Entheric fermentation and manure management methane emissions at Sercaia buffaloes farm

DANA POPA, RĂZVAN POPA, ADRIAN BOTA, LIVIA VIDU
Department of Animal Science
University of Agricultural Sciences and Veterinary Medicine, Bucharest
Marasti Blv, no. 59, Bucharest
ROMANIA
poparasvan@yahoo.co.uk www.zootehnie.ro

Abstract: The paper aimed to present the evolution of green house gases emissions (methane) from entheric fermentation and manure management at Sercaia buffaloes farm (one of few research institute for buffaloes), during the period 2014 -2017. The emissions are based on the data provided by National Reasearch and Development Station for Buffaloes Breeding, Brasov County, Romania. The data have been processed into the following indicators: buffaloes livestock, number of dairy females and youth categories buffaloes as 0-6 months, 6-12 months, 12-18 months, male above 18 months. All categories included in this study were in accordance with IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2006, chapter 11, Agriculture [1] (following catlle pattern) and parameters used in equations have national values (gross energy intake, digestible energy, Y_m, VS, EF). Emissions estimation was made in winter season, because the feed ratio for animals have a higher value than in summer season, which is a grazing period. After all the calculations we see that the methane emission trend from entheric fermentation and manure management were descending, due to the decrease in the number of animals, but in the last period (2016-2017), due to conversion to organic farming.

Key-Words: buffaloes, greenhouse gas emission, entheric fermentation, manure management

1 Introduction

Methane from enteric fermentation is the product of microbial activity from the animal rumen. The amount of methane produced in the enteric fermentation is positively correlated with the animal live weight, production and thus the quantity and quality of food intake in order to achieve the production concerned. In conditions of normal feed, methane is 15-30% of the total ruminal gas (a mixture of carbon dioxide, methane, hydrogen, nitrogen, etc.). The proportion of these gases varies according to feed nature and the fermentation intensity. The production of ruminal methane is not directly proportional to the consumed feed digestibility. Feed with high digestibility form less methane per unit of caloric energy consumed, than those with lower digestibility [2]. In other words, if the energy intake have higher value, the amount of methane from enteric fermentation will be higher.

On the other path, animal waste is a major source of anthropogenic greenhouse gases emissions, most of which is methane and nitrous oxide. Regarding methane, manure resulting from rearing of economic interest animal species contributes with 5-10% of the total emissions [4].

The natural degradation of animal waste during storage leads to the release of methane into the atmosphere, as a result of the anaerobic degradation of organic matter. The methan emissions from entheric fermentation and manure management is higher in cold season due to value of food ratio which contains more energy from feed used and more manure quantity kept on platform than in grazing seazon.

2 Problem Formulation

2.1 Livestock data

To estimate the methane emissions from entheric fermentation and manure management, the livestocks from the National Reasearch and Development Station for Buffaloes Breeding have been corrected with the "days of exploitation" factor that is specific to each subcategory of use within species. This correction factor refers to the number of days in a year, during which the animal is exploited and it is applied to youth categories. The correction of the livestock was made based on the following relation:

$$AAP = \text{Days of life} * \left(\frac{NAPA}{365}\right) \quad (1)$$

where:

AAP = average annual population;

NAPA = number of animals produced annually.

In these case, AAP =150 days.

2.2 Methods for calculation methan emissions from entheric fermentation

The methane emission was calculated based on equations of the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2006 [1]:

$$\text{Emissions} = EF_{(T)} * \frac{N_{(T)}}{10^6} \quad (2)$$

where:

Emissions = methane emissions from enteric fermentation, Gg CH_4/year;

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 / head/ year;

$N_{(T)}$ = the number of head of livestock species / category T in the country;

T = species or category of livestock.

$$\text{Total } CH_{4\ ENTERIC} = \sum_i E_i \quad (3)$$

where:

Total $CH_{4Enteric}$= total methane emissions from enteric fermentation, Gg CH_4/year;

E_i= the emissions for the i^{th} livestock categories and subcategories.

$$EF = \left[\frac{GE * \left(\frac{Ym}{100}\right) * 365}{55.65}\right] \quad (4)$$

where:

EF= emission factor, kg CH_4/head/year;

GE = gross energy intake, MJ/head/year;

Ym = methane conversion factor, per cent of gross energy in feed converted to methane;

55.65 (MJ/kg CH4) = the energy content of methane.

Specific values for GE, DE, Y_m and EF were developed.

When calculating the caloricity of the energy gross intake of each recipe or ration, the following equivalences were considered [6]:

1 g crude protein = 5.72 kcal;

1 g crude fat = 9.5 kcal;

1 g crude fibers = 4.79;

1 g SEN (non-nitrate extractable substances) = 4.17 kcal.

The GE calculation formula is [6]:

$$GE\ (kcal/kg) = 5.72 \cdot GP + 9.5 \cdot GB + 4.79 \cdot CelB + 4.17 \cdot SEN \quad (5)$$

where:

GE = gross energy intake;

GP = crude protein;

GB = crude fat;

CelB = crude fibers;

SEN = non-nitrate extractable substances

The rations were established according to the equation above, and the values of crude protein, crude fat, crude fibers and non-nitrate extractable substances were taken from the tables with the feed chemical composition [6]. The total value of the ration, expressed in Kcal was divided by 239, in order to obtain the equivalence in MJ (Mega Joules).

For each feed category, the values of crude protein, crude fat, crude fibers and non-nitrate extractable substances are included in a table [6]; these table values are multiplied by the caloricity specific to each nutrient (5.72 kcal for 1 g of crude protein, etc.), followed by the adding of the caloricities of each nutrients and the achievement of the respective forage caloricity.

This value is multiplied by the number of feed kilograms specified in the ration. Digestible energy (DE) is used to express the nutritional value of feed and rations, especially for herbivorous. For her establishment by calculation, similar to gross energy, mathematical equations can be used, however, in these case, must be considered the digestible content of the nutrients, which must be multiplied by the digestibility coefficients specific to each feed and species [6], then multiplied by the energy equivalents for digestible energy, energy that varies with the species, according to the table 1 [3]:

Table 1. The calculation of feed digestible energy

Specification	Digestible GP	Digestible GB	Digestible CelB	Digestible SEN
Symbol	X_1	X_2	X_3	X_4
Energy equivalent (**e**) for:				
Cattle	5.79	8.15	4.42	4.06
Swine	5.78	9.42	4.4	4.07
Poultry	5.72	9.5	4.23	4.23
Calculation equation	$X_1 \cdot e_1$	$X_2 \cdot e_2$	$X_3 \cdot e_3$	$X_4 \cdot e_4$

where **e** = the digestibility coefficient specific to each feed and animal species.

The percentage of digestible energy (DE%) of raw energy is calculated by applying the cross-multiplication rule, according to the following relation: DE % = (DE/GE) · 100.

The following equations were used to calculate the national values of Y_m (Cambra-Lopez equation, 2008):

$$Ym = -0.0038 \text{ x } (DE)^2 + 0.3501 \text{ x } DE - 0.811 \quad (6)$$

2.3 Methods for calculation methan emissions from manure management

For the calculation of methane emissions from animal waste management systems, equations of the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2006 [1] were used.

$$CH_{4\ MANURE} = \sum_{(T)} \frac{(EF_{(T)} * N_{(T)})}{10^6} \quad (7)$$

where:

$CH_{4Manure}$= CH4 emissions from manure management, for a defined population, $GgCH_4$/year;

$EF_{(T)}$= emission factor for the defined livestock population, kg CH_4 /head/year;

$N_{(T)}$= the number of head of livestock species/category T in the country*;*

T = species/category of livestock.

$$EF_{(T)} = (VS_{(T)} * 365) * \left[B_{O(T)} * 0.67kg/m3 * \sum_{S,k} \frac{MCF_{S,k}}{100} * MS_{(T,S,k)}\right] \quad (8)$$

where:

$EF_{(T)}$ = annual CH4 emission factor for livestock category T, kg CH_4 /animal/year;

$VS_{(T)}$ = daily volatile solid excreted for livestock category T, kg of dry matter /animal/day;

365 = basis for calculating annual VS production, days/year;

$B_{o(T)}$ = maximum methane producing capacity for manure produced by livestock category T, m^3CH_4/kg VS excreted;

0.67 = conversion factor of m3 CH_4 to kilograms CH_4;

$MCF_{(S,k)}$= methane conversion factors for each manure management system S by climate region k, %;

$MS_{(T,S,k)}$ = fraction of livestock category T's manure handled using manure management system S in climate region k.

$$VS = \left[GE * \left(1 - \frac{DE\%}{100}\right) + (UE * GE)\right] * \left[\left(\frac{1-ASH}{18.45}\right)\right] \quad (9)$$

where:

VS= volatile solid excretion per day on a dry-organic matter basis, kg VS /day;

GE = gross energy intake, MJ /day;

DE%= digestibility of the feed in percent (e.g. 60%);

(UE*GE) = urinary energy expressed as fraction of GE. Typically 0.04 GE can be considered urinary energy excretion by most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in the diet or for swine).

ASH = the ash content of manure calculated as a fraction of the dry matter feed intake (e.g., 0.08 for cattle).

18.45 = conversion factor for dietary GE per kg of dry matter (MJ kg-1). This value is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock. Thereafter, the result is converted into MJ (1 kcal = 239 MJ) to enter in the equation 9.

The manure management systems (MS) were solid storage and pasture/paddock, with different percentaje in analized period.

For other parameters necessary for calculating the methane emissions from manure management systems, i.e. B_0 and MCF, will use default values in order to meet the conditions for method 2 of IPCC 2006 implementation [1].

3 Problem Solution

3.1. Livestock data

The livestock data from the livestocks from the National Reasearch and Development Station for Buffaloes Breeding are presented in table 2 and table 3. The livestock number corrected by days of live (150 days) and used in estimate emissions from entheric fermentation and manure management is presented in table 4.

Table 2. Adult buffaloes herd size in 2014-2017 period

Head numbers/category	Reproduction male	Dairy female	Heifers	Buffaloes >18 months	
				Male	Female
2014	4	170	20	71	83
2015	4	173	12	84	42
2016	4	135	10	36	79
2017	2	124	7	29	64

Table 3. Youth buffaloes herd size in 2014-2017 period

Head numbers/ age category	0-6 months		6-12 months		12-18 months	
	Male	Female	Male	Female	Male	Female
2014	36	33	26	25	38	30
2015	21	22	23	22	21	12
2016	15	6	9	19	14	40
2017	40	21	4	4	12	15

Table 4. Herd size coreccted with “days of life” factor

Head numbers/category	2014	2015	2016	2017
Reproduction male	1,64	1,64	1,64	0,82
Heifers	42,33	22,19	36,58	29,18
Dairy female	69,86	71,10	55,48	50,96
Buffaloes male >18 months	29,18	34,52	14,79	11,92
Youth 12-18 months	27,95	13,56	22,19	11,10
Youth 6-12 months	20,96	18,49	11,51	3,29
Youth 0-6 months	28,36	17,67	8,63	25,07

The livestock size decrease in these period (2014-2017), due to economic reason and low power of subsidies (given for preservation only).

3.2.Methane emission from entheric fermentation

The methane emission from entheric fermentation for buffaloes livestock was calculated by ecuations 1 to 6, acoording with winter feed ratio for each category analyzed. For thus livestock, the winter ratio contains hey, corn silage, oat and concentrate mixture. Reproduction male are feeded in these winter period with 10 kg mountin hey, 12 kg corn silage, 1 kg oat and 3 kg concentrated mixture (corn, wheat bran, barley, soybean meal). The dairy buffaloes, heifers and female youth above

18 months received 8 kg of hey and 20 kg corn silage. The youth male more than 18 months age had a feed ratio with 6 kg hey, 10 kg corn silage, 1 kg oat, 2 kg concentrated mixture, youth more than 12 months age received the same recipe than male>18 months but without oat, young buffaloes between 6-12 months had 4 kg hey, 6 kg corn silage, 2 kg concentrated mixture and youth 0-6 months have hey ad libitum, 1.5 kg concentrated mixture, 4 kg corn silage and 4 liters of whole milk. Buffaloes milk production fits into the following parameters: the milk amount falls within 958-1455 kg/lactation limits, with a lactation duration of 252-285 days. The values used in methane emission from entheric fermentation are presented in table 5.

Table 5. The values used for calculation of methane emission from enteric fermentation

Specification	Average animal G (Kg)	GE (MJ/head/day)	DE (MJ/head/day)	DE%	Ym	EF (Kg/head/year)
Reproduction males	650	283.79	109,24	38,49	7.03	130.94
Dairy buffaloes	500	223.22	81,52	36,52	6.91	101.12
Heiffers + female>18 months	450	223.22	81,52	36,52	6.91	101.12
Males > 18 months	500	192.41	82,28	42,76	7.21	91.01
Youth 12-18 months	380	175.46	70,72	40,31	7.13	82.02
Youth 6-12 months	250	124.43	53,4	42,92	7.22	58.88
Youth 0-6 months	150	61.25	45,62	74,48	4.18	16.81

Table 6**.** The methane emission from enteric fermentation (Gg CH4/year)

Specification	CH_4 Emissions ($Gg*year^{-1}$)			
	2014	2015	2016	2017
Reproduction males	0,000215	0,000215	0,000215	0,000108
Dairy buffaloes	0,004280	0,002244	0,003698	0,002950
Heiffers + female>18 months	0,007064	0,007189	0,005610	0,005153
Males > 18 months	0,002655	0,003142	0,001346	0,001085
Youth 12-18 months	0,002292	0,001112	0,001820	0,000910
Youth 6-12 months	0,001234	0,001089	0,000678	0,000194
Youth 0-6 months	0,000477	0,000297	0,000145	0,000421
Total	0,0182	0,0153	0,0135	0,0108

The methane emissions from entheric fermentation decrease durind these period to all buffaloes category because the number of the animals decreased too (table 6). In 2017 was implemented a new food technology for farm conversion to organic farming and all forage and feed were certified as ecological. Therefore, the methane emission from entheric fermentation remains a herd size problem and quality of their food. The methane emissions from entheric fermentation were calculated at national level last time in 2012, in Romanian National Inventory [5], and the reported period was 1989-2011. For the mentioned period, methane emissions from enteric fermentation decreased by 65% at dairy buffaloes and those from other categories of buffaloes, with 69.7%.

Compared to the 2012 herd of buffalo in Romania fell by almost 40%, that means methane emissions from entheric fermentation decrease. Due herd dynamics is necessary to calculate methane emissions from enteric fermentation, especially at farms where can obtain comprehensive data on the structure of livestock, animal rations, system maintenance and manure management system.

3.3.Methane emission from manure management

The methane emission from manure management for buffaloes livestock was calculated by ecuations 7 , 8 and 9. The methane conversion factors (MCF) and the maximum methane production capacity of a given system (B_0) were taken from IPCC 2006, as follows for dairy/buffalo cows, table 10A-4; the MCF specific to the 2 existing management systems (MS) at Sercaia farm (solid storage, grazing/paddock) and a temperature of 14^0C, and for B_0, the default value corresponding to Eastern Europe was used (0.1). Default MCF for solid storage management system is 0.02 and for grazing/paddock management system is 0.01.

The percentajes of MS were established according to year climate and buffaloes category: for reproduction male and youth 0-6 months only solid management system (100%); for heifers, dairy buffaloes and female >18 months the management system is equaly divided (50% for grazing/paddock and 50% for solid storage); for male>18 months an youth 12-18 months, percentaje was 40% for grazing/paddock and 60% for solid storage and for youth 6-12 months, 60% for grazing/paddock and 40% for solid storage.

The values used for cestimate the methane emission from management system are presented in table 7, and calculated emissions are shown in table 8.

Table 7. The values used for calculation of methane emission manure management

Animal category	GE (MJ/day)	DE (Mj/day)	DE (%)	UE*GE	ASH (%)	VS (kg dry matter/head/ day	B_0 (m^3 CH_4/kg)
Reproduction males	283,79	109,24	38,49	0,047496	8	8,71	0,1
Dairy buffaloes	223,22	81,52	36,52	0,037359	8	7,07	0,1
Heiffers + female>18 months	223,22	81,52	36,52	0,037359	8	7,07	0,1
Males > 18 months	192,41	82,28	42,76	0,032203	8	5,49	0,1
Youth 12-18 months	175,46	70,72	40,31	0,029366	8	5,22	0,1
Youth 6-12 months	124,43	53,4	42,92	0,020825	8	3,54	0,1
Youth 0-6 months	61,25	45,62	74,48	0,010251	8	0,78	0,1

Table 8**.** The methane emission from manure management (Gg CH4/year)

Animal category	Methane emissions x 10^{-6} (Gg CH_4/year)			
	2014	2015	2016	2017
Reproduction males	6,999798158	6,999798158	6,999798158	3,499899
Dairy buffaloes	109,7413602	57,53430532	94,82505878	75,64696
Heiffers + female>18 months	181,1265168	184,3228671	143,8357633	132,1158
Males > 18 months	62,71457165	74,19752139	31,79893774	25,61581
Youth 12-18 months	57,12427859	27,72207638	45,36339771	22,6817
Youth 6-12 months	25,42288635	22,43195855	13,9576631	3,987904
Youth 0-6 months	10,81633986	6,740617594	3,291929523	9,562271
Total	453,946	379,949	340,073	273,110

Because the values of emissions were very small, we prefer to show without transformation in Gg (value/10^6). To obtain the true values of the emissions, the numbers must be devided by 10^6. The methane emissions from manure management decrease in the analized period due to herd size decrease too, and because the manure management system was improve by conversion to organic farming. Measures have been implemented to improve the solid manure storage at platform manure, so as to restrict the emission of greenhouse gases/methane (for liquid manure basin, covered with soil). Methane emissions from manure management at buffaloes were calculated in 2012 (last Romanian National Inventory) with EF (emission factor) 1.52 for dairy buffaloes and EF=0.78 for other buffaloes. In Romanian National Inventory were used 2 categories for these species: dairy buffaloes and other buffaloes (young, male, animal for slaughter) because are't enogh data to calculated for more categories. For these reason is very important to calculate, not estimate methane emission were data are real and available. In our paper we calculate those emissions or both enteric fermentation and manure management using available data and we could develop specific parameters.

4 Conclusion

Beside the number of herd decrease, another cause of emissions decrease is convertion to organic farming system, which develop manure management system environment friendly.

This paper it's a part of an ample project, according to national strategy for decrease the greenhouse gases emissions, which tacking into account farms evaluation for emissions status to elaborate local strategies for limited those emissions.

The technologies for mehane emissions mitigation will must improve at national level and manure platform design by organic farming can be used as a good practice model. At Sercaia buffaloes farm lived 25% from total buffalo herd in Romania.

We note that the decrease of herd size is not desirable because the Romanian Buffalo it is a species with vulnerable risk status (due to economic inefficiency).

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