GREENHOUSE GAS EMISSIONS BY CATTLE REARED IN AN INTEGRATED CROP-LIVESTOCK SYSTEM AND FINISHED IN FEEDLOT

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ABSTRACT
Beef cattle is one of the main sources of GHG in the agricultural sector, however, it is possible to implement improvements in this segment to mitigate GHG emissions. Beef production in an integrated crop-livestock system can achieve a positive carbon balance, but feedlot systems generally offers both lower area requirements and GHG emissions per kilogram of meat produced than traditional systems. In this way, beef cattle production systems that associate well-managed grass systems, with the supply of diets in the finishing phase is an alternative to increase the productivity of the system, in addition to contributing to the reduction of GHG emissions per kg of meat produced. Cattle excreta are also sources of GHG emissions to the atmosphere, mainly nitrous oxide (N_2O) and methane (CH_4), but considerably less is known on their environmental impact. Thence, the objective of the study was to evaluate the enteric methane production from two breed compositions as well as GHG emissions from beef cattle excreta in a feedlot system. Methane production (kg/period) was 19% lower in Nellore (NEL) than Angus x Nellore crossbred (AN) in grazing, and no difference was observed in feedlot. The NEL had less CH_4 intensity (CH_4/BW) in grazing but greater CH_4 per unit of ADG in the feedlot compared to AN. Breed composition did not influence the CH_4 yield (CH_4/DMI) in either phase, despite the difference in feedlot DMI (kg day^{-1}). Regarding to the GHG emission from excreta deposition, the occurrence of rainfall was determinant of very high N_2O fluxes either for urine or feces. Individual excreta were characterized by a period of small but significant fluxes, followed by a period of indistinguishable fluxes at the background level, and then a third period after rainfall portrayed the large impact of excreta on GHG emissions from the feedlot.
Key words: Enteric methane; Beef cattle; Bovine excreta

INTRODUCTION

Emissions of greenhouse gases (GHG) caused directly by Brazilian agriculture and livestock represent 28% of the total (ALBUQUERQUE et al., 2020) and are mainly derived from animal and plant production. Beef cattle is one of the main sources of GHG emissions in the sector, followed using nitrogen fertilizers, the deposition of animal excreta and the decomposition of cultural residues, among others (EMISSÕES ..., 2018). In recent years, agriculture has been recognized for its potential in reducing GHG emissions through the adoption of sustainable use and mitigation practices. Beef cattle is the sector with the greatest margin for implementing improvements in its production system, mainly related to increasing the efficiency of the use of pastures in Brazil (EMISSÕES ..., 2018). The relationship between efficiency in the production of agricultural systems and the reduction of emissions in the sector is an opportunity to achieve the growing demand for livestock products and providing a positive carbon balance (MANZATTO et al., 2019; SOUZA et al., 2019).

Beef production in feedlot systems generally offer substantially lower area requirements and lower GHG emissions per kilogram of meat produced than traditional extensive systems. However, GHG emissions in grazing systems can be considerably less than previously thought, since the use of rotated, more productive, and better-quality pastures, as in crop-livestock systems (CLS), has the potential to increase carbon sequestration in the soil, thus negating emissions by animals. Beef cattle production systems that associate grazing well-managed in the initial growth phase of the animals, with the supply of concentrated diets in the finishing phase seems to be an alternative to increase the productivity of the system, in addition to contributing for the reduction GHG emissions per kg of carcass produced. Another alternative that has been frequently used to increase the weight gain of animals is the genetic improvement in beef cattle. The crossing between *Bos indicus* and *Bos taurus* animals can improve the production rates of purebred cattle, in addition to having the potential to reduce methane emissions per kg of meat produced.

Cattle excreta are also sources of GHG emissions to the atmosphere, mainly nitrous oxide (N_2O) and methane (CH_4). Some studies have quantified the emission of N_2O by the beef cattle excreta in pastures, but little is known about these emissions in feedlots, especially in tropical conditions (SORDI et al., 2014; LESSA et al., 2014). The GHG emissions from the soil due to the deposition of animal excreta can be influenced by different factors such as climate, species, type of diet and the management system (BROUCEK, 2018), and some aspects present in feedlot can increase N_2O emission, such as high animal density, soil compaction and absence of vegetation (VAN GROENIGEN et al., 2005). Studies indicate that the emission of N_2O in feedlots is small (BAI et al., 2015), but the production of beef cattle in feedlots has been expanding in Brazil, and greater attention should be given to the emission of GHG by deposition of urine and feces. According to the IPCC (2006), the emission factor for N_2O (amount of N lost as N_2O) is 2% for the animals' excreta in pasture or in feedlot, without distinguishing between urine and feces. However, studies show that there is a difference in the emission factor between urine and feces (LESSA et al., 2014; SORDI et al., 2014).

From the above, the objective of the study was to evaluate the enteric methane production from two breed compositions in pasture and in feedlot where, also, the emissions of gases from the excreta of these animals were measured.

MATERIAL AND METHODS

Site description and experimental design

The study was conducted in an integrated crop-livestock system (CLS) installed in the Embrapa Maize and Sorghum experimental field, located at the geographical coordinates 19°29'4.37"S and 44°10'25.66"W, at 755 m altitude. The local and predominant climate in almost the entire Cerrado region is classified, according to the Köppen classification, as Aw - Type A: megathermic (tropical humid) - with average temperature of the coldest month above 18 °C and subtype w, dry winter and maximum summer rainfall (MACENA et al., 2008). The average annual coverage is 1350 mm, distributed between the months of October and March. The soil is a Oxisol, dystrophic Red Latosol according to the Brazilian Soil Classification System (SANTOS et al., 2013), clayey and smooth wavy relief.

The 22.0 ha area was divided into four 5.5 ha plots where, each year, the plots are rotated as crops for the production of grains (soybeans and corn) or silage (corn and sorghum) associated with grasses *Urochloa* (Syn. *Brachiaria*) or *Megathyrsus* (Syn. *Panicum*) and in the fourth field is the *Megathyrsus* pasture (Figure 1).

Figure 1. Sequence of annual crop rotation (Soybean; Corn + Urochloa; Sorghum + Megathyrsus) and Megathyrsus pasture conducted in the CLS plots. Photos: R. C Alvarenga.

Bovine animals with an average age of seven months were introduced in the system in July of each year and remained in it for twelve months. In the finishing phase, the animals were transferred to the feedlot where they were finished over approximately 110-120 days and slaughtered at the age of 22-23 months.

Trials were conducted in the years 2016/2017 and 2017/2018. At the beginning of each rainy season (October/November), the steers (10 months old) were divided into two groups, according to the breed: Nellore (NEL) and Angus x Nellore crossbred (AN) and grazed only the *Megathyrsus* grass, which was subdivided into five paddocks of approximately 1.1 ha each, used as a rotational grazing system with approximately seven days of grazing and 28 days of rest. Subsequently, these animals were finished in feedlot, with a 65:35 concentrate:silage ratio diet.

Evaluation of methane emission in beef cattle in CLS and in feedlot

During the grazing and feedlot period, enteric methane (CH_4) emissions from the animals were evaluated. The CH_4 emissions were measured using the sulfur hexafluoride (SF_6) tracer gas technique as reported by Johnson et al. (1994). Ten days before the start of each measurement, an SF_6 permeation tube was introduced directly into the rumen of each animal through the esophagus. Exhaled gases were collected from eight animals from both breed composition with a sampling apparatus containing a collection canister made of polyvinyl chloride (PVC) equipped with a capillary tube. The gases expired by the animals were sampled once a day until at least five samples were obtained per animal (Figure 2). The analyzes of the concentrations of CH_4 and SF_6 were determined by gas chromatography at the Gas Chromatography Laboratory of Embrapa Dairy Cattle, Juiz de Fora, Minas Gerais, Brazil.

Figure 2. Detail of the sampling apparatus used to collect enteric methane in cattle in feedlot (left) and pasture (right). Sete Lagoas, MG. Photos: S. T. Guimarães (L) and I. C. F. Maciel (R).

Evaluation of nitrous oxide and methane emission by the excreta of beef cattle in feedlot

In addition, N_2O and CH_4 emissions from the deposition of feces and urine on the surface of pens were also assessed in the feedlot. GHG emissions from excreta were measured using a closed static chamber technique, and the methodology was based on previously published studies (SAGGAR et al., 2004; LUO et al., 2013, 2015; VAN DER WEERDEN et al., 2016). Two weeks before the experiment, a base of the chamber (dimensions of 60.5 cm long x 40.0 cm wide) was inserted 8.0 cm into the soil in each plot and left for the entire experimental period.

The urine and feces of Nellore steers (n = 25, BW = 393 ± 31kg) were collected on days 34 and 35 of the feedlot. The excreta application was performed once, at the beginning of the experiment, in the dry season (winter 2017). Feces weight and urine volume were 1.3 kg and 1.3 L, respectively. Feces and urine were applied separately to the center of the base of the static chambers used for the measurement of GHG. A control treatment, without the addition of excreta, was included in the study. A trough was made around the top of the frame and filled with water at the time of gas monitoring to ensure the seal after coupling the top portion of the chamber to the base. The top portion was covered by an insulating material to avoid large differences between internal and external temperatures.

Gas samples were collected manually from each chamber and measurements were taken daily during the first four days after application (DAA) of excreta to account for possible instantaneous excreta emissions and, subsequently, every 2 and 3 days in the second and third weeks, respectively, and then weekly thereafter until 92 DAA. Air samples inside the chamber were collected at 0, 15, 30 and 45 min after closing the chamber using a 60 mL syringe and transferred to a 20 mL Exetainer flask with vacuum (Labco, Lampeter, United Kingdom). Extra samplings were performed when the precipitation exceeded 10 mm in 24 h. On each sampling day, gas measurements were taken once between 9 am and 10 am. Nitrous oxide and methane concentration were analyzed by gas chromatography. For more details on the execution of the GHG experiment of bovine excreta, see Maciel et al. (2021).

RESULTS AND DISCUSSIONS

Methane production (g day^{-1} and kg year^{-1}) was lower for NEL animals than for AN in both pasture and feedlot systems (P<0.01). Considering the entire period, NEL emitted 19% less methane than AN on pasture, but no differences between breed composition in feedlot were observed. Although AN have a higher daily methane emission, the total methane emission during the feedlot was the same for both breed compositions, because the period that the crossbred animals remained in feedlot was shorter than the NEL animals.

There was no difference in the dry matter intake (DMI) between breeds on pasture (5.9 vs. 6.23 kg DM per day for NEL and AN, respectively), however, in the feedlot, AN had greater DMI (12.4 kg day^{-1}) than NEL (9.3 kg day^{-1}). Despite the difference in DMI, breed composition did not influence the methane yield (g CH_4 per unit of DMI) neither in pasture nor in feedlot.

Regarding the methane emitted per unit of ADG, there was no difference between the two breed compositions on pasture (119.5 and 140.0 g of CH_4 per kg of ADG for NEL and AN, respectively). However, in feedlot, CH_4/ADG or CH_4/carcass ADG was significantly lower ($P<0.01$) in AN than NEL animals. Previous research has focused on the use of feedlots as a strategy to reduce methane emissions per kg of meat produced compared to the grazing system. However, most studies have evaluated continuous grazing systems, or have not considered the carbon sequestration by plants. In addition, in these studies, ADG is generally below what can be achieved in well-managed intensive grazing systems. A substantial reduction in net GHG emissions can occur in intensive grazing systems, even when requiring twice as much land as in feedlot systems, because of increased animal performance and carbon sequestration.

The results for GHG emission from the excreta showed significant effects of interaction between excreta type and days. Fluxes of N_2O were predominately low owing to the dry conditions throughout the monitoring period, exception made to a few days after excreta application (DAA), and principally after the three-day rainfall from 67 to 70 DAA. When comparing excreta treatments within each day of gas monitoring, the application of urine resulted in a significantly higher fluxes than those measured from feces or control. In the following day, N_2O flux from urine decreased, but was still higher than the control. From 3 to 69 DAA, N_2O fluxes were practically basal and similar between excreta treatments, coinciding with the increase in temperature. During this period, the soil was probably too dry. With the three consecutive rainfall events, starting at 67 DAA, soil N_2O fluxes started to increase. The CH_4 fluxes were around zero or negative for most of the time, but an initial flux from feces, of relatively low magnitude was significantly higher than from urine or control. This happened again at 10 DAA. As observed for N_2O, the rainfall events also induced high CH_4 fluxes.

Over the 92 DAA (winter/spring) of gas monitoring, three distinct periods could be withdrawn based on the gas flux trends and principally on the significant differences that were observed among treatments within each gas sampling date. A first period would comprehend the first 10 DAA, during which urine induced high N_2O fluxes (first two days) and CH_4 fluxes were produced in feces at days 1 and 10. We called this period “excreta inductive period”, or EIP, as all changes in fluxes were virtually associated to own excreta, more than the environment. From 13 until 56 DAA was the period of low fluxes, when no differences between treatments could be observed. This was called “dry period”, or DP. A third period was mostly associated to the effects of rainfall on both gas fluxes which lasted from 69 DAA to the end of monitoring, which was called “after rain induction period” or ARIP. On average of whole monitoring period, N_2O fluxes presented mean values of 180.4, 249.4 and 297.3 $\mu g\ N\ m^{-2}\ h^{-1}$ for control, feces, and urine, respectively. The highest mean flux of 650.7 $\mu g\ N_2O\text{-}N\ m^{-2}\ h^{-1}$ was observed for ARIP, followed by a mean flux of 47.2 $\mu g\ N_2O\text{-}N\ m^{-2}\ h^{-1}$ for EIP, when excreta were fresh. The mean flux for DP was 29.1 $\mu g\ N_2O\text{-}N\ m^{-2}\ h^{-1}$.

CONCLUSIONS

The potential for mitigating and neutralizing greenhouse gases is one of the benefits arising from the use of CLS, already recognized by science in Brazil. These reduce net GHG emissions per kg of carcass produced, which contributes positively to the role of the agricultural sector in climate change. The estimate of the carbon balance in CLS systems can provide added value to production, adding competitiveness to the sector in the face of market demands and is in line with the Brazilian GHG reduction policy in the country.

Excreta GHG emission data indicate that urine results in a prompt emission of N_2O and that occasional rainfall has potential to dramatically enhance the process. The CH_4 emissions seems to be of lower importance when dry conditions prevail, but the rainfall effect on emissions can be also relevant.

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