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Methane Production by two Breeds of Cattle in Tropical Conditions

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Abstract

This work aimed to measure methane emission by the most frequently used cattle for milk production in Brazil, Gyr and F1 Holstein x Gyr heifers feeding Tifton 85 (*cynodont spp.)* hay. Methane production was measured by a respirometric technique in six F1 Holstein x Gyr and six Gyr heifers fed Tifton 85 hay (*Cynodon spp.*) in a tie stall system consuming. After 21 adaptation days on feeding, heifers weighed 450kg and an apparent digestibility assay was performed. Feed intake and faecal production were measured for five days by total collection. Animals were housed for 24 hours in the respirometric chamber (open circuit type) receiving the experimental diet to quantify methane emission. Although dry matter (DM) intake was higher for crossbred heifers, nutrients digestibility was similar between breeds. Related to diet characteristics methane production was similar between genetic groups, with average values of 26.4 L methane/kg dry matter intake (L/kg DM), 43.2 L/kg digestible dry matter, 35.716 L/kg neutral detergent fiber, 57.3 L/kg digestible neutral detergent fiber, 29.5 L/kg organic matter and 45 L/kg digestible organic matter. Daily Methane production of crossbred heifers was higher than Gyr (173.76 *versus*136.77 L/d), due to higher DM intake of these animals. More productive animals may produce more methane per day because of the higher consumption of DM, so methane production data should be analyzed by relative and not absolute numbers.

Keywords: F1 - Holstein x Gyr; Gyr; Greenhouse gas; Indirect Calorimetry; Respirometry; Ruminant

Introduction

Methane is an end product of fermentation under anaerobic conditions in the rumen and has a negative effect on the environment as an important greenhouse gas. Methane also represents a loss of energy and low efficiency of diet utilization by ruminants [1]. Methane is the second most important greenhouse gas. Once emitted, methane remains in the atmosphere for approximately 9-15 years and is about 21 times more effective in trapping heat in the atmosphere than carbon dioxide over a 100 year period [2]. In addition to environmental impact methane production by ruminants has been widely studied due to their negative influence on the energy metabolism of the animal. Emissions of this gas may correspond to an energy loss of 5 to 12% of gross energy consumed by cows [3].

Methane emission depends on the amount of feed consumed, although this effect is moderated by feed digestibility and other feed and animal characteristics. Hegarty et al.[4] reported that cattle with lower residual feed intake (i.e. greater productive efficiency) reduced daily methane production when compared to animals less efficient. Thus, animals of different breeds fed the same diet could have different methane emissions denoting different efficiencies.

Cattle breeding represent a large share of world livestock production. Tropical grasslands are the basis of feeding in these systems, but there are few studies on methane production by these animals. This work aimed to contribute with original data of methane emission by the most frequently used cattle for milk production in Brazil, Gyr, and F1 Holstein x Gyr heifers.

Materials and Methods

Procedures adopted in this research were approved by the Committee of Ethics and Animal Experimentation of the Federal University of Minas Gerais, under protocol 217/10.

Location and duration of the experimental period

The experiment was conducted at Animal Metabolism and Calorimetry Laboratory in the Animal Science Department of Veterinary School of Federal University of Minas Gerais, Belo Horizonte, Brazil.

Animals and Experimental Facilities

Six Gyr and six F1 Holstein x Gyr dairy heifers were used. Initial live weight was 450kg and final live weight was 461kg. The animals were kept in the *tie-stall* system, to which they were already adapted.

Experimental diet

Diet was formulated according to NRC [5] for maintenance. Diet was low-quality Tifton-85 hay (*Cynodon spp.*) and 50 g/d commercial mineral supplement (Table 1-2), similar to extensive cattle rearing systems. The feed was provided twice a day at 9 am and at 5 pm and the heifers had *ad libitum* access to water.

Apparent digestibility assay

After 21 adaptation days, apparent digestibility assay was performed. Feed intake and orts were quantified every day and faeces production was

Table 1: Chemical composition of diet

Nutrient	Content (%)
DM (g/kg)	883.5
CP (g/kg of DM)	76.1
NDF (g/kg of DM)	652.0
ADF (g/kg of DM)	303.3
OM (g/kg DM)	831.6
Ash (g/kg of DM)	51.9

DM-Dry Matter; CP-Crude Protein; NDF-Neutral Detergent Fiber; ADF-Acid Detergent Fiber; OM- Organic Matter

Table 2: Composition of mineral supplement used in experimental diet

Macrominerals	Assurance levels (g/kg of product)
Calcium	130
Phosphorus	90
Potassium	80
sulphur	25
Magnesium	20
Sodium	80
Microminerals	**Assurance levels (mg/kg of product)**
Cobalt	110
Copper	2,200
Iodine	120
Manganese	2,800
Selenium	60
Zinc	8,600
Vitamins	**Assurance levels (UI/kg of product)**
A	375,000
D3	100,000
E (mg)	2,000

measured for five days by total collection. Fecal samples for DM analyses were collected in identified boxes, weighed, and sampled twice daily, once before each feeding (8h am and 4h pm). The second set of feces samples were also collected for bromatological analyzes. Diets were sampled daily after each feeding.

Respirometry

After apparent digestibility assay, animals were placed in open circuit type respirometric chamber described by Rodriguez et al.[6] for 24 h. Animals received the same diet fed in digestibility assay. Any small quantity of orts was removed, weighed and sampled at the end of each methane data acquisition period to determine dry matter intake during the indirect calorimetry procedure. It is essential for performing measurements in cell respiration chamber the animals maintain DM intake observed in the digestibility trial.

Chemical Analysis

The analysis described below was performed in Laboratory of Animal Nutrition of Veterinary School of Federal University of Minas Gerais (UFMG). Samples of diet, orts, and feces were analyzed for dry matter (DM) (procedure 934.01; AOAC 2000), ash (procedure 967.05; AOAC 2000), crude protein (CP) (N.6.25; procedure 968.06; AOAC 2000), neutral detergent fiber (NDF) [7] and acid detergent fiber (ADF) [8] and ash (AOAC, 2000).

Statistical Methods

The experimental design was completely randomized, with each animal representing one experimental plot. Statistical model was ($Y_{ij} = M + G_i + e_{ij}$) where: M=the overall mean; G_i=effect of genotype and e_{ij}=random error associated with observations. Parameters analyzed were subjected to variance analysis using SAEG [9].Statistical Analysis System statistical package, version 8.0, and means were compared by Fisher's F test at 5% probability (P<0.05).

Results and Discussion

Nutrients intake and total tract apparent digestibility

Intake of DM, organic matter (OM) and NDF were significantly (P<0.05) higher for crossbred F1HxG (Table 3). Average weight gain obtained for both Gyr and F1 Holstein x Gyr heifers was 0.193 kg/d. When expressed per unit of metabolic weight, nutrient intake was also higher for F1 H x G heifers indicating that the body weight or size of the animal was not the determining factor of greater consumption in crossbred heifers.

Assessing diets with 20% concentrate and 80% Tifton-85 hay in zebu cattle, Ítavo et al.[10] found NDF intake of 71.86 gper kg metabolic BW. In another study evaluating diets based on Tifton-85 hay with 40% concentrate for Nellore cattle, Ataíde Jr. et al.[11] found an intake of 44 g NDF per kg metabolic BW. Mandebvu et al.[12] provided a diet composed exclusively by Tifton-85 hay (94.0% OM, 12.6% CP, 71% NDF and 31.5% ADF) to growing beef steers with initial body weight of 244 kg. The DM intake by the growing beef steers was 5.0 kg/d or 2.01% of BW. DM digestibility was 55.2% OM and NDF intake was 4.7 and 3.6 kg/d, respectively, lower than Gyr and F1 Holstein x Gyr heifers intake. Although steers had ad libitum access to food, the difference observed could be explained by the lower live weight of steers causing a physical limitation for consumption. Mandebvu et al.[12] found digestibility values of 55.2% for DM, 56.1% for OM and 58.6% for NDF. According to NRC [5] diets with DM digestibility above 60% when consumed at levels above maintenance may have lower utilization in the digestive tract. In this work, DM intake between genetic groups did not significantly modified apparent digestibility probably because both treatments DM was offered near maintenance levels. Average DM, OM and NDF digestibilities were 61.50%, 63.95%, and 65.00% respectively.

Methane production

Methane production was expressed in several ways related to diet and was similar between genetic groups (Table 4), although methane daily production of crossbred heifers was higher than Gyr (2.27 *versus* 1.42 Mcal/d). It is well recognized that methane production by livestock is closely related to dietary intake. Pelchen and Peters et al.[13] demonstrated

Table 3: Daily intakes and digestibility of nutrients by Gyr and F1 Holstein x Gyr heifers

Item	Genetic group		P-value	CV (%)
	Gyr	F1 Holstein x Gir		
DM (kg/day)	6.15[a]	7.76[b]	<0.01	7.29
DM (g/MBW)	66.47[a]	75.75[b]	0.02	7.06
DM (% BW)	1.43[a]	1.81[b]	<0.01	6.19
DM apparent digestibility (%)	61.18	61.88	***	6.98
OM (kg/day)	5.81[a]	7.31[b]	<0.01	6.63
OM (g/kg MBW)	62.88[a]	71.43[b]	0.01	6.52
OM apparent digestibility (%)	63.78[a]	64.12[a]	***	6.04
NDF (kg/day)	4.55[a]	5.73[b]	<0.01	6.62
NDF (g/MBW)	49.23[a]	55.99[b]	<0.01	6.48
NDF digestibility (%)	65.61[a]	64.4[a]	***	5.35

DM-Dry Matter; OM-Organic Matter; NDF-Neutral Detergent Fiber expressed in kilograms per day (kg/day), in grams per kilogram of metabolic body weight (g/kg $BW^{0.75}$) and in percentage of body weight (% BW); *P*< 0.05; CV = Coefficient of Variation (%)

Table 4: Methane production of F1 Holstein x Gyr and Gyr heifers measured by respirometric technique

Summary Text for the Table of Contents

Methane is a greenhouse gas, produced by feed fermentation in the digestive tract of ruminants. Besides its environmental impact, reducing methane production from cattle has the potential to increase production efficiency.

Some works have been published about methane production on silage diets, but tropical grasses are the most utilized forage on cattle feeding in these areas, especially for the most frequently Zebu cattle used for milk production in Brazil, Gyr, and F1 Holstein x Gyr heifers.

Item	Genetic group		P-value	CV (%)
	Gyr	F1 Holstein x Gyr		
L CH_4/day	136.77	173.76	0.07	23.27
L CH_4/kg DM	24.60	28.19	0.08	12.71
L CH_4/kg DDM	40.44	45.95	0.19	14.99
L CH_4/kg NDF	33.08	38.35	0.07	13.13
L CH_4/DNDF	50.61	58.01	0.13	14.29
L CH_4/kg OM	27.87	31.05	0.17	12.19
L CH_4/kg DOM	43.01	48.68	0.24	15.90

Methane production in liters per kilogram of dry matter consumed (L CH_4/kg DM), liters per kilogram of digestible dry matter (L CH4/kg DDM), liters per kg of neutral detergent fiber consumed (L CH_4/kg NDF), liters per kilogram of insoluble digestible neutral detergent fiber (L CH4/DNDF), liters per kilogram of organic matter of consumed (L CH4/kg OM) and liters per kilogram of digestible organic matter (L CH_4/kg DOM). CV = coefficient of variation expressed in percentage.

in sheep that methane emissions increased with increasing live weight, feeding level measured as multiples of maintenance and digestibility of dry matter and decreased for rations with greater ratios of crude fiber intake and intake of N-free extracts.

Greenhouse gases have been often reported in absolute values, which can lead to misinterpretations. The best way to express methane production by ruminant should be related to diet, both in quantity consumed and in the composition of the diet. In addition, the higher animal production needs higher food intake to meet nutritional requirements for tissues and milk synthesis. Thus, a correct way of expressing the potential environmental impact of gases produced by bovine would be to express it in relation to the quantity of product generated by the animal [14]. The highest production of methane per day by crossbred heifers occurred because they consume more feed, but there were no differences between breeds when methane was expressed in relation to different dietary parameters. Milk potential of crossbred heifers is greater than twice as high as zebu, and possibly the production of methane in relation to milk production will not be higher in them [15].

The methane emission measured by the SF6 principle by Angus steers fed barley-based diet ad libitum varied from118 to 554 L of methane/day with a mean value of 251 L per day [4]. Values for methane production reported for heifers in the present study were lower probably due to its lower dry matter intake. However, when expressed in L/kg DM intake the average methane production of heifers our work (26.39 L/kg DM) resembles the maximum production described by Hergarty et al.[4] of 27.68 L/kg DM. In tropical feeding conditions (low-quality forages) and animals (usually low producing breeds), average methane production has been reported to be 19.1 g/kg or 27.3 L/kg DM intake (n=142), 35.8 g/kg or 51.1 L/kg digestible DM intake (n=69), and 5.84% of GE intake (n=142) in cattle [14]. Shibata et al.[16] studied the relationship between dry matter intake and methane production by compiling data from 190 trials with dairy cattle, beef cattle, sheep and goats and their results suggested that methane production per unit of feed intake decreased with increasing feeding level, although the absolute amount of methane has increased. So, even though the Angus steers had a higher dry matter intake (38% higher comparing the average consumption of both works) than F1 HxG and Gyr heifers, the barley-based diet had lower fiber content when compared to the Tifton-85 hay diet (178 and 652, respectively).

A Brazilian work [17] using crossbred (*Bos taurus taurusx B. taurusindicus*) heifers consuming only *Brachiaria decumbens* pasture without fertilization ad libitum described a methane emission of 227 g/day and 58 g/kg DDM intake. The values mentioned by the authors are higher than the values obtained in our work, possibly due to the higher dry matter intake and a lowest quality of the *B. Decumbens* grass which contained more NDF and ADF and less protein (719 g/kg, 362 g/kg and 6.5 g/kg respectively) when compared to Tifton-85 hay used in our diet. The relationship between the quantity and quality of diet and methane emissions has been well established by several authors. Johnson & Johnson et al.[18] reported that the type of carbohydrate fermented influences the production of methane most likely due to impacts on ruminal pH and microbial population. The fermentation of the fiber cell wall components produces greater proportion acetic: propionic acid and consequently more methane. Feeding of animals with higher-quality digestible feed-grain concentrates reduces methane emissions from enteric fermentation (and achieves more efficient of conversion of actual food energy). The FAO report shows that, in absolute terms, the total greenhouse-gas emissions from intensive (feed-grain based) production methods especially methane are much less than from extensive (pasture-based) methods [19].

The use of respirometric chambers is the most sensitive method for measuring methane. According to Machado et al.[20], the growing demand for studies related to methane production and the efficiency of animal energy use has renewed interest in respirometry in recent decades. Data from this technique with zebu are still scarce.

Much of the investigation of methane production by cattle has been focused lately on the production of the gas related to feeding and energy efficiency. That being said, the comparison of methane production by two different breeds largely used in Brazil for milk production could give us a clue about which breed could be more energetically and productively efficient.

Nkrumah et al.[21] mention a genetic link between methanogens and their hosts such that the presence of methanogenic bacteria in an animal requires a quality of the host that is under phylogenetic rather than a dietary constraint. These authors observed that methane production was 28 and 24% less in low residual feed intake (RFI) animals compared with high and medium RFI animals, respectively. In Hegarty et al.[4] study, cattle selected for a low RFI also had a reduced total feed intake. The methane produced as a fraction of DMI did not differ between low and high selected lines. In the study of Nkrumah et al.[21], steers with a low RFI produced less methane per unit feed than other steers. Zhou et al.[22] determined that cattle that differ in feed efficiency also differ in prevalence of methanogenic species, which may be a possible mechanism for the reduced methane production. According to Nkrumah et al.[21] and Hegarty et al.[4] methane has been more of function of lower intake level rather than a selection against methane production itself. The results presented by Freetly and Brown-Brandl et al.[23] do not support the initial hypothesis that increased feed efficiency decreases methane production because when heifers were fed a high corn silage ration, the relationship between BW gain: DMI ratio and methane production was positive, which is opposite of what was hypothesized by other authors. Increased CH4 production rate with increased BW gain: DMI ratio may result from a complete fermentation of feedstuffs that leads to increased nutrient availability and increased CH4 production. Apparently, this could not be detected on the breeds evaluated as there was no difference between the genetic groups regard to methane emission expresses in several ways. The lack of difference in methane production expressed as a function of digestible DM, digestible NDF and digestible OM is consistent with the lack of difference found in the digestibility of these variables as shown in table 3 indicating that methane production is probably more related to the dietary constituents and their digestibility than to a possible breed effect.

Conclusion

There was no effect of racial group on methane production, indicating that this parameter is more related to dietary constituents and their digestibility.

Methane daily production of crossbred heifers was higher than Gyr due to higher dry matter intake of these animals. More productive animals may produce more methane per day because of the higher consumption of dry matter, so methane production data should be analyzed by relative and not absolute numbers.

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