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THE INFLUENCE OF THE STRUCTURE OF THE DAIRY COW RATION ON CO_2 EMISSIONS

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Abstract

The aim of the research undertaken was to highlight that emission reductions can be made available to producers in the steer farming sector and the adoption of current best practices and technologies for the rearing and health of animals, feed rations can be a tool that would help the dragline sector reduce greenhouse gases, and was realized on the Moara Domneasca farm on a flock of 27 dairy cows at different stages of Montbeliarde's lactation between November 2019 and September 2020. Daily milk production was establised per lactation cycle, within the lactation cycle of 3 distinct stages and the establishment of two seasons, summer and winter. The influence of feed strategies applied on milk production, manure chemical composition and CH_4 and CO_2 emissions were analyzed. The dairy production of the cows varied in the management of green feed rations between 21.97 L/head in the upward stage of lactation and 20.54 L/head in the plateau phase and in winter succulent rations, milk production was 21.29 L/head in the ascending phase, 19.93-20.27 L/head in the plateau phase and 18.56 L/head in the ascending phase. The methane emission from enteric fermentation has the highest values for the variants 6 and 4, which contains rots (sunflower and soybean), maize, and wheat bran and the lowest emissions are recorded for the ration variant 1 which is rich in green fodder.

Key words: *emissions, enteric fermentation, manure, milk production.*

INTRODUCTION

Naturally occurring methane is generated by anaerobic fermentation, where bacteria break down organic matter producing hydrogen (H_2), carbon dioxide (CO_2) and methane (CH_4). This process naturally occurs in the digestive system of domesticated and wild ruminants, natural wetlands, and rice patties. In ruminants, methane is produced mostly by enteric fermentation where microbes decompose and ferment plant materials, such as celluloses, fiber, starches, and sugars, in their digestive tract or rumen. Enteric methane is one by-product of this digestive process and is expelled by the animal through burping. While other by-products (acetate, propionate and butyrate) are absorbed by the animal and used as energy precursors to produce milk, meat and wool. Enteric methane production is directly related to the level of intake, the type and quality of feed, the amount of energy consumed, animal size, growth rate, level of production, and environmental temperature. Between 2 to 12% of a ruminant's energy intake is typically lost through the enteric fermentation process. (www.fao.org).

Under normal feed conditions, methane accounts for 15-30% of the total ruminal gas (mixture of carbon dioxide, methane, hydrogen nitrogen, etc.). The proportion of these gases is variable according to the nature of the feed and the intensity of the fermentation. The production of light methane is not directly proportional to the digestibility of the feed consumed. Highly digestible feed forms less methane per unit of calorific energy consumed than those with lower digestibility (Blaxter & Clapperton, 2007).

MATERIALS AND METHODS

The research was carried out on the Moara Domneasca teaching farm of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, on a flock of 27 dairy cows at different stages of Montbeliarde's lactation between November 2019 and September 2020.

The dairy cows are kept in free stabulation in a shelter with modern facilities. During the summer or when the weather is favorable, the animals are taken into the enclosure. For the rational feeding of this category of animal, knowledge should be given of the energy and nutrient requirements so as to formulate balanced rations, but also to reduce polluting emissions from farms.

The dairy cows are kept in free stabulation in a shelter with modern facilities. During the summer or when the weather is favorable, the animals are taken into the enclosure. For the formulation, optimization and verification of feed rations for dairy cows account has been taken of their average body weight (650 kg), daily milk production per lactation cycle, the establishment within the lactation cycle of 3 distinct stages and the establishment of two seasons specific to our country, namely summer and winter.

The bottom-up phase of the lactation cycle runs from the birth to the maximum daily yield, which is common in the first two months of lactation. The increase in milk at this stage is due to the multiplication of the alveolar tissue in the ug and the establishment of a new hormonal balance characteristic of lactation. The ingestion capacity is at a level of 85-90% of the maximum value. Specific problems are caused by reduced ingestion capacity, requiring the use of high-quality high energy and protein feed (Maciuc, 2015).

The plateau phase is characterized by the relatively constant maintenance of milk production and lasts 5-7 weeks. During the plateau phase, the hormonal balance is maintained at a favorable level to the intense synthesis of milk, characterized by a milk production level of about 96 to 98% of the maximum daily yield, while the ingestion capacity is about 90 to 95% of the maximum value. At this stage, the mobilization of body reserves is insignificant, which implies sharp increases in the energy inputs of the ration at the same level of milk production in week 3 of lactation.

Specific problems are caused by reduced ingestion capacity compared to requirements, requiring the use of high energy and protein high quality feed. From a practical point of view, it is the most complex stage and it has to be given special attention (Popescu et al., 2005). Failure to ensure nutrient requirements in the ration over a relatively short period of a few days leads to large reductions in milk production over a long period of time.

The downward phase of the lactation curve means the drop in milk production, initially slow and then growing more pronounced, until weaning. The normal rate of drop in milk production is considered to be 10% per month for pregnant cows and 4-6% per month for non-increase in the residual fraction of the milk, the involution of the glandular tissue of the udder and the state of gestation (Miresan et al., 2003).

In the first part of this phase, the feeding of cows is relatively easy to ensure due to the high ingestion capacity and the continuous decline in milk production. The nutrient to be administered may also be of medium quality, as the nutrient intake can be satisfied by higher food consumption. At the end of lactation there is a process of total recovery of body reserves, which implies greater increases in the energy and protein inputs of the ration intended for this purpose. At this stage, there are no specific problems in the preparation of the ration. From a practical point of view, it is the most manageable stage due to the high ingestion capacity compared to the level of milk production. The use of the test chemical in the food is recommended. Starting with the 40^{th} lactation week, attention will also be paid to the intake of nutrients for gestation (Pop et al., 2006).

Feed and by-products of plant origin have been introduced in the construction and optimization of rations in order to highlight the possibility of developing farms where very good results are achieved only by using local feed resources wisely.

A particularly important role during the summer period is the green mass, which can cover 60-80% of the volume feed content of the ration and constitutes a food rich in the nutrients needed for milk production.

The feed ration is relatively balanced, except for the increased protein and mineral feed in the event of the administration of higher amounts of green fodder during the summer period.If the green mass quality is very good, the quantities of concentrates in the ration may be reduced by 5-10%.

During the winter period the green table is replaced by succulent soiled fodder without significantly altering the intake of concentrates in the ration.

RESULTS AND DISCUSSIONS

The influence of feed strategies applied on milk production.

The evaluation of the productive performance (Table 1) was carried out with a milk quantity and quality monitoring system, which enabled the identification of the animals in the milking room, the monitoring of breeding and ruminants (DairyPlan C21).

The dairy production of the cows varied in the management of green feed rations between 21.97 L/head in the upward stage of lactation and 20.54 L/head in the plateau phase. In the case of winter succulent rations, milk production was 21.29 L/head in the ascending phase, 19.93-20.27 L/head in the plateau phase and 18.56 L/head in the ascending phase. Romania's entry into the EU has imposed the common market milk quality standards.

In terms of milk fat content, it varied between 3.62-3.78% in the upward phase of the lactating curve, 3.77-3.91% in the plateau phase (3.88-3.91% in winter rations and 3.77% in summer ration) and 3.54% in the downward phase of lactation.

Milk protein content varied between 3.17-3.23% in the upward phase of lactation, 3.27-3.39% (3.30% in summer ration) in the plateau phase and 3.08% in the descending phase. The average acidity of the milk was 6.50 and all milk samples were in line with the recommendations on the maximum limit of the total plate count (10 x 10^4 NTG/ml), the average being 8.68 x 10^4 NTG/ml.

The influence of feed strategies applied on manure chemical composition

In order to determine the influence of the nutrient variants tested on the chemical composition of the manure (Table 2), three samples per ration variant have been analyzed.

It is noted that when using green feed rations the proportion of water in the manure determined by drying in the oven at 105°C varied between 76.36 to 77.12%, while for the other rations the water content was 70.11 to 75.07%. The ash content determined by ashing at a temperature of 50°C varied between 8.01% on the green fodder variant in the ration and 10.51% on the variant of the ration administered in the descending phase of the lactation curve.

The nitrogen content determined by the Kjeldahl method was lower for variations in green fodder ration in the structure (0.45-0.55%) and for the other variants the nitrogen values were between 0.60-0.87%.

The influence of feed strategies applied on shelter's methan emissions

Methane emission from enteric fermentation will be estimated using IPCC method 2. The calculation of the methane emission shall be carried out on the basis of equations 10.19, 10.20, 10.21 from *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2006:*

$$Emisions = EF_{(T)} * \frac{N_{(T)}}{10^6}$$

where:

Emisions = methane emission from enteric fermentation, kg CH_4/year;

$EF_{(T)}$ = emissions factor for dairy cow, kg CH_4/head/year

$N_{(T)}$ = the herd of animals of the species/ category T

T = category of animal

$$\text{Total } CH_{4\ \text{ENTERIC}} = \sum_i E_i$$

where:

Total $CH_{4\text{Enteric}}$ = total methane emissions from enteric fermentation, kg CH_4/year

E_i = emissions from animal categories

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

where:

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

EB = gross energy, MJ /head/year;

Ym = methane conversion factor, which is the percentage of raw energy in the administered feed converted to methane

55.65 (MJ/kg CH_4) = energy content of CH_4

Gross energy (GE)

The following equivalences (Stoica, 2001) have been used to calculate the calority of the gross energy of each ration: 1 g crude protein (PB) = 5.72 kcal; 1 g raw fat (GB) = 9.5 kcal; 1 g crude fiber (CelB) = 4.79 kcal; 1 g SEN (non-nitrogenous extractive substances) = 4.17 kcal. The formula for calculating GE is:

GE (kcal/kg) = 5.72·PB + 9.5·GB + 4.79·CelB + 4.17·SEN

where:
GE = gross energy intake (kcal/kg);
PB = crude protein (%);
GB = raw fat (%);
CelB = crude fiber (%);
SEN = non-nitrogenous extractive substances (%).

The rations have been formulated earlier according to the animal feeding schedule and the values of crude protein, crude fat, crude cellulose and non-nitrogenous extractable substances (Table 2) have been obtained from analyzes carried out in its own laboratory, i.e. by calculation (SEN).

The values of gross energy (MJ/kg) for feed constituents of the rations and the total energy value of the rations delivered to the dairy cows expressed in GE are given in Table 3.

Digestible energy (DE) is used to express the nutritional value of feeding stuffs and rations, especially for grazing animals. Mathematical equations have been used to establish it by calculation, as in the case of raw energy, but in this case the digestibility content of nutrients is taken into account, taking into account the digestibility factors specific to each feed and species, namely taurine (Dragotoiu et al., 2017), then multiplied by the energy equivalents for digestible energy, which are different by species. The percentage of digestible energy (ED%) in the raw energy is calculated by applying the three simple rule according to the relationship: ED % = (ED/EB)·x 100.

The following equation shall be used to calculate the values of Ym: Ym = -0.0038 x (ED%)2 + 0.3501 x ED% – 0.811 (Cambra-Lopez equation, 2008).

The equation for calculating the enthic CO_2 emission shall be (Users' guide for estimating carbon dioxide, methane, and nitrous oxide emissions from agriculture using the State inventory tool, 2019):

CO_2 enteric (kg/year) = (Emission CH_4 x 25 GWP) / 1,000,000,000

The values obtained for the methane emission from enteric fermentation and the CO_2 equivalent are given in Table 4, Figures 1 and 2, respectively.

Table 1. The quantitative, qualitative and microbiological parameters of milk production

Exp. variant	Lactation phase	Milk production (l)	Milk protein (%)	Milk fat (%)	pH	Total number of germs (NTG/ml x 10^4)
V1	The upward phase	21.97±0.55	3.17±0.04	3.62±0.37	6.47±0.04	8.8±0.16
V2	The upward phase	21.29±1.26	3.23±0.21	3.78±0.52	6.50±0.02	8.5±0.09
V3	Plateau phase	20.27±0.84	3.27±0.07	3.88±0.42	6.48±0.05	8.7±0.08
V4	Plateau phase	19.93±1.26	3.39±0.07	3.91±0.73	6.53±0.04	8.6±0.08
V5	Plateau phase	20.54±0.84	3.30±0.07	3.77±0.42	6.48±0.05	8.9±0.12
V6	Down phase	18.56±0.88	3.08±0.10	3.54±0.41	6.52±0.03	8.6±0.11

Table 2. Chemical composition of manure obtained in experimental period

Feed variant	Water (%)	Ash (%)	N (%)
V1	77.12	8.01	0.45
V2	75.07	8.24	0.60
V3	75.25	8.52	0.75
V4	73.42	9.56	0.81
V5	76.36	8.35	0.55
V6	70.11	10.51	0.87

Table 3. Value of gross energy (GE) of the component feeding stuffs and rations delivered to cows during the experimental period

Feed	GE (Mj/kg)	DE (Mj/kg)	Total ration GE (Mj)	Total ration DE (Mj)	Ration variant
Lucerne hay	16.25	8.26	370.68	269.17	V1
Hay clover	15.69	7.86	333.90	216.61	V2
Fodder beet	2.37	1.87	314.81	205.16	V3
Beer Brewery	3.78	2.35	322.16	205.34	V4
Corn soiled	4.78	2.78	329.51	218.68	V5
Spring bowl	3.36	2.17	315.52	198.20	V6
Clover	3.55	2.34			
Maize	16.57	14.20			
Barley	16.14	13.05			
Sunflower rot	17.88	12.56			
Soybean rot	17.87	16.05			
Wheat bran	16.57	10.69			

Table 4. CH_4 emission from enteric fermentation

Experimental variant	GE (Mj/zi)	DE (Mj/zi)	DE(%)	Ym	EF	Head number	CH_4 emissions (kg/year)	CO_2 x 10^{-9} Emissions (t/year)
1	370.68	269.17	72.615	4.574	111.21	10	1112	27.803
2	333.9	216.61	64.873	5.909	129.40	10	1294	32.350
3	314.81	205.16	65.169	5.866	121.12	12	1453	36.336
4	322.16	205.34	63.739	6.066	128.17	12	1538	38.452
5	329.51	218.68	66.365	5.687	122.91	10	1229	30.727
6	315.52	198.20	62.817	6.187	128.03	12	1536	38.408
							8163	204.077

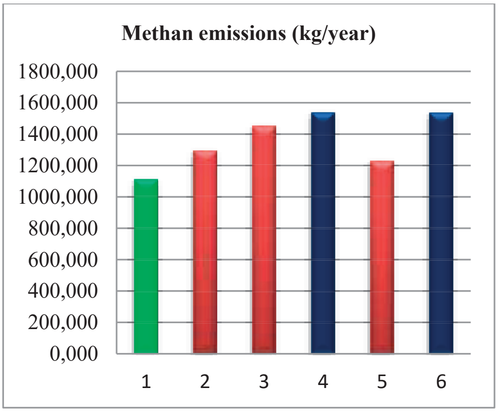

Figure 1. Methane emissions from enteric fermentation in the 6 variants

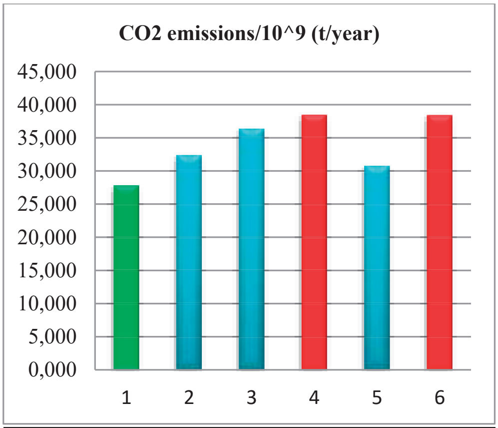

Figure 2. CO_2 equivalent emissions in the 6 variants

From the analysis of the data presented in Table 4, it can be observed that the methane emission from enteric fermentation has the highest values for the variants 6 and 4, the values being close (1538 kg/year and 1536 kg/year respectively) and the lowest emissions are recorded for the ration variant 1 with green fodder. In variant 2 with a reduced proportion of fibrous fodder a value of 1294 kg/year has been obtained.

The trend of equivalent CO_2 emissions also closely follows the line of CH_4 emissions from enteric fermentation and is directly dependant.

Sun & Colabas (2012) reported substantially lower CH_4 values in sheep fed with green fodder and rape (*Brassica napus*) respectively.

Dewhurst (2012) provided an overview of the various aspects of feeding lactating cows with contaminated feeding stuffs (corn, pulses).On the basis of these comments, it concluded that the decrease in fiber content and the faster passage of pulses through the digestive tract of the cows decrease the production of CH_4.

CONCLUSIONS

Together with the aspects of milk production, a number of measures are needed on the use of feed and feeding techniques that take into account the digestibility, quality and composition of the feed ration, which can reduce the methane generated during digestion.

The methane emission from enteric fermentation has the highest values for the variants 6 and 4, which contains rots (sunflower and soybean), maize, and wheat bran and the lowest emissions are recorded for the ration variant 1 which is rich in green fodder. In variant 2 with a reduced proportion of fibrous fodder a value of 1294 kg/year has been obtained. It is a middle value of CH_4 emissions from enteric fermentation.

Emission reductions can be made available to producers in the steer farming sector and the adoption of current best practices and technologies for the rearing and health of animals, feed rations can be a tool that would help the dragline sector reduce greenhouse gases.

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REFERENCES

Blaxter, K.L, & Clapperton, J.L. (2007). Prediction of the mount of methane produced by ruminants. *British Journal on Nutrition*, 19, 511–522.

Dewhurst, R.J. (2012). Milk production from silage: Comparison of grass, legume and maize silages and their mixtures. *Proc. XVI Int. Silage Conf. MTT Agrifood Research Finland*, University of Helsinki, Hameenlinna, Finland, 134–135.

Maciuc, V., Leonte, C., & Radu-Rusu, R.M. (2015). Handbook of good practices in cattle breeding. Iași, RO: Alfa Publishing House.

Mireșan, V., Ersek, A., & Răducu, C. (2003). Physiology of domestic animals. Cluj-Napoca, RO: Risoprint Publishing House.

Pop, I.M., Halga, P., & Avarvarei, T. (2006). Animal nutrition, I-III, Iași, RO: Tipo Moldova Publishing House.

Popescu, Al., Drăgotoiu, D., Marin, M., Pogurschi, E., & Dobrică, G. (2005). Theoretical basis for optimizing rations for lactating cows. București, RO: Amanda Edit Publishing House.

Stoica, I., & Stoica, L. (2001). Basics of animal nutrition. București, RO: Coral Sanivet Publishing House.

Sun, X.Z., Hoskin, S.O., Muetzel, S., Molano, G., & Clark, H. (2011). Effect of chicory (*Cichorium intybus*)and perennial ryegrass (*Lolium perenne*) on methane emissions *in vitro* and from sheep. *Anim. Feed Sci. Technol.*, 166–167, 391–397.

www.fao.org

IPCC Guidelines for National Greenhouse Gas Inventories, vol. 4, chapter 10, 2006.

Users's guide for estimating carbon dioxide, methane, and nitrous oxide emissions from agriculture using the State Inventory Tool, 2019.