 1).

Although, this CH_4 total emission was very small compare to a typical emission due to ruminal fermentation. In the same region, a daily ruminal methane emission was in the order of 170 g/day/head (Bárbaro et al., 2008, steers weighing about 280 kg). Other values given for the ratio CH_4 from FM over CH_4 from rumen are below 1% for grazing cows.

Table 1
Total CH_4 emissions from fecal matter (FM) and dry matter (DM) from steers grazing in the morning (M) and in the afternoon (A) after deposition in the field over measurement periods (27 days).

	M	A	P-value
Methane production mg/kg FM	92.24	16.13	<0.001
SD	16.12	6.02	
CV (%)	17.48	37.32	
Methane production mg/kg DM	576.5	89.6	

Table 2
Physicochemical characteristics: dry matter (DM), crude protein (CP), ash and organic matter (OM) (% of the DM) of fecal samples used to determine CH_4 emissions. (M) Morning group and (A) afternoon group.

	Initial conditions		Final conditions	
	M	A	M	A
pH	7	6–7		
DM (%)	16	18	71.5	77.8
CP (%)	15.4	13.7	20.4	20.3
Ash (%)	24.6	32.3	35.6	32.9
OM (%)	75.4	67.7	64.4	67.1

The CH_4 flux at the soil–atmosphere interface, was weak and negative, and thus indicated small uptake. The average uptake value was about 2 ng/m^2/s and, in consequence, it was not included in the estimation of methane emission from FM.

The chemical composition of the FM composite samples is given in Table 2. The pH, dry matter, crude protein, ash and organic matter content, were analyzed at the beginning and at the end of the experiment.

The main difference between the two lots was the loss of a considerable fraction of organic matter in lot M (11%) which was not observed in lot A. Part of this loss is very likely emitted in a form of CH_4 and therefore is qualitatively consistent with the reported difference in CH_4 emission.

4. Conclusions

Methane emission from FM deposited by grazing cattle is a small contribution to pastoral systems GHG emission, which is mainly due to ruminal processes. The above-mentioned results from a region where methane emission from feces had not been studied before, confirm this assertion, providing values below 0.5% for the ratio between fecal and ruminal emissions. Furthermore, the results obtained in the present work are considerable smaller than the values used in the Argentine National Inventory but they are in the same order of magnitude those published elsewhere.

However, the experiment here described has produced an unexpected and potentially important result: there was a significant relative difference in the CH_4 emitted from the fecal samples between those deposited by steers grazing oat in the vegetative period during the morning (lot M), and those from steers grazing the same oat field in the afternoon (lot A) under identical conditions. The effect is consistent with a higher loss of dry organic matter in the feces from lot M.

Even if the generality of these results for other pastures or different stages should be verified, the results here presented may be important.

In non-pastoral feed systems, methane emissions from FM are relevant. Therefore, it is interesting to pose the question whether similarly marked changes could be obtained from pastoral systems with different kinds of pasture or different feeding schedules. Besides, the other GHG emissions from feces should also be measured because they may significantly contribute to GHG emissions in grazing systems.

The present results suggest that the origin of the differences in digestive processes related to the changes in the status of pastures across the day deserves study in its own right.

Conflict of interest

None declared.

Acknowledgements

Financial support was provided by the PICT 2010-1010 of the Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT) of the Ministerio de Ciencia, Tecnología e Innovación Productiva (MINCyT) (Argentina) and the Instituto de Promoción de la Carne Vacuna Argentina (IPCVA). The authors of this manuscript widely thank Dr. Horacio L. Gonda for the advice.

References

Bárbaro, N., Gere, J., Gratton, R., Rubio, R., Williams, K., 2008. First measurements of methane emitted by grazing cattle of the Argentinean beef system. N. Z. J. Agric. Res. 51, 209–219.
De Klein, C.A.M., Eckard, R.J., 2008. Targeted technologies for nitrous oxide abatement from animal agriculture. Proceedings of the 3rd Greenhouse Gases and Animal Agriculture Conference. Aust. J. Exp. Agric. 48, 14–22.
Delagarde, R., Peyraud, J.L., Delaby, L., Faverdin, P., 2000. Vertical distribution of biomass, chemical composition and pepsin–cellulase digestibility in a perennial ryegrass sward: interaction with month of year, regrowth age and time of day. Anim. Feed Sci. Technol. 84, 49–68.
Flessa, H., Ruser, R., Dorsch, P., Kamp, T., Jimenez, M.A., Munch, J.C., Beese, F., 2002. Integrated evaluation of greenhouse gas emissions (CO_2, CH_4, N_2O) from two farming systems in southern Germany. Agric. Ecosyst. Environ. 91, 1175–1189.
González-Avalos, E., Ruiz-Suárez, L.G., 2001. Methane emission factors from cattle manure in México. Bioresour. Technol. 80, 63–71.
Huarte, A., Cifuentes, V., Gratton, R., Clausse, A., 2010. Correlation of methane emissions with cattle population in Argentine Pampas. Atmos. Environ. 44, 2780–2786.

Jarvis, S.C., Lovell, R.D., Panayides, R., 1995. Patterns of methane emission from excreta of grazing animals. Soil Biol. Biochem. 27, 1581–1588.

Parkin, T.B., Venterea, R.T., 2010. Sampling Protocols. Chamber-Based Trace Gas Flux Measurements, http://www.ars.usda.gov/research/GRACEnet

República Argentina, 2007. Segunda Comunicación Nacional de la República Argentina a la Convención Marco de las Naciones Unidas sobre Cambio Climático. Secretaría de Ambiente y Desarrollo Sustentable, Buenos Aires http://www.ambiente.gov.ar/archivos/web/UCC/File/Segunda%20Comunicacion%20Nacional.pdf

Saggar, S., Bolan, N.S., Bhandral, R., Hedley, C.B., Luo, J., 2004. A review of emissions of methane, ammonia and nitrous oxide from animal excreta deposition and farm effluent application in grazed pastures. N. Z. J. Agric. Res. 47, 513–544.

Sánchez Chopa, F., Nadin, L.B., Trindade, J., Amaral, G., Bremm, C., Riffatti, M., Milano, G., Gonda, H., 2009. Intake and daily weight gain in steers grazing winter oats (*Avena sativa*). Entry time to daily paddock: morning vs afternoon. Rev. Argent. Prod. Anim. 29, 221–223.

Steinfeld, H., Gerber, P., Wassenaar, T.D., Castel, V., de Haan, C., 2006. Livestock's long shadow: environmental issues and options. Food & Agriculture Org..

Williams, D.J., 1993. Methane emission from manure of free-range dairy cows. Chemosphere 26, 179–187.

Williams, K.E., Gere, J.I., Sanchez Choppa, F., Nadin, L.B., Juliarena, M.P., Gratton, R., Milano, G.D., Gonda, H.L.,2010. Metano en el aire expirado por terneros en pastoreo. Horario de ingreso a una franja diaria: Mañana vs. Tarde. In: Comunicacion 33° Congreso Argentino de Producción Animal. Asociación Argentina de Producción Animal (AAPA)., pp. 474–475.