Scientific Paper

Estimation of methane emissions from enteric fermentation of dairy cattle on a farm in Camagüey, Cuba[1]

Yudith Lamothe-Crespo[1] *https://orcid.org/0000-0003-2937-878X*, María del Carmen Guerra-Rojas[1] *https://orcid.org/0000-0003-2727-9702*, Marlon Rodríguez-Abreu[1] *https://orcid.org/0009-0007-0040-4776* and Janet Blanco-Lobaina[2] *https://orcid.org/0009-0004-0484-4320*

[1]*Centro de Investigaciones para el Mejoramiento Animal de la Ganadería Tropical CIMAGT. Ministerio de la Agricultura Cuba. Avenida 101 No. 6214, entre 100 y 62. Reparto Loma de Tierra. Cotorro. La Habana, Cuba.* [2]*Instituto de Pastos y Forrajes. Ministerio de la Agricultura. Avenida Independencia km 8½ Boyeros, La Habana CP 10 800, Cuba. E-mail:* yudith@cima-minag.cu, yudith71lamothe@gmail.com

Abstract

Objective: To quantify methane emissions from the source of enteric fermentation of cattle on a farm in the Camagüey province, Cuba.

Materials and Methods: Emissions of enteric CH_4 from 11 milking dairy cows of the Siboney de Cuba (⅝Holstein x ⅜Cebú) species, belonging to the La Liliana farm in Camagüey, were calculated as a local contribution to the updating of the national GHG inventory, for the Agriculture, Forestry and Other Land Uses (AFOLU) module. The 2006 guidelines recommended by the Intergovernmental Panel for Climate Change (IPCC) and the Tier 2 estimation method for the agriculture module were used.

Results: Methane emissions from enteric fermentation of milking cows managed at the La Liliana farm in 2023 were 1 326,38 kg CH_4/year (37 138,64 kg CO_2-eq/year), which confirms it as a key subcategory within the National GHG Inventory for dairy cows. The main elements contributing to the high CH_4 emissions were digestibility due to low diet quality, lactation and animal weight.

Conclusions: The study on methane (CH_4) emissions in Siboney de Cuba cows in the farm show that these emissions are significant and contribute substantially to the greenhouse gas inventory. This underlines the importance of considering dairy cows as a key subcategory in greenhouse gas mitigation.

Keywords: feeding, greenhouse effect, milk production

Introduction

Animal husbandry is a fundamental pillar for the global economy and food security, as it contributes significantly to the nutrition of the population. However, its close relationship with climate change represents an environmental challenge of great magnitude, given its high contribution of greenhouse gases (GHG), higher than that of most agrifood activities.

Emissions associated with this sector come mainly from two processes: enteric fermentation and manure management (Gerber *et al*., 2013; FAO, 2018). Among these, methane (CH_4) –the second gas with the greatest impact on global warming- registered an alarming increase between 2020 and 2021 (FAO, 2023). According to estimates based on life cycle analyses, animal husbandry generates approximately 7,1 gigatonnes (Gt) of CO_2 eq annually, equivalent to 14,5 % of global anthropogenic emissions (FAO, 2018). In this context, Latin America and the Caribbean rank second in livestock GHG emissions, only behind Asia (Tubiello *et al*., 2014), with countries such as Brazil, Mexico, Argentina and Colombia as the largest regional contributors. In fact, Brazil and Mexico are among the top ten global emitters of CH_4 (Benaouda *et al*., 2017). This reality motivated numerous studies aimed at quantifying emissions and designing mitigation strategies in the region.

Cuba is not among the major GHG emitters on a global scale, the National Greenhouse Gas Inventory (1990-2022) revealed that enteric fermentation represents 71,6 % of emissions from the agricultural sector, exceeding the 25 % threshold that categorizes it as a critical source. This data underlines the relevance of livestock CH_4 in the national GHG balance. However, since 2016 a downward trend was observed, mainly attributable to the decrease in the animal population, especially cattle following the

[1] Work presented at the International Convention Agrodesarrollo 2024. Plaza América Convention Center, Varadero, Cuba. October 21-25, 2024

Received: December 19, 2024
Accepted: March 28, 2025

How to cite a paper: Lamothe-Crespo, Yudith; Guerra-Rojas, María del Carmen; Rodríguez-Abreu, Marlon & Blanco-Lobaina, Janet. 2025. Estimation of methane emissions from enteric fermentation of dairy cattle on a farm in Camagüey, Cuba. *Pastures and Forages*. 48:e04.

economic crisis that began in 1990. That crisis generated a chronic deficit of inputs (concentrate feeds, fuels, fertilizers, among others), which impacted both yields and herd size. This was compounded by the restrictions resulting from the COVID-19 pandemic during the last three years, which accentuated the contraction of the sector.

Despite advances in GHG estimation using various methodologies, there are still limitations associated with the uncertainty of default data and the lack of accurate local information. Therefore, it is imperative to develop comprehensive studies with national parameters that allow for more accurate calculations. In this sense, the quantification of enteric CH_4 emissions in animal husbandry farms such as the one analyzed in this work provides disaggregated data adjusted to real conditions, facilitating the determination of specific emission factors for dairy cows. These results would not only serve as a basis for evaluating the impact of feeding strategies with different composition and digestibility, but also to improve the accuracy of the National GHG Inventory. Hence, the objective of this work was to quantify methane emissions from enteric fermentation in cattle from a dairy farm in the Camagüey province, Cuba.

Materials and Methods

Location. This study was carried out at La Liliana farm, located in the Jimaguayú municipality in the Camagüey province, Cuba, and dedicated mainly to milk production. In the first stage, reconnaissance visits were made and information was collected from the herd in order to characterize the farm, collect the information in a database for the subsequent selection of the sample and estimation of enteric methane emissions.

Sample. A total of 11 milking cows of the Siboney de Cuba genotype (⅝Holstein x ⅜Zebu) with homogeneous characteristics in milk production and body condition, with more than two calvings, were used. The animals have a semi-grazing regime, diurnal in an area with scattered trees, quartered with energized wire fence and during the night they are stabled in the barns, and water consumption is *ad libitum*. The farm has a total area of 69,8 ha, of which 61 ha are used for animal production. Feeding is based on natural pasture with concentrate feed supplementation. The base period was 2023.

Experimental procedure. For the quantification of enteric methane emissions, the methodological guidelines and software for the elaboration of National GHG Inventories of the IPCC, 2006 version, were used. Taking into consideration the availability of activity data, information on emission factors, proper parameters for estimations and following the decision tree for emissions resulting from animal husbandry, tier 2 was applied as cattle are a main category in the 1990-2016 inventory (CITMA, 2020) and is mainly based on animal productivity and diet quality and quantity. The activity data was obtained in correspondence to the number of cattle in the study [$N_{(T)}$] and it was assumed that: low milk production cows = milking cows. Parametric data characteristic of the stock managed in the farm were available, according to those established by the IPCC: number of cattle heads, lactating cows (#), live weight, LW (kg), weight gain per day LWGd (kg), mature weight MW (kg), feeding status, daily milk production (kg/day), fat content (%), feed digestibility (%). For the last two parameters, data were obtained by documented expert judgment. These data allowed calculating the farm's own emission factors for the cattle category, subcategory milking cow. It is nothing more than the coefficient that relates the activity data to the amount of the chemical compound that constitutes the source of the last emissions (IPCC, 2006). Equation 2.3 was used for the calculation of enteric methane emissions.

Equation 10.19[2] Enteric fermentation emissions from a cattle category

$$\text{Emissions} = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6}\right)$$

Where:

Emissions = methane emissions from enteric fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined cattle population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = number of cattle heads of species/category T in the country

T = cattle species/category

The emission factor for the studied cattle category was estimated based on the gross energy intake (GE) and methane conversion factor (Ym) corresponding to the category, from Equation 2.5:

[2]Equation 10.19; Chapter 10; Volume 4; 2006 IPCC Guidelines.

Equation 10.21[3] Chapter 10; Volume 4; IPCC 2006 Guidelines

$$EF = \frac{[GE*(Ym/100)*365]}{55{,}65}$$

Where:

EF: emission factor (kg CH_4 head^{-1} year^{-1})
GE: gross energy intake (MJ head^{-1} day^{-1})
Ym: methane conversion factor, percentage of feed gross energy converted to methane

The constant 55,65 (MJ/kg CH_4) is the energy content of methane

Farm-specific parametric data, provided by the farmer and experts, were available for the calculation of gross energy intake. The equation for the calculation was:

Equation 10.16[4] Chapter 10; Volume 4; IPCC Guidelines 2006

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{labor} + NE_p}{REM}\right) + \left(\frac{NE_g + NE_{wool}}{REG}\right)}{\frac{DE\%}{100}} \right]$$

Where:

GE = gross energy, MJ day^{-1}
NEm = net energy required by the animal for main tenance, MJ day^{-1}
NEa = net energy for animal activity, MJ day^{-1}
NE1 = net energy for lactation, MJ day^{-1}
NElabor = energy for labor, MJ day^{-1}
NEp = net energy required for pregnancy, MJ day^{-1}
REM = ratio of net energy available in a diet for maintenance to consumed digestible energy
NEg = net energy for growth, MJ day^{-1}
NEwool = net energy required to produce one year of wool, MJ day^{-1}
REG = ratio of net energy available in a diet for growth to consumed digestible energy
DE% = digestible energy expressed as a percentage of gross energy

Results and Discussion

Table 1 shows the estimate, for the year 2023, of methane emission from enteric fermentation of milking cattle managed on the farm, which was 1 326,4 kg CH_4/year (37,138.6 kg CO_2-eq/year).

The emission factor obtained in the study for low-production dairy cows (milking cows), with a diet based on natural pasture and concentrate feed in smaller proportion, is close to that of the country EF =101,27 kg CH_4 head^{-1} year^{-1} for this cattle category. This is due to the fact that the last reports were obtained from studies carried out in the country, with its own parameters that allowed having refined data, coherent with the reality of Cuba. Feedstuff digestibility is the studied parameter that had more weight in the calculation of the emission factor, since the less digestible the feed is, the higher the enteric CH_4 emissions.

These results coincide with those reported by Hernández (2020) in Mexico, where cattle that consumed less digestible feedstuffs, mainly dairy cows, emitted more enteric CH_4. The other parameter was the animal's weight and lactation, since it has higher feed intake, which also leads to an increase in the volume of CH_4 production at the rumen level.

On the other hand, feed intake is positively correlated with animal size, growth rate and lactation. Similar results were reported by Vega (2022) in Cuba.

Conclusions

Methane emissions in Siboney de Cuba cows in the farm showed that these emissions are significant and contribute substantially to the greenhouse gas inventory. The estimated emissions were 1 326,4 kg CH_4 year^{1}, which is equivalent to 37 138,6 kg CO_2-eq year^{1}. This underlines the importance of considering dairy cows as a key subcategory in greenhouse gas mitigation.

The factors that most influenced the calculation of the emission factor were animal weight and gross energy requirement, especially during stages of higher feed intake. The low quality of the feedstuff supplied to the cows in the studied farm was associated with an increase in methane emissions due to enteric fermentation.

Acknowledgments

The authors thank the owner of the La Liliana farm for allowing access to his farm and providing valuable data for the development of this study, in addition to the support of project PN 0-50 of the National Program of Science, Technology and Innovation "Climate change in Cuba: Impacts, mitigation and adaptation", which provided funding for the study.

[3] Equation 10.21; Chapter 10; Volume 4; 2006 IPCC Guidelines.
[4] Equation 10.16; Chapter 10; Volume 4; 2006 IPCC Guidelines

Table 1. Estimation of methane (CH_4) emissions, IPCC Tier 2 methodology.

Parameter	Result	Source
Live weight of the animal, kg	450 average weight	Calculated for the studied sample
Coefficient that varies for each animal category	0,386	IPCC Guidelines (2006)
Net energy required by the animal for its maintenance LU day	37,7	
Coefficient corresponding to the feeding situation of the animal	0,7	IPCC Guidelines (2006)
Net energy for animal activity	6,4	
Coefficient with value of 0,8 females	0,8	IPCC Guidelines (2006)
Live and mature body weight of an adult female	375	Data provided by the farmer
Net energy for growth	-	
Pregnancy coefficient	0,1	IPCC Guidelines (2006)
Percentage of calving cows (% of calving cows)	0,7	Data provided by the farmer
Net energy for pregnancy	2,6	
Quantity of produced milk, kg milk day^{-1}	7,5	Data provided by the farmer
Milk fat content in % (fat)	3,5	Expert's criterion
Net energy for lactation	21,5	
Digestible energy expressed as gross protein percentage. Range of 45-55 IPCC (2006)	52,8	Calculated for the studied sample
Relation between net energy available in the diet for growth and consumed digestible energy	0,2	Calculated for the studied sample
Relation between net energy available in the diet for growth and digestible energy for intake	0,5	Calculated for the studied sample
Gross energy	282,8	
Factor of conversion into methane. % of gross energy of the feedstuff turned into methane	6,5	IPCC Guidelines (2006)
Emission factor for enteric fermentation (kg CH_4 head^{-1} year^{-1})	120,6	Calculated for the studied sample
Quantity of animals. LU cattle heads (animal quantity)	11,0	Studied sample
(t CH_4)	1,3	Calculated for the studied sample
(kt CH_4)	0,0013	Calculated for the studied sample
Emission for enteric fermentation, kg CH_4 year^{1}	1 326,4	Calculated for the studied sample
CO_2 equivalent (kg CO_2-eq year^{-1})	37 138,6	Calculated for the studied sample

Conflict of interests

The authors declare that there is no conflict of interests.

Authors' contribution

- Yudith Lamothe-Crespo. Participated in the design of the experiments, data processing, calculation, analysis and interpretation of the results, and reviewed the manuscripts for publication.
- María del Carmen Guerra-Rojas. Contributed to data processing and quantification of enteric methane emissions and reviewed manuscripts for publication.
- Marlon Rodríguez-Abreu. Participated in the capture and analysis of primary data for the characterization of the farm under study and reviewed manuscripts for publication.
- Janet Blanco-Lobaina. Participated in the characterization of the feed base of the farm and reviewed manuscripts for publication.

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