INFLUENCE OF CLIMATE AND DIET ON METHANE POTENTIAL FROM DAIRY MANURE IN AND OUT OF LACTATION

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Highlights

- Lactating cow manure yields higher methane due to more digestible, energy-dense diets.
- Seasonal climate affects methane yield by altering feed quality and animal metabolism.
- Winter samples from non-lactating cows showed the lowest methane production potential.

Introduction

The intensification of dairy cattle production systems is already a reality and is a trend that is growing steadily. The goal is to maximize the efficiency of animals in smaller areas. One of the consequences of this intensification is the accumulation of waste in increasingly smaller spaces, making it essential to implement techniques that can mitigate the environmental impact resulting from this accumulation (Mendonça; Otenio; De Paula, 2021). Anaerobic digestion is a technique that has been extensively studied and is continually being improved. It is a viable alternative, as it not only reduces the polluting power of the waste in question, but also enables the generation of low-cost renewable energy (Ferraresi, 2021).

The growing and continuous improvement of engineering applied to the development of new biodigesters allows for the purification of effluents, as well as the generation of biogas, enabling the integration of this process with thermoelectric plants, the use of the natural gas distribution structure already in place, in addition to the generation of fuel for vehicles, thus opening up new opportunities for the new era.

The seasonal climate inherent to a continental country like Brazil, combined with the multiplicity of feeding options provided to animals, culminates in a diversity of combinations that determine variations in the composition of the substrates to be subjected to anaerobic digestion, resulting in varying biogas production potentials.

Dairy farming and cattle farming differ in terms of animal management and feed sources, and in dairy farming there are also differences in terms of diet for cows in lactation and non-lactation periods (dry periods). Therefore, the energy potential of each sector must be assessed individually and the responses for one sector may not necessarily be valid for the other sector. In the case of Brazil, it is also necessary to consider the climatic variations that occur throughout the year, together with periods of greater and lesser rainfall, which greatly influence the feed options to be provided.

The objective of this work was to identify the influence of seasonal climate variation, as well as dietary variation, on the biochemical potential of methane (BMP) of cattle manure from lactating and non-lactating cows.

Material and Methods

Bovine manure samples were collected from lactating and dry-season (non-lactating) cows, referred to in this study as L and NL, respectively. Two samplings were performed in different climatic seasons, one in fall and another in winter. The samples were collected in Poços de Caldas - MG, Brazil. The total solids, volatile solids, and fixed solids parameters of the substrates were determined using the American Public Health Association methodology (Apha, 2022). The methane production potential was investigated using the VDI 4630 (2006) methodology, which recommends biochemical methane potential (BMP) tests considering a 2:1 ratio of volatile solids of the inoculum and substrate.

The tests were performed in 250 ml borosilicate flasks, containing 125 ml of useful volume. The flasks were kept at 35 °C under 20 rpm for approximately 65 days. The volume of biogas produced was measured using a 500ml Hamilton syringe. The biogas composition was determined by gas chromatography. The inoculum used in all tests came from a UASB reactor that treats waste from a poultry slaughterhouse (Pereiras - SP, Brazil). Based on experimental data on the cumulative methane production of each experimental condition, the modified Gompertz equation (Eq. 1) was used to estimate the experimental parameters: methane production potential, maximum methane production rate and lag phase time.

$$P_{CH4}(t) = Pmax * exp\left\{-exp\left[\left(\frac{(Rmax*e)}{Pmax}\right) * (\lambda - t) + 1\right]\right\} \qquad (1)$$

Where:
P_{CH4} (t): specific cumulative methane production (Nml CH4 g/ VS)
P_{max} : maximum specific methane production (Nml CH4 g/ VS)
Rm_{ax} : maximum methane production rate (Nml NCH4 g/VS d)
λ: lag phase (d)

Results and Discussion

The specific methane production (SMP) resulting from L diets were higher in summer, winter and spring (Table 1) compared to NL diets. This superiority is due to the high energy and nutritional density of the L diet, composed of a higher proportion of concentrate (corn grains and soybean meal), with higher levels of rapidly degradable carbohydrates (starch), proteins and lipids, giving it greater digestibility, faster passage through the gastrointestinal tract, greater consumption, resulting in manures with higher levels of biomethane-soluble organic matter. Additionally, the L diet has lower levels of fibrous components (cellulose, hemicellulose and lignin) compared to the NL diet, in which non-lactating cows feed directly on Brachiaria, with no concentrate supplementation. This fact also favors manure originating from the L diet for higher SMP, as it has lower fiber contents that are poorly biodegradable.

Table 1 - Specific methane production (SMP - ml NCH_4/g SV) and methane (CH_4) and carbon dioxide (CO_2) contents in biogas produced from feces originating from L and NL diets, collected in summer, autumn, winter and spring

	Summer		Fall		Winter		Spring	
	L	NL	L	NL	L	NL	L	NL
PEM (ml NCH_4/g SV)	407.65	388.89	122.1	145.13	218.38	184.60	219.40	208.56
CH_4 (%)	41.85	46.76	40.24	41.16	39.43	48.55	44.72	45.2
CO_2 (%)	17.5	20.19	17.27	22.30	15.70	21.54	24.53	30.52

The direct influence of climate on pasture was demonstrated by observing the lowest SMP recorded for manure originating from the combination NL/winter (184.6 ml NCH4/g VS), compared to NL/summer (388.89 ml NCH4/g VS) and NL/spring (208.56 ml NCH4/g VS). In winter, non-lactating cows feed on brachiaria in its worst nutritional state (absence of leaves, stems and new shoots) and also present high levels of lignin due to the cold and dry climate, characteristic of the region under study (Figure 1).

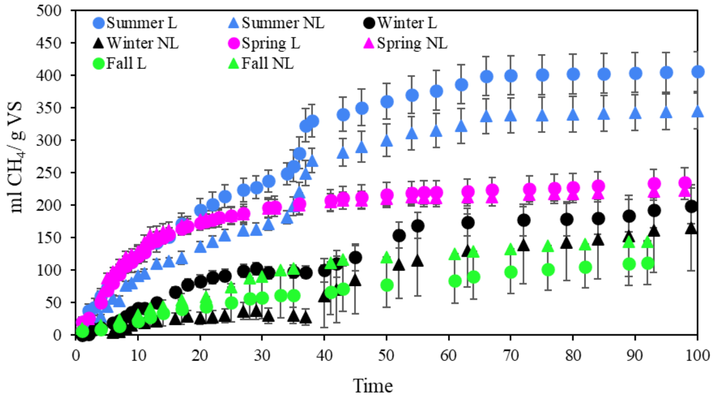

Figure 1 - Specific methane production (SMP) recorded in PBM trials for L and NL diets according to the seasons

The influence of climate variation altering the metabolism of ruminants in order to regulate homeothermy was also demonstrated when comparing summer and winter, which are seasons that commonly present opposite climatic conditions. It can be observed that in summer, for L diets, PEM were 86.67% higher than in winter (407.65 ml NCH4/g VS in summer and 218.38 ml NCH4/g VS in winter), and for NL diets in summer, PEM were 110.6% higher than in winter (388.89 ml NCH4/g VS in summer and 184.60 ml NCH4/g VS in winter). In other words, feces originating from both L and NL diets produced more PEM in summer. This statement can be justified by the greater need for thermoregulation in winter, that is, ruminants require more energy to maintain body T°C within the thermal comfort zone (homeothermy) and, to do so, they need to metabolize more nutrients from the diet. Consequently, fewer biomethanizable compounds, which would favor AD and biogas formation, will be excreted in feces during winter.

Moraes, Zaiat e Bonomi (2015) highlights the existence of relevant qualitative and quantitative variations in waste, influenced by climate conditions and the type of installation. Fibrous components are structural components of grasses and constitute evolutionary adaptations that give them tolerance to adverse climate conditions, such as lack or excess of rainfall, high and low temperatures. These fibrous components are part of the cell wall of these plants. According Orrico Junior *et al.* (2021), optimized forage consumption occurs when animals are in dense pastures with leaves accessible to the animal, common in summer with high temperatures and high humidity.

In this study, the Gompertz kinetic model was used to determine the kinetic parameters observed in relation to specific methane production and, when applied to anaerobic digestion, it helps to interpret the growth rate of methane production (Table 2).

Table 2 - Kinetic parameters of the Gompertz model and specific methane production

	Summer		Fall		Winter		Spring	
	L	NL	L	NL	L	NL	L	NL
P_{max}. (Nml CH4 g/VS)	407,65	388,89	122,1	145,13	218,38	186,86	219,4	208,56
$R_{máx}$ (Nml CH4 g/VS d)	9,270	6,594	1,745	3,050	3,737	2,53	11,229	13,296
Lag phase (λ)	0	0	0	0	1,204	14,05	0	0
R^2	0,986	0,980	0,980	0,993	0,977	0,9705	0,968	0,958

The L and NL combinations in spring presented the highest rates of maximum methane production velocities (11.229 and 13.296 μm), respectively. In second place were the velocities achieved by the L and NL combinations in summer (9.270 and 6.594 μm). The L and NL/winter and L and NL/autumn trials presented approximate maximum velocity values, with the exception of the L/autumn combination, which presented the lowest maximum velocity (1.745 μm). In the trials performed with fecal samples from winter, we observed a lag phase of approximately 1 day for the lactation diet and 14 days for the non-lactation diet. The R2 values, obtained from the kinetic modeling, were above 95%, indicating that the data from this study fit the modified Gompertz model.

Conclusion

Dietary variations, especially differences in energy and nutritional density, and seasonal climate variations influenced methane production from cattle manure. Manure from lactating cows (diet L), after being subjected to PBM tests, resulted in higher specific methane production and higher methane production rate when compared to manure from the NL diet. The lowest methane production potential was recorded in manure from the NL/winter combination, resulting from the lower excretion of biomethanizable compounds in these manures, due to the low energy and nutritional density of this diet, as well as due to the higher proportion of fibrous compounds (poorly biodegradable), common in this diet. In the winter season, the L and NL diets presented lower PEM when compared to the L and NL diets in the summer. This behavior suggests that ruminants have directed additional energy expenditure to achieve a caloric increase in order to maintain homeothermy, resulting in lower excretion of nutrients and energy in manure.

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