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Nitrous oxide emission from excreta of different beef cattle breeds finished in feedlot

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Abstract – The objective of this work was to compare nitrous oxide (N_2O) emissions from urine and manure of Nellore and crossbred (Nellore x Angus) cattle finished in feedlot. Twenty Nellore and 20 crossbred bulls were fed a diet consisting of 75% concentrate and 25% roughage. Excreta were applied to the pens after 43 days of confinement, when N_2O monitoring started through static chambers. The data were subjected to the analysis of variance, and averages were compared by Tukey's test. The N_2O fluxes from urine and manure were similar among the breeds, with important peaks after rain events. The cumulative emissions of N_2O from urine per kilogram of body weight gain (BWG) and the total emissions from manure per kilogram of BWG were 22.7% and 24.4% higher in Nellore cattle. There is no breed effect on N_2O flux and cumulative emissions by excreta from confined beef cattle; however, the crossbreed emits less per kilogram of BWG. There is a high correlation between rainfall volume and the N_2O emissions of the next day, which indicates a period between rain occurrence and the increase in N_2O emission.

Index terms: Angus, genetic groups, greenhouse gas emission, Nellore.

Emissão de óxido nitroso de excretas de diferentes raças de gado de corte terminados em confinamento

Resumo – O objetivo deste trabalho foi comparar as emissões de óxido nitroso (N_2O) pela urina e pelas fezes de bovinos Nelore e mestiços (Nelore x Angus) terminados em confinamento. Vinte bois Nelore e 20 mestiços foram alimentados com dieta composta de 75% de concentrado e 25% de volumoso. As excretas foram aplicadas nos currais após 43 dias de confinamento, quando se iniciou o monitoramento de N_2O por meio de câmaras estáticas. Os dados foram submetidos à análise de variância, e as médias foram comparadas pelo teste de Tukey. Os fluxos de N_2O da urina e das fezes foram semelhantes entre as raças, com picos importantes após a ocorrência de chuvas. As emissões cumulativas de N_2O da urina por quilograma de ganho de peso corporal (GPC) e as emissões totais das fezes por quilograma de GPC foram 22,7% e 24,4% maiores na raça Nelore. Não há efeito da raça sobre o fluxo de N_2O e as emissões cumulativas de excretas de bovinos de corte confinados; entretanto, o gado mestiço emite menos por quilograma de GPC. Há alta correlação entre o volume de chuva e as emissões de N_2O do dia seguinte, o que indica um período entre a ocorrência de chuva e o aumento da emissão de N_2O.

Termos para indexação: Angus, grupos genéticos, emissão de gases do efeito estufa, Nelore.

Introduction

Nitrous oxide (N_2O) production in the soil occurs mainly through the processes of nitrification and denitrification (Cardoso et al., 2017), with the latter being responsible for the largest daily fluxes (Smith, 2017). Specifically on pastures, N_2O emissions from cattle excreta are generally more influenced by climatic factors, with a marked increase after rain events in the summer (Barneze et al., 2014; Bretas et al., 2020; Zhu et al., 2021; van der Weerden et al., 2023). However, there is little information on N_2O emissions from excreta from beef cattle reared in feedlot in tropical regions (Maciel et al., 2021). In this system, the absence of vegetation and the high animal density increase soil compaction, i.e., result in a high soil bulk density, which leads to a higher N_2O emission (Cardoso et al., 2017).

Greenhouse gas emissions (GHG) from feedlot pens are being investigated in several countries, such as the United States and Canada (Parker et al., 2018; McGinn et al., 2019). However, in Brazil, there is only one known study evaluating N_2O emissions from excreta from cattle reared in feedlot (Maciel et al., 2021). Furthermore, there is no known information, in the literature, about the effect of different breeds on these emissions under feedlot conditions. Pelster et al. (2016), for example, observed that the excreta from Friesan (*Bos taurus taurus*) steers showed lower cumulative emissions than those from the Boran (*Bos taurus indicus*) breed, but on pastures. This difference could be attributed to the fact that taurine cattle frequently have a greater average daily gain and nutrient use efficiency than zebuine cattle (Maciel et al., 2019), which may reduce N concentration in the excreta and the amount of N_2O emitted. From these findings, the hypothesis of the present study is that the excreta from crossbred cattle (Nellore x Angus) emits less N_2O than that from Nellore cattle.

The evaluation of N_2O emission from the urine and manure of different breeds reared in feedlot can provide information about the emission dynamics of this gas and the environmental impact of this system. This assessment can generate more accurate information for carrying out GHG inventories and determining which breeds generate less environmental impact in tropical conditions.

The objective of this work was to compare N_2O emissions from urine and manure of Nellore and crossbred (Nellore x Angus) cattle finished in feedlot.

Materials and Methods

All evaluations were approved by the ethics committee on animal use of Universidade Federal de Minas Gerais, under protocol number 16/2018. The experiment was carried out at Embrapa Milho e Sorgo, located in the municipality of Sete Lagoas, in the state of Minas Gerais, Brazil (19°28'S, 44°15'W, at 732 m altitude). According to Köppen-Geiger, the climate of the region is classified as Cwa, humid subtropical, with dry winters and hot and rainy summers (Alvares et al., 2013). During the experiment, the average monthly precipitation was 36.3 mm, the average maximum air temperature was 28.4ºC, and the average minimum air temperature was 14.8ºC.

The total feedlot period lasted 129 days, from 6/8/2018 to 10/15/2018, with the first 21 days being used for cattle adaptation. According to their breed composition, 40 bulls were divided into two groups: 20 Nellore, with a live weight (LW) of 391±6.35 kg; and 20 crossbreed (Nellore x Angus), with a LW of 385±7.10 kg, without differences for initial LW (p=0.534 for the F-value for the breed effect in the analysis of variance). Each group was distributed in pens with an area of 18.5 m^2 per animal, with free access to diet and water. The starter diet had a 50:50 roughage to concentrate ratio on a dry matter (DM) basis, being increased to a 25:75 ratio over three weeks. The cattle were fed three times a day at 8 a.m., 11 a.m., and 3 p.m. The final diet consisted of 25% corn silage, 49.9% ground corn, 22.8% whole soybean, and 2.3% mineral and vitamin compound, adjusted daily to maintain 5.0 to 10.0% refusals.

The soil of the experimental area was clayey, with 0.22% nitrogen; more soil characteristics are found in Maciel et al. (2021). On all sampling days, the temperatures of the surface soil of the pen at a 10 cm depth, air, and the interior of the chambers were recorded using a digital thermometer. In the confinement area, a pen was isolated for three months (without cattle access) before the beginning of gas monitoring. The following five treatments were evaluated: manure or urine of Nellore or crossbred (Nellore x Angus) beef cattle; and a control, without added excreta. All treatments were arranged in a completely randomized design with four replicates, totaling 20 chambers.

For the evaluation of N_2O emission, the used method was that of closed static chambers, which were produced by the researchers of the present study at Embrapa Milho e Sorgo. The chambers, with a 1.5 cm wide U profile welded on the perimeter of a steel frame base (60 cm length, 40 cm width, and 8.0 cm height), forming a hollow box with a trough on the top side, were inserted 8.0 cm into the soil, two weeks before the trial. Chamber height was 45 cm and deployment time was 45 min, at a ratio of 60 cm h^{-1}, with a thermally-insulated bottomless box made of PVC to avoid large differences between internal and external temperatures. The trough around the frame top was filled with water at the time of gas monitoring to seal the chamber.

The manure and urine of five animals were collected and mixed to form a composite sample. Approximately 0.5 kg of manure from each animal was collected immediately after defecation or directly from the rectum. For urine collection, cattle were manually stimulated until urination. The samples were stored at 4°C during the two days of collection. From the excreta samples from each breed, N and C concentrations were determined by the Kjeldahl method ID 954.01 of Association of Official Analytical Chemists – AOAC (Cunniff, 1995), and by dry oxidation, respectively. For Nellore and the crossbreed, C concentrations were 419 and 415 g kg^{-1} in manure, whereas N concentrations were 20.3 and 7.3 g L^{-1} in manure and 23.0 and 7.1 g L^{-1} in urine, respectively.

Before excreta application on the forty-third confinement day (on 8/29/2018, the beginning of winter), the manure and urine were removed from the freezer and kept at room temperature for 12 hours. In the treatments with the addition of manure, 2.0 kg of this material (weighed on a digital scale) were placed in the center of the chambers. In the treatments with urine addition, 1.7 L of this material (measured in a graduated cylinder) was homogeneously spread in the chamber. Gas monitoring started on the day of excreta application, and, on each sampling day, gas measurements were conducted from 9 to 11 a.m., a period when the measured flux is expected to represent the mean daily flux.

In the first week, sampling frequency was daily and then, at about every three days, totaling 19 samplings. When a rainfall event occurred, the plots were sampled daily for three days. During chamber deployment, 25 mL headspace air samples were taken using 60 mL polypropylene syringes at 0, 15, 30, and 45 min after the chambers were sealed. The collected samples were transferred to previously evacuated 20 mL chromatography vials (Labco Limited, Lampeter, United Kingdom).

N_2O concentration was determined by gas chromatography using the GC-2014 chromatograph (Shimadzu Corporation, Tokyo, Japan), equipped with a flame ionizer and electron capture detectors, back-flush, and the AOC-5000 automatic gas injection system (Shimadzu Corporation, Tokyo, Japan). The increase or decrease of N_2O concentration within the chamber headspace for the gas samples collected at 0, 15, 30, and 45 min were generally linear ($R^2>0.90$), which is why N_2O hourly fluxes (μg m^{-2} h^{-1}) were estimated by linear regression according to the change in gas concentration within the chamber over time (De Klein et al., 2012). The used equation was: $F = [(\delta Gas/\delta t)\times(M/Vm)\times H]$, where F is the hourly flux of N_2O (μg N); δGas is the change in headspace gas concentration of N_2O over time (μL L^{-1}); δt is the enclosure period (hours); M is the molar weight of N in N_2O; Vm is the molar volume of gas (L mol^{-1}) at headspace temperature during sampling; and H is the height of the headspace (mm).

Cumulative emissions from each excreta type per chamber were determined as the sum of total emissions from each chamber over a 35 day period and expressed in μg m^{-2}, assuming homogeneous and representative fluxes. These emissions were divided both by the total weight gain per animal in the 35 day period, expressed in μg m^{-2} kg^{-1} body weight (BW), and by total dry matter intake per animal over the 35 day period, expressed in μg m^{-2} kg^{-1} DM. The total cumulative emission per chamber per kilogram of manure was multiplied by the total fecal output of each animal in the 35 day period and expressed in microgram per animal. This total emission per animal was divided by BW gain per animal over the period of 35 days and expressed as μg kg^{-1} BW.

The direct N_2O emission factor (EF), which represents the percentage of N in the applied excreta (manure or urine) emitted as N_2O, was estimated by the following equation (Krol et al., 2016): $EF = \{[(N_2O - N_{excreta}) - (N_2O - N_{control})]/\text{excreta N}$

applied}×100, where N_2O - $N_{excreta}$ is the emission of each treatment with excreta (manure or urine), N_2O - $N_{control}$ is the emission of the control treatment, and excreta N applied is the amount of N in urine or manure applied to the emission chambers.

Individual dry matter intake (DMI), expressed in kilogram per animal per day, was evaluated by sampling ten animals from each breed using titanium dioxide (TiO_2) as an external marker according to the methodology described in Myers et al. (2004). Fecal production was calculated by the equation: FP = [TiO_2 offered / (TiO_2 in manure / DM of manure)], where FP is the fecal production estimated by TiO_2 in gram of DM per day, TiO_2 offered is the amount of TiO_2 offered to each animal (10 g per animal per day), TiO_2 in manure is the percentage of titanium in manure, and DM of manure is the dry matter of manure at 105°C. In vitro dry matter digestibility (IVDMD), expressed in gram per kilogram of DM, was determined according to Tilley & Terry (1963). Fecal production data were used to estimate DMI in kilogram per animal per day through the equation: DMI = FP / (1 - IVDMD). Nitrogen intake was obtained using the following equation: NI = (DMI×CP)×0.16, where NI is N intake in gram of N per animal per day, DMI is the dry matter intake in kilogram of DM per animal per day, CP is diet crude protein in g kg^{-1} DM, and 0.16 is the percentage of N in crude protein.

N retention in the animal, in function of weight gain, was estimated considering the average N concentration of 2.7% accumulated in the tissue during the confinement period (Goulart et al., 2008). The total N excreted in the manure was estimated as the product of manure total dry mass and N concentration. The N excreted in the urine was determined by the equation: N urine = N consumed - N manure - N retained.

The tests of Shapiro-Wilk and Bartlet were used to verify the statistical assumptions of normality and homogeneity of variances, respectively. The daily N_2O fluxes from excreta were evaluated by the two-way analysis of variance (ANOVA) using: a split-plot arrangement with two breeds and the control group, i.e., Nellore urine, crossbreed urine, and control or Nellore manure, crossbreed manure, and control; and four repeated evaluations over time, at 0, 18, 24, and 34 days after application (DAA), representing excreta application, the occurrence of the first rains, the period without rain, and the new occurrence of rain, respectively. Mauchly's sphericity test (Mauchly, 1940) was applied, and, when significant ($p<0.05$), the Greenhouse-Geisser correction test (Greenhouse & Geisser, 1959) was performed. The treatment averages were compared using Tukey's test, at 5% probability. The N_2O flux was lognormal, transformed to meet the statistical assumptions.

The cumulative emissions were analyzed by one-way ANOVA, and the breeds' averages were compared by Fisher's test. Pearson's correlation analysis was performed between rainfall and N_2O emission data. The calculated correlations were between: rainfall and N_2O emission in the same day, without a period between these events; rainfall and N_2O emission in the next day, with a 24 hour period between these events; and rainfall and N_2O emission in the next two days, with a 48 hour period between these events. The correlation was considered weak, moderate, and high when the coefficient of correlation (r) was $r<0.3$, $0.31<r<0.7$, and $r>0.71$, respectively. All analyzes were performed using the R software (R Core Team, 2019).

Results and Discussion

The interaction between breed and DAA and breed as the main factor had no significant effect on daily N_2O flux ($p>0.05$), which was altered by DAA alone (Table 1). The N_2O fluxes from urine and

Table 1. Nitrous oxide (N_2O) emission from excreta of Nellore and crossbred (Nellore x Angus) cattle finished in feedlot and from the control group without excreta application(1).

Excreta emitted (μg N m^{-2} h^{-1})	Days after application (DAA)				SEM(2)	p-value(3)		
	0	18	24	34		G	DAA	G×D
N_2O urine	43.3c	1,192a	223b	297ab	0.152	0.091	<0.001	0.152
N_2O manure	67.0c	433a	198b	277b	0.470	0.496	<0.001	0.470

(1)Means value followed by different letters in the lines, differ between DAA by Tukey's test, at 5% probability. (2)SEM, standard error of mean. (3)G, main effect of breed; DAA, main effect of days after application; and G×D, interaction between breed and DAA.

manure increased slightly in the first two days after urine application (Figure 1); however, on the day of application, these fluxes were lower ($p<0.05$) than at 18, 24, and 34 DAA. The highest N_2O fluxes from urine were observed at 18 and 34 DAA and from manure at 18 DAA ($p<0.05$). These fluxes increased with the rain events that occurred between 16 and 19 DAA and were more intense in the areas affected by excreta, especially urine. This effect of rain remained for 10 days, after which, the fluxes returned to baseline levels for 7 days. At 33 and 34 DAA, the N_2O fluxes increased again due to the new rain events.

Although statistical analyzes were not performed in all DAA, there was a small increase in the N_2O daily flux from manure after the initial application, probably due to the increase in substrate moisture

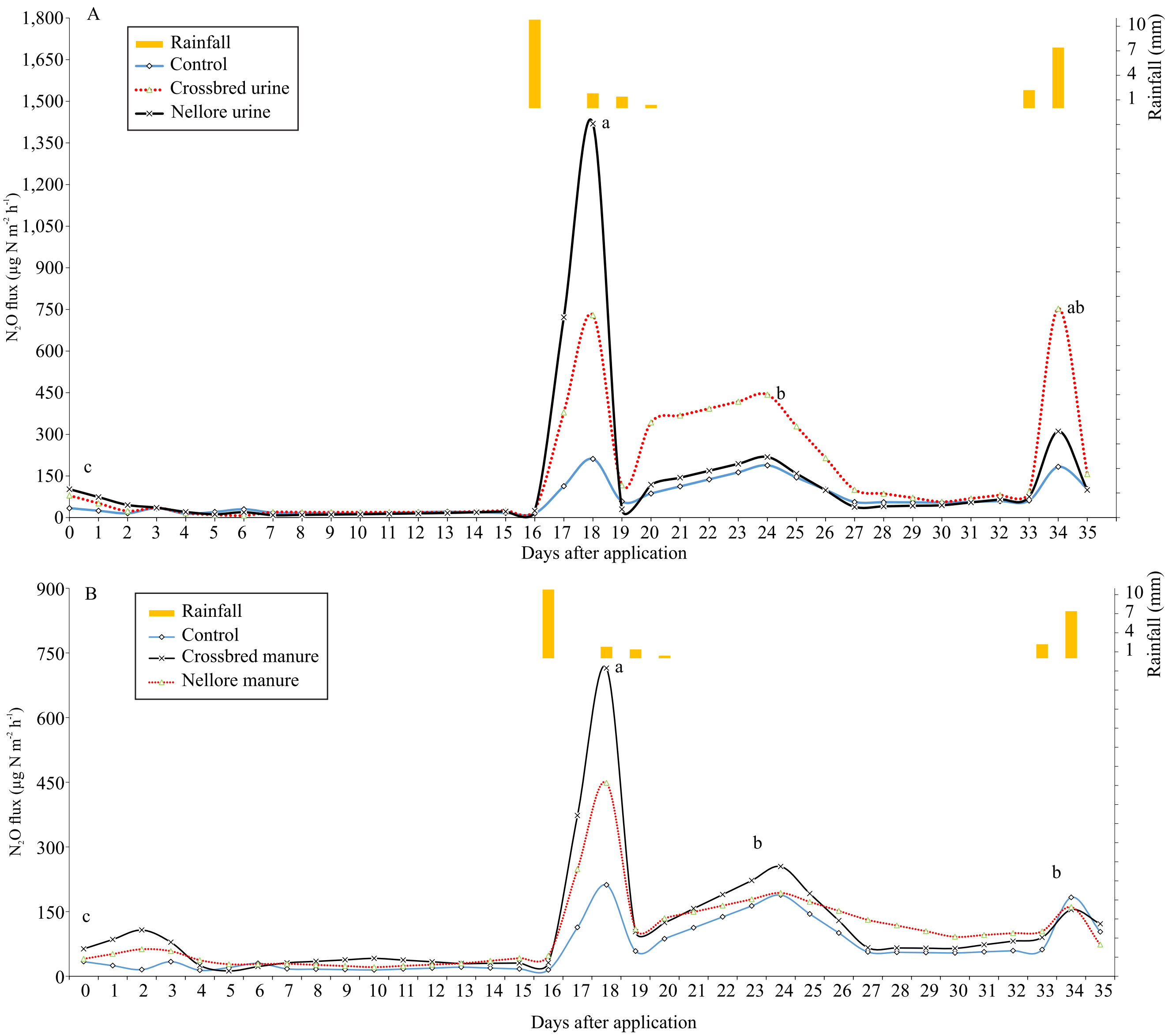

Figure 1. N_2O fluxes from urine (A) and manure (B) of Nellore and crossbred (Nellore x Angus) cattle finished in feedlot and from the control group (without excreta application). Different lowercase letters indicate a difference between days after application (considering the average value of the three treatments) by Tukey's test, at 5% probability.

and availability. A similar increase was observed by Maciel et al. (2021) in excreta from Nellore cattle reared in feedlot at the same location. In terms of practical feedlot management, the constant cleaning of the pens and the removal of excreta before and during the period of rains can reduce N_2O emission.

Another evidence of the effect of soil moisture on N_2O emission was the high correlation between N_2O emission and rainfall. Contrastingly, Maciel et al. (2021) found a very low correlation (r=0.097) between soil moisture and N_2O emission, and Aguilar et al. (2014), no correlation at all. However, it is common for an emission peak to occur after rainfall (Barneze et al., 2014), which is why the correlations between rain volume and N_2O emissions were tested with different periods between these events, in order to represent the rain effect on the emissions in the following days.

No correlation was observed between rainfall and N_2O emission in the same day and in the 48 hour period between these events for any excreta type (Figure 2). However, there was a correlation between rainfall and N_2O emission in the 24 hour period between these events for all excreta types. The correlation was moderate for the control (r=0.67; p=0.0017) and crossbreed urine (r=0.63; p=0.0039), but high for Nellore urine (r=0.82; p=0.00002), crossbreed manure (r=0.82; p=0.00002), and Nellore manure (r=0.75; p=0.0002).

The obtained results showed that the rain events were highly correlated with the emissions in next day (24 hour period), which indicates an interval between rain occurrence and N_2O flux peak. According to Baggs & Phillipot (2010), N_2O reductases are more sensitive to O_2 than NO_3^- and NO_2^- catalases. Therefore, these N_2O-producing catalase enzymes remain more active in the presence of oxygen when there is no rain. This means that, when the medium becomes anaerobic again after new rains, the N_2O/N_2 rate increases significantly after 1 to 2 days, which may explain the period between these events observed in the present study. Furthermore, the denitrification process takes place mainly when there is more than 70% of soil water-filled pore space (WFPS) with an adequate NO_3^- and carbon availability. Baggs & Phillipot (2010) concluded that NO_3^- concentrations below 10 μg g^{-1} soil limit the denitrification process. Bretas et al. (2020) observed concentrations close to this limit in bovine excreta, which indicates a low NO_3^- availability to support the denitrification process and N_2O flux peak alone. This low concentration may indicate that the nitrification process (ammonia oxidation) prior to the medium becoming anaerobic can produce NO_3^- and supply substrate for denitrification, allowing of increases in N_2O fluxes.

The induction of N_2O emissions due to rain events in a tropical climate was also reported by Barneze et al. (2014) and Bretas et al. (2020). Rain events increase the proportion of WFPS, which creates an anaerobic condition in the soil (Smith, 2017), favoring the denitrification process and N_2O emissions (van der Weerden et al., 2023). On sampling days between approximately 4 and 16 DAA (immediately before the first rain), the N_2O fluxes from the excreta remained at baseline levels, which highlights the controlling effect of rain on N_2O emission. However, the compacted soil of the pen area, caused mainly by the lack of vegetation and high cattle density, probably also favored anaerobiosis as rainfall events were not so intense (Aguilar et al., 2014; Cardoso et al., 2017).

After the first rain, two peaks were observed in the N_2O flux: the first was more intense and shorter, and the second, less intense and longer. This second peak in N_2O flux was also reported by Krol et al. (2015) at 10 to 12 days after rainfall, lasting for 44 days, by Parker et al. (2017) at 15 days after rainfall for 40 days, and by Parker et al. (2018) at 3 to 4 days after rainfall for 18 days. According to Parker et al. (2017), the main mechanism that may have generated this second peak was nitrification due to the increase in NO_3-N and reduction in NH_4-N in manure. Under moist/loose and moist/compacted soil conditions, Aguilar et al. (2014) also observed a second N_2O peak after excreta application at 5 and 17 days, respectively, which may be explained by the difference in soil density that may have delayed gas diffusion from the soil to the atmosphere, justifying the difference between these studies.

The N_2O flux was similar among the evaluated breeds (Table 2), showing the lack of breed effect. This similarity in daily fluxes was supported by the lack of difference between breeds for DMI (Table 3) and by the partitioning of N excretion in manure and urine, which likely resulted in a similar substrate concentration in the excreta. However, the cumulative emissions per chamber of N_2O from urine and total N_2O emissions from manure per animal in the 35 day period were

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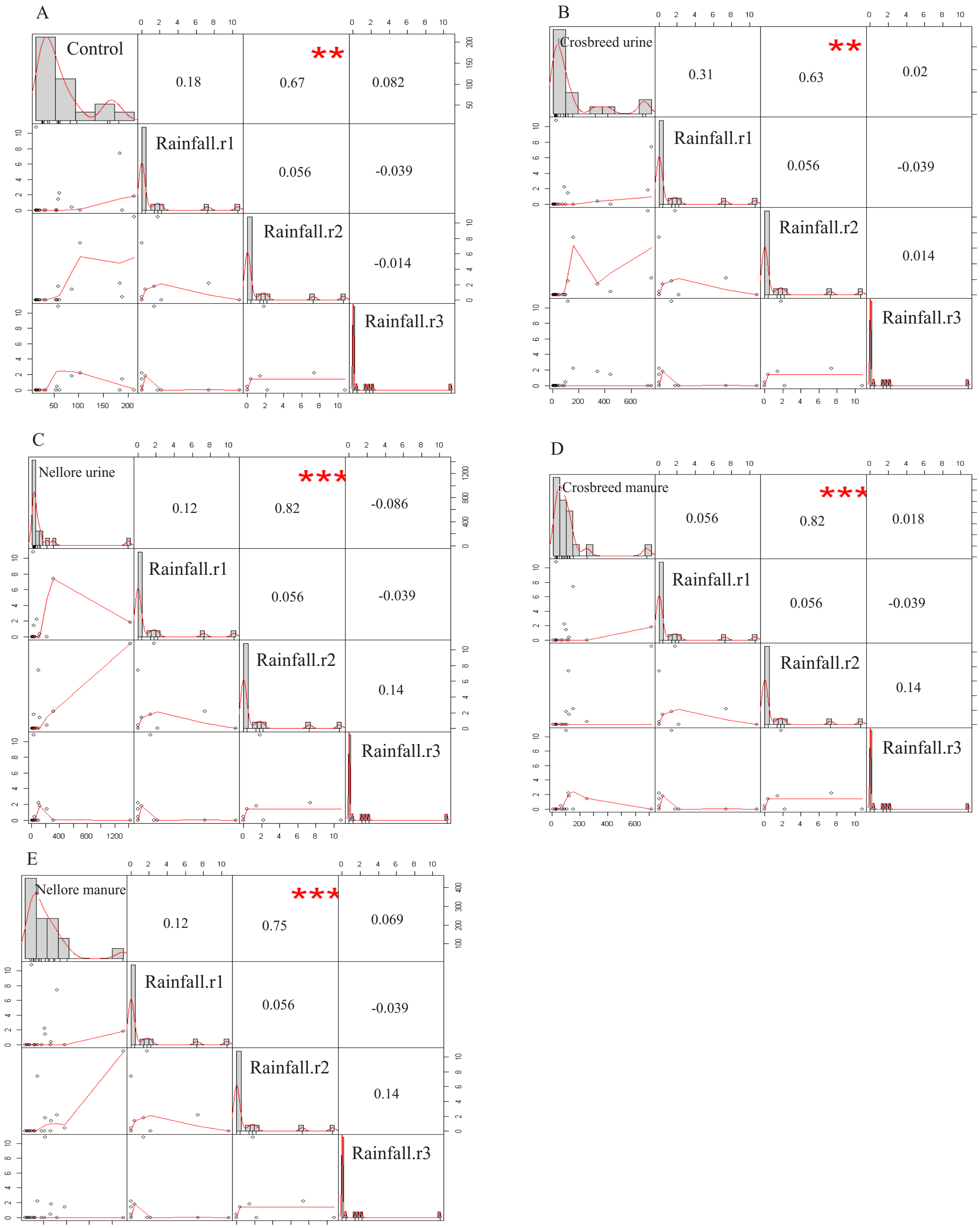

Figure 2. Correlation coefficient between the following nitrous oxide emissions from excreta and rain events: A, control (without excreta application) and rainfall; B, crossbreed (Nellore x Angus) urine and rainfall; C, Nellore urine and rainfall; D, crossbreed manure and rainfall; and E, Nellore manure and rainfall. Values inside the boxes refer to the correlation coefficient. Rainfall r1, analysis without a period between rainfall and nitrous oxide emission; Rainfall r2, analysis with a 24 hour period; and Rainfall r3, analysis with a 48 hour period. ** and ***Significant at 0.1 and 0.01% probability, respectively.

22.7% (p=0.017) and 19.6% (p=0.034) higher in Nellore (Table 2), probably due to the higher BW gain and feed efficiency in crossbred cattle. Crossbred cattle show a better performance due to heterosis and the complementarity of the crossbreeding of *Bos indicus* x *Bos taurus*, resulting in genetic gains (Favero et al., 2019). The poorer performance of Nellore cattle could also be explained by the fact that, in Brazil, this breed is usually reared exclusively on pastures, with limited interactions with humans, causing a more aggressive and alert behavior in feedlot pens, which increases energy expenditure with activities not related to BW gain (MacKay et al., 2013).

Dijkstra et al. (2013) found that the emissions of N_2O from urine applied to the sampling area were greater than those from the control. In the present study, dry conditions predominated on the days when urine was applied, which probably contributed to N losses due to ammonia volatilization, a phenomenon that reduces the availability of N for denitrification when the soil is subsequently moistened (Smith, 2017). Higher emissions usually occur because urine contains a high proportion of labile nitrogenous organic compounds. For Barneze et al. (2014), N_2O production from urine deposition on soils is mainly explained by the induction of the nitrification of the existing NH_4^+ in urine, in addition to the new NH_4^+ formed by urine urea hydrolysis. Furthermore, according to Dijkstra et al. (2013), urine produces higher N_2O emissions than manure because the latter contains only a small fraction of N in labile form and a larger part in organic forms more resistant to degradation. Another factor that contributes for the almost immediate increase in N_2O after urine deposition is the large volume of water that saturates soil pores and favors denitrification.

Table 2. Nitrous oxide cumulative emissions per chamber from manure or urine per kilogram of body weight (BW) gain and total emissions per animal from manure per kilogram of BW gain and per kilogram of dry matter intake in the 35 day period of Nellore and crossbred (Nellore x Angus) cattle finished in feedlot.

Emission	Breed		SEM[1]	p-value
	Crossbreed	Nellore		
	Emission according to weight gain			
Manure cumulative N_2O emission (μg N m^{-2} kg^{-1} BW)	1,606.0	1,666.0	75.8	0.701
Urine cumulative N_2O emission (μg N m^{-2} kg^{-1} BW)	990.0	1,280.0	61.2	0.017
Total manure N_2O emission in the 35 day period (μg N^{-1} animal)	4,601,850.0	4,639,166.0	177,263.0	0.920
Total manure N_2O emission (μg N m^{-2} kg^{-1} BW)	48,963.0	60,891.0	2,878.0	0.034
	Emission according to intake			
Manure N_2O emission (μg N m^{-2} kg^{-1} DM)	349.0	366.0	15.3	0.604
Urine N_2O emission (μg N m^{-2} kg^{-1} DM)	215.0	204.0	10.9	0.625

[1]SEM, standard error of the mean.

Table 3. Performance, intake, and feed efficiency of Nellore and crossbred (Nellore x Angus) cattle finished in feedlot[1].

Variable[2]	Nellore	Crossbreed	SEM[3]	p-value
Final weight (kg per animal)	567b	613a	2.50	0.006
Total weight gain (kg per animal)	175b	227a	1.60	<0.001
Average daily gain (kg per animal per day)	1.63b	2.11a	0.015	<0.001
Average daily gain in carcass (kg per animal per day)	1.12b	1.41a	0.006	<0.001
Hot carcass weight (kg per animal)	317b	344a	1.27	0.004
Dressing percentage (%)	55.9	55.7	0.084	0.602
Dry matter intake (kg per animal per day)	9.94	9.57	0.138	0.685
Feed efficiency (kg BWG kg^{-1} DM)	0.140b	0.180a	0.0009	0.026
Water intake[4] (L per animal per day)	30.4	37.7	-	-

[1]Means followed by equal letters, in the rows, do not differ by Fisher's test, at 5% probability. [2]BWG, body weight gain; and DM, dry matter. [3]SEM, standard error of the mean. [4]Water intake was obtained as average intake of all animals and, therefore, no statistical analysis was performed.

There was no effect ($p>0.05$) of breed on N intake (mean values of 174 g per animal per day), retention (mean values of 41 g per animal per day), and excretion (mean values of 83 and 51 g per animal per day in urine and manure, respectively). For the Nellore and crossbred cattle, the N_2O emission factors were 0.10 and 0.16% of applied N for urine and 0.16 and 0.20% of applied N for manure, respectively. The emission factors were lower than those of 0.32 and 2.83% observed for manure and urine, respectively, by Maciel et al. (2021) in feedlot pens in the same location. This lower emission in the present study occurred due to the shorter evaluation period and lower rain volume during the evaluations, which generates lower daily fluxes. However, the observed emission factors were very close to those of 0.13% for manure and 0.77% for urine in wet climate reported by the IPCC 2019 refinement (Hergoualc'h et al., 2019). Zhu et al. (2021) synthesized emission factor data of excreta applied to pastures in tropical regions and found values of 0.13% for manure and 0.65% for urine, also in wet climate, which are very similar to those of the IPCC 2019 refinement (Hergoualc'h et al., 2019). Despite the limited number of researches on emissions from feedlot pens, these results showed that, with excreta application, the values of the emission factor are similar to those of the IPCC 2019 refinement, which indicates that these guidelines are adequate for N_2O estimation.

Considering other works in Brazil, the emission factors obtained in the present study were similar to those of 0.2% of applied urine N found by Barneze et al. (2014) and of 0.03% of applied manure N and of 0.15% of applied urine N observed by Bretas et al. (2020) for cattle on pastures. Bell et al. (2015) reported a higher emission factor in bovine excreta in the summer than in the spring, whereas Mazzeto et al. (2014) found emissions 2.9 and 2.5 times higher in the Southeast and North of the country, respectively, in the summer, when compared with the winter, mostly due to the higher WFPS in the former season. In the present study, the low emission factor observed was attributed to the small volume of rainfall during the experimental period and, mainly, to the short measurement period of 35 days.

The N_2O emissions from excreta under typical winter conditions in central Brazil were strongly influenced by climatic factors. This shows that, to establish representative data for beef cattle feedlots in the country, it is necessary to carry out measurements for longer periods and at more comprehensive scales locally and nationally, in order to establish more appropriate emission factors that represent the national livestock.

Conclusions

1. There is no breed effect on nitrous oxide (N_2O) fluxes and cumulative emissions from urine and manure of confined beef cattle, although the crossbreed (Nellore x Angus) emits less per kilogram of body weight gain than the Nellore breed.
2. The N_2O flux from beef cattle excreta in feedlot is mainly influenced by rain occurrence due to the high correlation between rainfall volume and N_2O emissions in the next day, indicating a period between rain occurrence and the increase in N_2O emission.

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