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ESTIMATES OF METHANE ENTERIC EMISSIONS FROM THE ROMANIAN DAIRY CATTLE SECTOR BETWEEN 2015-2024

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Abstract

The aim of this paper was to estimate methane emissions resulted from the enteric fermentation of dairy cattle, between 2015 and 2024 in Romania. The number of dairy cattle used in this paper was reported by the National Institute of Statistics, with enteric emissions being estimated using Tier 1 and Tier 2 methodologies provided by the International Panel on Climate Change Guidelines (IPCC, 2006) and expressed as Gg CH_4 yr^{-1} and t CO_2-eq. The gross energy intake (GE), digestible energy (DE), and methane conversion factor (Y_m) values for Tier 2, were calculated according to national reference values. Total methane emissions estimated for dairy cattle, decreased from 2.972.264 t CO_2-eq/year to 2.672.010 t CO_2-eq/year for Tier 1 and from 2.745.591 t CO_2-eq/year to 2.468.235 t CO_2-eq/year for Tier 2, from 2015 to 2024. The decrease in methane emissions was attributed to the decrease of dairy cattle numbers. The results can provide information on the status quo of the dairy industry, when the environmental footprint is concerned, as well as benchmark information in order to develop appropriate future strategies to reduce carbon footprint of the cattle sector.

***Key words**: dairy cattle, enteric fermentation, methane emissions.*

INTRODUCTION

The livestock sector represents an anthropogenic source of greenhouse gases (GHG), and thus contributes to climate change (Vagoni et al., 2019).

Given their digestive system, ruminants are responsible for the increasing CH_4 emissions at the global level (Ghassemi-Nejad et al., 2024), with methane resulting from enteric fermentation, representing approximately 35-70% of the carbon footprint (CF) of milk produced (Mc Geough et al., 2012).

Historical studies have shown that global enteric CH_4 emissions started to increase from the middle of the 19^{th} century (Garnier et al., 2019), with the intensification of the dairy industry and the increase of livestock units.

The production of methane varies significantly according to the nature of the feed and the fermentation intensity (accounting for 15-30% of the total ruminal gas), and it is positively correlated with the animal live weight and diet characteristics, this method is recommended for the development of country-specific factors to enhance the accuracy of enteric CH_4 estimation. The Tier 3 method is applying to a national inventory when comprehensive production levels (Popa et al., 2017; Tubiello et al., 2013).

To calculate CH_4 emissions from ruminants, a set of equations provided by the International Panel on Climate Change Guidelines (IPCC, 2006) was developed.

The IPCC suggested a three tier (Tier 1, Tier 2, and Tier 3) approach for national GHG inventories (Jo et al., 2016), with the recommended development of region-specific emission factors (RSEF). The Tier 1 method involves default values for emission factors, and the data are based on previous studies, presenting the emission factors by region based on animal numbers.

The Tier 2 method is an improved and more complex method that requires information about animal categories, feeding and production systems, and manure management. The calculation is based on the gross energy (GE) intake and conversion rate of gross energy intake into methane energy (Y_m), which can be chosen according to the level of productivity and knowledge of all factors influencing enteric and manure CH_4 emissions can be considered. This method is complex and laborious, requiring a series of exact region – specific factors.

The aim of this paper was to estimate methane (CH_4) emissions resulted from the enteric fermentation of dairy cattle, between 2015 and 2024 in Romania.

MATERIALS AND METHODS

The number of dairy cattle used in this paper to estimate CH_4 emissions was reported by the National Institute of Statistics (INS, 2024).
The enteric CH_4 emissions were estimated using Tier 1 and Tier 2 methodologies, according to the methodologies and guidelines of the International Panel on Climate Change (IPCC, 2006).
For accuracy, the enteric CH_4 emissions were calculated for an experimental a dairy cattle herd, of the the Research and Development Institute for Bovine Balotesti, during 2022-2024 period.
The gross energy intake (GE), digestible energy (DE), and methane conversion factor (Y_m) values for Tier 2, were calculated according to national reference values.
The enteric emissions were expressed as Gg CH_4 yr^{-1} and t CO_2-eq.
The methane emission was calculated based on equations 10.19 and 10.21 of the IPCC Guidelines (2006), using the formulas:

$$Emissions = EF_{(T)} \times N_{(T)}/10^6$$

where:
Emissions = methane emissions from enteric fermentation, Gg CH_4/yr^{-1};
$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 /$head^{-1}/yr^{-1}$;
$N_{(T)}$ = the number of head of livestock species/category T in the country;
T = species/category of livestock.

$$EF = [GE \times (Y_m/100) \times 365]/55.65$$

where:
EF = emission factor for enteric fermentation (kg $CH_4/head^{-1}/yr^{-1}$);
GE = gross energy intake (MJ/head/year);
Y_m = methane conversion factor, per cent of gross energy in feed converted to methane;
The factor 55.65 (MJ/kg CH_4) is the energy content of methane.
To quantify methane emissions (t CO_2-eq) from dairy cattle enteric fermentation, the basic formula of the IPPC Tier 2 approach was used:

$$Emissions = N_{(T)} \times (EF_{enteric}/1000) \times GWP_{CH4}$$

where:
Emissions = methane emissions from enteric fermentation of dairy cattle, t CO_2-eq;
$N_{(T)}$ = the number of head of livestock species/category T in the country;
$EF_{(T)}$ = emission factor for the defined livestock population, kg $CH_4/head^{-1}/yr^{-1}$;
$GWP_{100\ CH4}$ = the global warming potential of CH_4 in 100 years;
1 kg CH_4= 25 kg CO_2-eq (Forster et al., 2007).

The gross energy intake (GE) was calculated based on the following equation:

$$GE\ (kcal/kg) = 5.72 \times GP + 9.5 \times GB + 4.79 \times CelB + 4.17 \times SEN$$ (Stoica, 1997)

where:
GE = gross energy intake;
GP = crude protein;
GB = crude fat;
CelB = crude fibres;
SEN = non-nitrate extractable substances.

The percentage of digestible energy (DE) of raw energy was calculated according to the following relation:

$$DE\ \% = (DE/GE) \times 100$$

To calculate the national values of Y_m the following equations (Cambra-Lopez, 2008) was used:

$$Y_m = -0.0038 \times (DE)^2 + 0.3501 \times DE - 0.811$$

Specific values for GE, DE, Y_m and EF were developed or were used from the literature (Table 1). For the Tier 1, emission factor (EF) was 99 kg/head/year for dairy cows in Eastern Europe with an average annual milk production of 2.550 kg assumed by IPCC, 2006.
For the Tier 2, emission factors (EF) of 81.18 kg/head/year and 87.35 kg/head/year were considered for dairy cows with an average body weight between 620-650 kg, average milk yield between 11.1-13.84 kg, and a diet (kg/head/day) consisting of 20-25 kg of maize silage, 4-4.5 kg quality alfalfa hay, and 2-2.5 kg concentrates.
Emission factor (EF) of 91.45 kg/head/year was considered for dairy cows with an average body weight of 650 kg, average milk yield 15.00 kg/head/day and a diet (kg/head/day) consists of 25-30 kg silage maize, 5 kg alfalfa

hay, and 6 kg concentrates. Emission factors (EF) of 95.23 kg/head/year, 115.40 kg/head/year, and 119.84 kg/head/year were considered for dairy cows with an average body weight of 650 kg, average milk yield between 16.30-16.48 kg/head/day and a diet (kg/head/day) consists of 28 kg silage maize, 7 kg alfalfa hay, and 6 kg concentrates.

Table 1. The values used for calculations of methane emission from dairy cows' enteric fermentation

Specification	Body Weight, kg	Average Milk Yield, kg/head/day	GE[1], MJ/head/day	DE[2], MJ/head/day	DE, %	Y_m[3], %	EF[4], kg/head/year	Source
The value used for the number of dairy cattle reported by the National Institute of Statistics (NIS)								
Tier 1	-	-	-	-	-	-	99	IPPC, 2006
Tier 2	620	11.1	232.76	159.74	68.63	5.32	81.18	Popa et al., 2016
Tier 2	650	13.84	249.15	170.59	68.47	5.35	87.35	Popa et al., 2016
Tier 2	650	15.00	282.85	200.12	70.75	4.93	91.45	Own calculation
The value used for the number of dairy cattle from the Research and Development Institute for Bovine Balotesti								
Tier 2 - 2022	650	16.30	310.27	217.00	69.93	4.68	95.23	Own calculation
Tier 2 - 2023	650	16.37	312.34	211.93	67.85	5.85	119.84	Own calculation
Tier 2 - 2024	650	16.48	314.20	210.44	66.97	5.60	115.40	Own calculation

[1]GE = gros energy intake; [2]DE = digestible energy of gross energy; [3]Y_m = methane conversion factor of gross energy in feed converted to methane; [4] EF = emission factor.

RESULTS AND DISCUSSIONS

Total methane emissions estimated (Tier 1) from the Romanian dairy cattle sector between 2015-2024 are presented in Table 2. Applying the Tier 1 methods to Romanian's livestock, the obtained results revealed that the enteric CH_4 emissions decreased from 118.89 Gg CH_4/yr^{-1} (2.972.264 t CO_2-eq/year) to 106.88 Gg CH_4/yr^{-1} (2.672.010 t CO_2-eq/year) between 2015 and 2024. In contrast with our results, Sallaku et al. (2011) reported a higher value of 4.6943.4 t CO_2-eq/year obtained on a small herd of 22.580 dairy cows using the Tier 1 method.

Table 2. Summary of methane emissions estimated from the Romanian dairy cattle sector between 2015-2024

Years/Specification	Dairy cows, heads/year	Tier 1	CH_4 emission/head/year Gg[2] CH_4/yr^{-1}	*t CO_2-eq*[3]
2015	1.200.915		118.89	2.972.264
2016	1.201.132		118.89	2.972.801
2017	1.168.975		115.72	2.893.213
2018	1.170.076		115.83	2.895.938
2019	1.147.399	EF[1]: 99	113.59	2.839.812
2020	1.130.638		111.93	2.798.329
2021	1.118.342		110.71	2.767.896
2022	1.104.215		109.31	2.732.932
2023	1.077.589		106.68	2.667.032
2024	1.079.600		106.88	2.672.010

[1]EF = emission factor; [2]Gg CH_4/yr^{-1} = gigagrams CH_4/year; [3]t CO_2-eq = tons CO_2 equivalent.

Summary of methane emissions estimated (Tier 2) from the Romanian dairy cattle sector between 2015-2024 are presented in Table 3.

Applying the Tier 2 methods using EF: 81.18 kg/head/year and EF: 87.35 kg/head/year, published by Popa et al. (2016), the enteric CH_4 emissions decreased gradually from reference year 2015 until the reference year 2024.

The decrease of CH_4 levels at national scale was attributed to the decrease in animal numbers.

Table 4 summarizes the methane emissions estimated from the Romanian dairy cattle between 2015-2024 using Tier 2 method, EF of 91.45 kg/head/year (own calculation).

Total methane emissions estimated for dairy cattle decreased from 109.82 Gg CH_4/yr^{-1} (2.7445.591 t CO2-eq/year) to 98.72 Gg CH_4/yr^{-1} (2.467.798 t CO2-eq/year) between year 2015 to year 2024.

Similarity, the decrease in methane emissions was attributed to the decrease of dairy cattle numbers.

Table 3. Summary of methane emissions estimated from the Romanian dairy cattle sector between 2015-2024

Years/ Specification	Dairy cow, head/year	Tier 2	CH_4 emission/head/year	
			Gg[2] CH_4/yr^{-1}	*t CO_2-eq*[3]
2015	1.200.915	EF[1]: 81.18	97.49	2.437.256
		EF: 87.35	104.89	2.622.498
2016	1.201.132	EF: 81.18	97.50	2.437.697
		EF: 87.35	104.91	2.622.972
2017	1.168.975	EF: 81.18	94.89	2.372.434
		EF: 87.35	102.10	2.552.749
2018	1.170.076	EF: 81.18	94.98	2.374.669
		EF: 87.35	102.20	2.555.153
2019	1.147.399	EF: 81.18	93.14	2.328.646
		EF: 87.35	100.22	2.505.632
2020	1.130.638	EF: 81.18	91.78	2.294.629
		EF: 87.35	98.76	2.469.030
2021	1.118.342	EF: 81.18	90.78	2.269.675
		EF: 87.35	97.68	2.442.179
2022	1.104.215	EF: 81.18	89.64	2.241.004
		EF: 87.35	96.45	2.411.329
2023	1.077.589	EF: 81.18	87.47	2.186.966
		EF: 87.35	94.12	2.353.184
2024	1.079.600	EF: 81.18	87.64	2.191.048
		EF: 87.35	94.30	2.357.576

[1]EF = emission factor; [2]Gg CH_4/yr^{-1} = gigagrams CH_4/year; [3]t CO_2-eq = tons CO_2 equivalent.

Table 4. Summary of methane emissions estimated from the Romanian dairy cattle sector between 2015-2024

Years/Specification	Dairy cow, head/year	Tier 2	CH_4 emission/head/year	
			Gg[2] CH_4/yr^{-1}	*t CO_2-eq*[3]
2015	1.200.915		109.82	2.745.591
2016	1.201.132		109.84	2.746.088
2017	1.168.975		106.90	2.672.569
2018	1.170.076		107.00	2.675.086
2019	1.147.399	EF[1]: 91.45	104.92	2.623.240
2020	1.130.638		103.39	2.584.921
2021	1.118.342		102.27	2.556.809
2022	1.104.215		100.98	2.524.511
2023	1.077.589		98.54	2.463.637
2024	1.079.600		98.72	2.468.235

[1]EF = emission factor; [2]Gg CH_4/yr^{-1} = gigagrams CH_4/year; [3]t CO_2-eq = tons CO_2 equivalent.

Table 5 presents a summary of methane emissions estimated from a dairy cows' experimental herd between 2022 and 2024. The CH_4 emissions from enteric fermentation were calculated first by the Tier 1 method, resulting in an estimated amount of 210.37 *t CO_2-eq* in year 2022, 207.90 *t CO_2-eq* in year 2023, and 198.00 *t CO_2-eq* in year 2024 (0.008415 Gg CH_4/yr^{-1} to 0.007920 Gg CH_4/yr^{-1}).

Following the Tier 2 approach, the CH_4 emission/head/year were of 202.36 *t CO_2-eq* in year 2022, 251.66 *t CO_2-eq* in year 2023, and of 230.80 *t CO_2-eq* in year 2024, which were higher than the default value for EF Tier 1 from IPCC (2006).

Results are in line with those of (Popa et al., 2021), which showed that feed diets have a significant influence on enteric CH_4 emission.

Also, diet supplemented with 0.2 l/head/day rapeseed oil and 0.1 l/head/day sunflower oil showed a CH_4 emissions values of 1.41 kg CH_4/year (35.30 t CO_2 x 10^{-9}/year) and 1.39 kg CH_4/year (34.75 t CO_2 x 10^{-9}/year) in a herd of 29 Montbeliarde dairy cows in different lactation stages (Popa et al., 2022). Furthermore, in dairy buffaloes, the methane emissions estimates from enteric fermentation were between 0.002244 - 0.004280 Gg CH_4/yr^{-1} during 2014-2017 (Popa et al., 2017), values that are lower than those for dairy cattle.

Table 5. Summary of methane emissions estimated from the Romanian Black and Spotted dairy cows

Years/Specification	Dairy cows, heads/year	Tier 1	CH_4 emission/head/year Gg[2] CH_4/yr^{-1}	*t CO_2-eq*[3]
2022	85		0.008415	210.37
2023	84	EF[1]:99	0.008316	207.90
2024	80		0.007920	198.00
		Tier 2		
2022	85	EF:95.23	0.008094	202.36
2023	84	EF:119.84	0.010066	251.66
2024	80	EF:115.40	0.009232	230.80

[1]EF = emission factor; [2]Gg CH_4/yr^{-1} = gigagrams CH_4/year; [3]t CO_2-eq = tons CO_2 equivalent.

The paper presents the *status-quo* of the Romanian dairy sector and the resulting GHGs. We admit some limitations of the study, such as the lack of determinations of the current feed energy content and reporting data based on national averages, rather than on farm specific indicators (milk yield, reproduction performances, feed production, etc.). However, there is a strong body of literature showing that the process of rumen methanogenesis is important in achieving a regional strategy to further reduce methane gas emissions.

To decrease GHG emissions from the sector, enteric methane emissions from dairy cattle should be decreased without reducing livestock numbers, rather than identifying management and nutritional solutions, such as various feed additives.

The ways to reduce greenhouse gas emissions need to be adapted to specific local targets and conditions, by improving feed digestibility, forage quality, and diet composition; with an aim to improve the selection strategies and health of the animals; crop management and manure management (Marin et al., 2020). Furthermore, dietary optimization and the use of feed additives can reduce enteric CH_4 emissions directly, whereas selective breeding could have effects in the future generations (Kroliczewska et al., 2023), given the long productive cycle of cattle, with between-generation intervals of 4.5-5 years. Moreover, in cattle the production of ruminal methane is directly proportional to the digestibility of feed ingested. Feed with high digestibility produces less methane per unit of caloric energy consumed, than feed with lower digestibility (Yayli & Kilic, 2020). Sauvant & Giger-Reverdin (2009) shown that diet composition and intake are representing the main factors affecting CH_4 production by ruminants, with forages that have higher structural carbohydrates producing more CH_4 than those fed mixed diets containing higher levels of non-structural carbohydrates per unit of fermented material at the rumen level.

CONCLUSIONS

Total methane emissions estimated for the Romanian dairy cattle decreased during the period 2015-2024. The decrease in methane emissions was attributed to the decrease in the number of dairy cattle at national level.

The results obtained revealed that Romanian estimates of enteric CH_4 emissions differ when calculated using the IPCC Tier 2 methodology, compared to the IPCC Tier 1 methodology. As a result, more research is needed to identify the most accurate method between the two.

Strategies to reduce enteric methane emissions in combination with increasing animal performance (without reducing animal numbers) could lead to a reduced intensity of enteric CH_4 emissions.

The current results can provide information on the *status quo* of the dairy industry in terms of environmental footprint, as well as baseline information to develop appropriate future strategies to reduce the carbon footprint of the cattle sector numbers.

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