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Methods of Calculating the Emissions of Greenhouse Gases from Cattle and Buffalo Housing in Bulgaria

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Abstract. A methodology for measuring greenhouse gases from mixed excrements from cattle and buffaloes was developed. A universal formula was used to calculate them. The authors gave an example of a calculation. They reflected the typical excrement distribution based on the most used animal breeding technologies and the net energy in feed and excrements in Bulgaria.

Key words: cattle farming, greenhouse gases.

Introduction

Over the years, the European legislation requires more decisive measures to limit pollution in the continent caused by waste products from both air and liquid emissions. In this respect, a number of emission limit values have been established and implemented for all Member States - Environmental policy review, 1996/62; Directive 2001/80/EC (EC, 2001); Directive 2009/29/EC (EC, 2009).

All levels of the practical training of future environmental professionals should include the implementation of strategies for objectively reporting any problems. In this way, the learners will acquire basic skills that will form the basis for good practices of limiting emissions and maintaining the ecological balance in nature (Vakleva, 2014; 2017).

Cattle farming and buffalo farming are considered some of the major greenhouse gas pollutants (FAO, 2017). At the same time, these livestock sub-sectors are the most developed in Bulgaria. This is why measuring the gas emissions in them accurately is the basis for finding more accurate technological solutions for limiting them. Another important point is that accurate emission calculations are the basis for a fairer allocation of greenhouse gas emission allowances.

The development and implementation of up-to-date methodologies for calculating of livestock emissions has been the subject of previous publications of ours. These works observed other livestock sub-sectors (Penkov *et al.*, 2012; 2014). Similar principles of calculation are shown in our previous publications for sheep and goats (Penkov *et al.*, 2019), but the technique of calculation is different due to the different technologies and terms of cattle housing.

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The aim of the publication is to offer an objective methodology for calculating the fertilizer emissions from cattle/buffalo breeding in Bulgaria, based on "volatile solid excretion".

Material and Methods

For the general separation of greenhouse gases from all excrements we use the adopted by us formula of the MEW which converts all emitted gases (base – methane) into a conditional „pollutant" (IPCC, 2001):

VS = GE*(1 kg-dm/18.45 MJ)*
(1–DE/100)*(1 – ASH/100)
(original formula for 24 hours per 1 kg DM)

VS=(DMI*18.45)*(1-DEI/100)*(1-%ASH/100)
(adopted formula on base total DM intake and total DE intake per 1 animal/24 hours)

where: VS- volatile solid excretion per 24 hours on a dry matter weight basis – kg DM (dry matter) per 24 h; DMI- dry matter intake – kg/animal/24h; 18.45 – mean gross energy content in 1 kg dry matter of the fodders – MJ; DEI – digestible energy intake from 1 animal/24h (as coefficient, or percentage) from the gross energy intake; %ASH – percentage of ash in the DM of the excrements

For greater clarity we are going to demonstrate our reasoning with the following example: define the volatile solid excretion for 1 year (365 days) in a farm with 100 dairy cows, average annual fertility of the cow herd – 90% (90 calves born alive per 100 cows). All heifers stay in the farm until they become 18 months old (2 months into their first pregnancy). All bull calves are sold for fattening when they are 120 days old. The example is chosen as typical for technological conditions of cattle in Bulgaria, but the numbers can be changed to any specific technologies.

The average data for emitted mixed excrements (faeces and urine) as well as for the dry matter and ash content in them is taken from Petrov *et al.* (1983). The data for the content of percentage/coefficient of the energy exchange as well as for the dry matter intake in each animal category is calculated on the basis of the new energy system for assessment of fodders in Bulgaria (Todorov, 1997). Because of the similarity in the utilization of nutrients in cattle and buffalos, we are assumed that the principle of the calculation will be the same in both species.

Results

Defining the quantity of the manure waste from the animals in the farm and the chemical composition of the faeces and the urine:

According to the aforementioned source for a 24-hour period 25 kg of faeces and 15 kg of urine are emitted from a cow (live weight of 500-550 kg). 12.5 kg of faeces and 7.5 kg of urine are emitted from a calf (live weight of 250 kg).

Although the data for the dry matter content in the faeces may vary greatly depending on the fodder intake, Petrov *et al.* (1983) provide us with general values which are 16.66% for cows (variations from 13.77% to 18.75%) and 18.86% for calves with a live weight of 250 kg on average with variations from 16.46% to 22.16%. Bearing in mind that suckling calves are freely given concentrate as well as hay from the first week, in the calculations we assume that at the end of the first month the dry matter in their faeces will not be any different from the aforementioned data. The ash content in the cow faeces are 1.1% total in fresh faeces (Petrov *et al.*, 1983) or 6.6% when recalculated on the basis of dry matter (DM). For calves the data is 1.3% and 6.97% respectively.

For the urine the data cited by the same source is respectively: For cows: DM – 4.18% (variations from 2.91% to 6.98%); calves (250 kg) – 4.68% (variations from 3.63% to 5.61%). The average ash content in the cow urine is 0.103% (2.46% on the basis of dry matter), and for calves – 1.74% (37,2% on the basis of dry matter). We believe that the percentage values do not vary substantially depending on the age and the physiological condition of the different cattle categories.

Defining the quantity of the dry matter intake of the animals, according to the formulas given by TODOROV (1997).

For dairy cows with a live weight of 500 kg and an average annual milk yield of 7300 kg (average milk yield throughout the year of 20 кg), the daily consumption of dry matter is the following: DMI = $(0.093*500^{0.75})$ + 0.3 * 20 = 15.83 kg, where $500^{0.75}$ – metabolizable mass of the animal.

For heifers with a live weight of 250 kg and an average daily growth of 0,75 kg, the daily consumption of dry matter (in kg per 24 hours) is: DMI = 6/ {(25/250) + (0.34*0.75) + 0.57} = 6.49 kg. Since this is the average live weight between the birth of the calf and its transformation into a pregnant heifer – second month, we assume that the average consumption per day from the birth to the 548 day after the birth will be 6.49 kg.

For bull calves with a live weight of 250 kg and an average daily growth of 1.0 kg, the daily consumption of dry matter (in kg per 24 hours): DMI = 6.1/{(25/250) + (0.34*1.0) + 0.57} = 6.04 kg, but the bull calves are sold at the end of the third month on the basis of a live weight of 125 kg, thus the average consumption of dry matter before the sale will be 3.02 kg. From the birth the bull calves begin their consumption from 0 kg, so the average consumption of dry matter per every 24 hours at the farm will be 1.51 kg.

Defining the correlation expressed in percentage between the gross energy intake and the nett energy intake. We offer replacement of metabolizable energy with nett energy, because it is - an objective indicator of the distribution of energy in the body (TODOROV, 1997).

For dairy cows with a live weight of 500 kg and a daily milk yield of 20 kg – the daily nett energy intake is 87 MJ, and the gross energy intake is – 15.83*18.45 = 292.06 MJ, therefore DEI = 87/292.06 = 0.298.

For heifers for breeding purposes and young cows: the daily intake of nett energy is 34.2 MJ, and of gross energy – 6.49*18.45 = 119.74 MJ, therefore DEI = 87/292.06 = 0.298.

For bull calves for fattening with a final weight of 125 кg (bred for additional fattening in other farms): the daily intake of nett energy is 19.2 MJ, and of gross energy – 1.51*18.45 = 29 MJ, therefore DEI = 18.45/29 = 0.636.

Calculating the greenhouse emissions from the different cattle categories in the farm.

Recalculation of the average percentage of ashes in mixed excrements of dairy cows:

- Faeces: 25 kg * 16.66% = 4.165 kg DM * 6.6% = 0.275;
- Urine: 15 kg*4.18% = 0.627 kg * 2.46% = 0.016 or the total percentage of ashes in the excrements is 0.291% in the DM.

Released emissions from 100 dairy cows, per 365 days: VS = {(15.83*18.45)*(1-0.298/100)*(1-0.291/100)* 100* 365} = 11294299 kg dry matter (11,294.30 tons).

Recalculation of the average percentage of ashes in mixed excrements of calves (250 kg LW):

Faeces: 12.5 * 18.86% = 2.3575 kg DM * 6.97% = 0.164.

Urine: 7.5* 4.68% = 0.351 kg DM * 37.2% = 0.131 or the total percentage of ashes in the excrements is 0.297% in the DM.

Released emissions from heifers for breeding purposes and young cows until the age of 18 months and recalculation for 1 year.

For 1 year with 90 calves born, 45 will be female and 45 will be male, therefore: VS = {(6.49*18.45)*(1- 0.298/100)*(1-0.297/100)* 45* 365} = 1995053 kg dry matter (1995.05 tons).

Released emissions from bull calves during their time at the farm (approximately 120 days) – this will also be for the whole year: VS = {(1.51*18.45)*(1- 0.636/100)*(1-0.297/100)* 45* 120} = 149041 kg dry matter (149.04 tons).

The total quantity of volatile solid excretion per the whole year on a dry matter weight basis from the farm activity under the stipulated conditions will be 13438.39 tons.

Discussion

The proposed calculations are rather broad, but they represent to the greatest level the correlation between the fodder intake (forage: concentrate) as well as their average energy transformation in the body of the ruminant animals (correlation gross energy: nett energy). All formulas included in the calculations are revised and adapted by us for the needs of the current examination. Apart from the data used from the aforementioned sources, we conformed the basic examinations of the energy transformation from gross energy content of the fodders to its specific transformation to metabolizable energy separately in the organism of full-grown dairy cows and young grooving calves (INRA, 1987). The daily consumption of dry matter of the different cattle categories in defined on the official basis in Bulgaria (TODOROV, 1997).

The methods which are proposed are compatible with the modern ideas of defining the emissions from manure waste from cattle and can be used for defining the quotas for each European Union member state (on the basis of the statistical data about the number of cattle/buffalos in the different categories) and also have at least two advantages:

1. The methods can be used for recording the emissions in investment programs for setting up and modernizing cattle breeding farms – mainly in the dairy cattle breeding, but they can be used as a basis for creating methods for the field beef (for meat production).

2. The methodology as a whole (or parts of it) can solve practical problems in ecology education in the specialised agricultural secondary schools and universities and also in the educational establishments where ecology is taught.

We believe that the last 2 activities in particular will fill a void and bring the Bulgarian and European specialised education near the level of the modern ecological requirements.

Last, but not least, there is the fact that the aforementioned calculations can be digitalised (in Excel) and developed into an automated software programme for calculating emissions.

It is proper to mention that apart from the manure waste the ruminant animals also release a significant amount of fermentation gases (mainly methane) which should be added. There gases are described in the literature according to their quantity and age and they are not the subject of this article.

Recalculation based on 365 days instead of 24 hours is more acceptable because emission allowances are determined for 1 year.

Conclusions

The proposed methodology is compatible with the used principles of greenhouse emission's recording. It could be for developing practical cases for the people who study domestic animal's ecology/breeding and for all professionally concerned parties.

The basic calculations described in this article can easily be digitalised and developed into a software package for automatic calculation of greenhouse emissions.

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