ESTIMATION OF GHG EMISSIONS FROM POINT OF VIEW OF LITTER MANURE MANAGEMENT IN LITHUANIAN AGRICULTURE

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Abstract. The article analyses the emissions of carbon dioxide (CO2), methane (CH4) and dinitrogen monoxide (N2O) in the litter manure management and composting technologies. The impact of agricultural activity on climate change has been observed in the recent years. This was found to be related to structural changes in the holding of farm animals. From 2011 to 2018, the number of farms holding up to 50 cattle decreased by 41 %, but by 17 % increased the number of farms holding 50 and more cattle in Lithuania agriculture. Calculations have shown that greenhouse gas emission in dense manure management systems is about 862.06 kt CO2 e, and that emissions of soils and pastures make up about 2282 kt CO2 e in Lithuania. According to the EU legal requirements, manure is considered to be waste the livestock owner has to account for and eliminate using as crop fertilizer and not polluting the environment. One of this biodegradable waste management ways is granulation, as processing of recyclable materials into organic products. Manure compost granulation can increase bulk density, improve storability, reduce transportation costs, and make these materials easier to handle using existing handling and storage equipment, also there can be GHG emission reduction effect achieved in manure compost granulation technology. Experimental studies have shown that the maximum CO2 emissions of ground cattle manure compost and its granules are 9 times lower, and emissions from a surface area up to 28 times lower than CO2 emissions from fresh cattle manure.

Keywords: GHG emissions, methane, dinitrogen monoxide, carbon dioxide, compost, granules.

Introduction

The main greenhouse gases (GHGs) in manure management systems are methane (CH_4), dinitrogen monoxide (N_2O) and carbon dioxide (CO_2). Agriculture is the second most significant source and accounted for 21.5 % of the total emissions [1; 2].

The agricultural sector is the second contributor to the worldwide emissions of greenhouse gases (GHG), as it is responsible for 13.5 % of GHG emissions. Obtained results by scientists showed that between 1990 and 2016 most of the EU-27 countries witnessed a significant reduction of GHG emissions from the agricultural sector [3]. Livestock farming has an impact on global warming with about 10 % of total GHG emissions from the EU-27. The dairy sector had the highest GHG emission in the EU-27, with annual emission of 195 Tg CO_2-eq. Enteric fermentation was the main source of GHG emissions in the European livestock sector (36 %) followed by N_2O soil emissions (28 %) based on 2003-2005 data [4].

From 1990 to 2010, GHG emissions in the Lithuanian agriculture decreased 2.3 times, while in 2010 they stabilised and made 21.4 %. However, in 2016, GHG emissions increased to 22.9 %. Increase of emissions is related to increase in the number of livestock in certain categories and the increasing demand for quality food [2]. The country's growing economy is inevitably linked to higher CO_2 emissions. In the period 2021-2030, the EU predicts a reduction of GHG emissions up to 40 %. Lithuania has committed to reduce GHG emissions in agriculture by about 10-12 %.

One of the most important challenges for livestock farming is the use of safe and environmentally friendly production methods. Particular attention must be paid to clean and environmentally friendly technologies that allow more efficient use of resources, reduction of potential pollution, mitigation and adaptation to climate change [5]. The most important sources of concentrated pollution are livestock farms. As livestock farms grow, large quantities of livestock and manure are concentrated in agricultural areas.

The aim of the work is to estimate GHG emissions according to statistical changes in livestock numbers and manure production, and advanced litter manure management technologies.

Materials and methods

In 2016, the Lithuanian Energy Institute prepared Methodological guidelines for GHG forecast [1]. Tier1 and Tier2 methodologies should be used to calculate GHG emissions [6]. According to the Tier1 method, it is sufficient to know the number of livestock by category and emission factor. For

DOI:10.22616/ERDev.2020.19.TF070

example, methane CH_4 emissions (Gg CH_4 yr^{-1}) from manure management, for a defined population can be calculated using this simplified equation.

$$CH_4^{emision} = \sum_{(T)} (EF_{(T)}{}^{populiation_{(T)}}), \quad (1)$$

where $EF_{(T)}$ – emission factor for the defined livestock population, kg CH_4 $animal^{-1}$ yr^{-1}
T – number of head in the population of livestock category, units.

The Tier2 method is more detailed, evaluating manure management systems, manure composition, gas conversion rates and other factors. Simplified methods for calculating gas emissions can be used to determine general manure emissions, their changes and trends [1]. Emission of direct N_2O emissions can be calculated using this simplified equation [6].

$$N_2O^{emmision} = \sum_{(T)} (N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)}) \cdot EF_{3(S)}, \quad (2)$$

where $N_{(T)}$ – number of head in the population of livestock category, units;
$Nex_{(T)}$ – annual average N excretion per head for livestock category, kg N $animal^{-1} \cdot yr^{-1}$;
$MS_{(T,S)}$ – fraction of total annual N excretion for each livestock category T;
$EF_{3(S)}$ – emission factor for direct N_2O emissions, kg $N_2O\text{-}N \cdot (kg\ N)^{-1}$;
S – manure management system;
T – livestock category, units.

Enterprise "Agrolinija", which owns 378 beef cattle and 186 suckler cows, was chosen as the object for the experimental research. During the barn period, all animals are housed in three barns on deep litter (straw). About 6 thousand m^3 of littered manure are accumulated per year. During the barn period, in two stables part of the manure is put to compost heaps, and the rest is dumped into the manure storage. The enterprise declares about 1000 ha of cultivated soil, according to the number of livestock, manure is used for fertilization of about 200 ha of soil. The amount of livestock manure applied to the soil each year, including livestock manure, may not exceed 170 kg nitrogen per hectare and 25 kg phosphorus per hectare and other requirements [7]. The technological scheme of litter manure composting, granulating and spreading in soil is presented in Fig. 1.

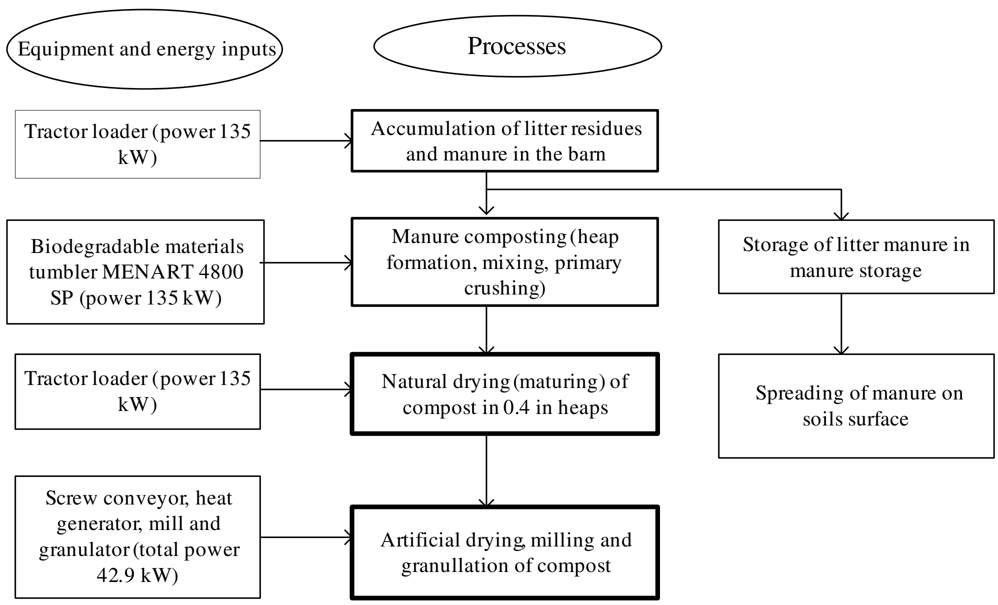

Fig. 1. **Technologies for composting, granulation and surface spreading of cattle manure**

Compost production begins with taking out the cattle from the farm for the summer season to pasture. Stacks of composted manure are mixed several times. It is very important to choose the right amount of manure mixes, as this determines the quality of the raw material used for production of milled compost and granular fertilizers. During the next stage, the compost is transported to natural drying (maturing) premises. The compost maturation process takes place until the moisture content of the compost does not exceed 30 %. At the beginning, milled cattle manure compost is produced, and later it is used for production of granulated manure compost fertilizers.

In laboratory conditions a thermal camera of 1.05 m^3 capacity was used to estimate emissions of fresh manure of livestock cattle, composting, maturation and granulation products, which maintained a constant temperature with the help of the thermostat. Concentration of carbon dioxide (CO_2) was measured with a portable CO_2, temperature, and humidity meter AZ 77535 with a CO_2 measurement range of 0 to 9999 ppm, with an error of ± 30 ppm; temperature measurement range -10 to + 60 ºC, tolerance ±0.6 ºC. Based on the measured maximum CO_2 concentrations, CO_2 emissions were calculated using modified equation 3 in the relevant manure management technological operations [8]:

$$F = VMp(C_1 - C_0)R^{-1}(T + 273)^{-1} A^{-1} h \, , \tag{3}$$

where F – CO_2 emission rate, $mg \cdot m^{-2} \cdot h^{-1}$;
V – camera volume (1.05 m^3);
M – mole mass of gas (44.01 $g \cdot mol^{-1}$);
p – gas pressure (101.08 kPa);
C_1 – maximum gas concentration in the chamber, ppm;
C_0 – gas concentration in the chamber at the beginning of measurement, ppm;
R – gas constant (8.314 $J\ K^{-1} \cdot mol^{-1}$);
T – gas temperature (20 ºC);
A– surface area of manure (0.5 m^2, amount of manure 3 l);
h – gas measurement period (0.08 h).

A methodology for evaluation of CH_4 and other GHG emissions from manure management systems shall be applied [6].

Results and discussion

According to the EU requirements, manure is considered as waste that the owner of the livestock must account for and dispose of without polluting the environment. Thus, the legal responsibility for the proper management of manure rests with all producers, and it is logical to assume that large and medium-sized farms can do this more rationally and that small producers should withdraw from the market. In Lithuania, this process is already very intensive, as between 2011 and 2016 the number of small livestock farms decreased by 41 % and the number of medium and large farms with 50 and more cattle increased by 17 %. However, a bigger problem is that the quantities of manure that continue to be produced are almost unrecorded on small and some medium-sized farms. The main factors affecting GHG emissions are changes in livestock numbers and technological solutions in manure management systems. According to 2018 Lithuanian statistics publication, the number of dairy cows decreased, but the number of other livestock and the amount of litter manure increased [9]. For calculations there were used 2017 statistic data [9]. Table 1 shows the number of livestock by category and the amount of manure entering the manure management systems.

Table 1

Number of livestock by category and amount of manure produced (2017)

Livestock category	Number of animals, thousand	Quantity of litter manure, thousand, t	Quantities of manure spread in soil, thousand, t
Cattle	404.1	286.6	252.1
Dairy cows	272.8	391.3	290.2
Pigs	611.9	230.3	150.7
Others (sheep, goats, etc.)	169.7	56.8	54.9
Poultry (98 % hens)	10400	333.4	290.8
Total		1298.4	1038.7

The results of calculation of methane (CH_4) emissions are presented in Table 2. According to the statistically declared livestock numbers and the resulting litter manure quantities in 2017, a potential methane emission makes about 15.32 $ktCH_4$.

Table 2

Methane (CH_4) emissions from litter manure systems (2017)

Livestock category	Number of animals, thousand	Emission factor, $kgCH_4$ $animal^{-1}$ yr^{-1}	Emission, $ktCH_4$	Emission, CH_4 kt CO_2e
Cattle	404.1	5.72	2.31	57.75
Dairy cows	272.8	9.64	2.63	65.75
Swine	611.9	4.0	2.45	61.25
Poultry	10400.0	0.73	7.59	189.75
Others	169.7	1.98	0.34	8.50
		Total	15.32	383.00

Having conversed CO_2 equivalent value (coefficient 25), we get 383.0 CH_4ktCO_2 e. Based on the number of livestock, the highest CH_4 emission comes from poultry manure (189.75 CH_4 kt CO_2 e). Emissions from cattle, cows and swine manure differ insignificantly.

Emissions of N_2O were calculated in two steps. The first step was to calculate nitrogen excretion in N kg·t^{-1} followed by N_2O emissions by livestock category. The calculation results are shown in Table 3.

Table 3

Emission of dinitrogen monoxide (N_2O) in litter manure systems (2017)

Livestock category	Quantity of manure, thousand, t	Nitrogen excretion rate, N kg·t^{-1}	Emission, ktN_2O	Emission, kt N_2O CO_2 e
Cattle	511.8	70	0.36	108
Dairy cows	869.6	100	0.87	267
Swine	1151.7	20	0.23	69
Poultry	333.4	0,6	0.02	6
Others	56.8	16	0.09	27
		Total:	1.5	477

According to the declared manure amount, a total emission of 1.5 ktN_2O was received. Conversion to CO_2 equivalent (coefficient 300) gives 477 N_2O kt CO2 e. The largest emission of N_2O is obtained from dairy cow manure.

A carbon dioxide emission 1.989 $kgCO_2$ m^{-3} was used to calculate CO_2 emissions during the barn period. The calculation results are shown in Table 4.

Table 4

Carbon dioxide (CO_2) emissions from manure systems (2017)

Livestock category	Quantity of manure, thousand, t	Quantity of litter manure, thousand, m^3	Emission of carbon dioxide, $ktCO_2$
Cattle	286.6	229.3	0.46
Dairy cows	391.3	313.0	0.62
Swine	230.3	184.2	0.37
Poultry	333.4	266.7	0.52
Others	56.8	45.4	0.09
Total	1298.4	1038.4	2.06

By livestock category, the highest CO_2 emission is from cow and poultry manure. The total CO_2 emission of manure management systems during the barn period was 2.06 $ktCO_2$, from soils there was 74.8 $ktCO_2$, methane (CH_4) 303.4 kt CO_2 e and dinitrogen monoxide (N_2O) emission was 441.8 kt CO_2 e.

The calculations of GHG emissions in soils and fields estimated that 1038.7 thousand tons of litter manure were released per year; during the grazing period, about 846.6 thousand of livestock was grazed, and about 200 thousand hectares of soils and fields were fertilized by litter manure. The calculation results are shown in Table 5.

Table 5

Calculated GHG emissions in soils and fields (2018)

Livestock category	Quantities of manure spread in soils, thousand, t	N_2O, kt CO_2 e	CH_4, kt CO_2 e	CO_2, kt CO_2 e
Cattle	252.1	470.2	48.9	28.6
Cows	290,2	548.8	57.1	35.4
Swine	150.7	293.9	30.6	14.9
Poultry	290.8	548.2	53.1	33.2
Others	54.9	97.9	14.3	6.9
Total	1038.7	1959.0	204.0	119.0

For calculating direct N_2O emissions, nitrogen excretion from manure is assumed to be 0.02 kg N_2O-N·(kg N)$^{-1}$ and soil fertilized manure emissions are 8 kg N_2O-N·(kg N)$^{-1}$ [6].

Having performed calculations, it was shown that direct N_2O emission from spreading manure was 2.078 ktN_2O (624 kt CO2 e), from grazing livestock 2.85 ktN_2O (855 kt CO2 e) and from cultivated soils 1.6 ktN_2O (480 kt CO2 e). The total N_2O emissions in the CO_2 equivalent of the pasture period were 1959 kt CO2 e.

The calculated CH_4 emission during the grazing period was 8.16 ktCH_4 (204 kt CO2 e). Based on manure emissions from fields and livestock, CO_2 emissions were 119.5 kt CO_2. Then, the total emissions of the main climate changing gases over a 6 month period are about 2282 kt CO2 e.

Enterprise "Agrolinija" applies two manure management systems. The first one is dedicated to the production of compost and granular organic fertilizers and includes 4 stages of manure management: manure storage in a barn, manure composting, compost maturation and production of milled compost and granules. The second manure management system involves accumulation of the manure in the manure shed and spreading of manure in the fields and soils. According to the requirements of the Best Practice, more than 40 different ways of handling manure are identified [10]. The most widely used technologies can be divided into autonomous (typical for small and medium-sized farms) and less common primary and secondary manure treatment technologies, which should result in the production of already purified organic product in the form of fertilizers.

The experimental investigations were carried out to measure CO_2 emissions from the technological operations of fresh cattle manure; it is composting; maturation of compost and production of milled compost and granules (Fig. 2).

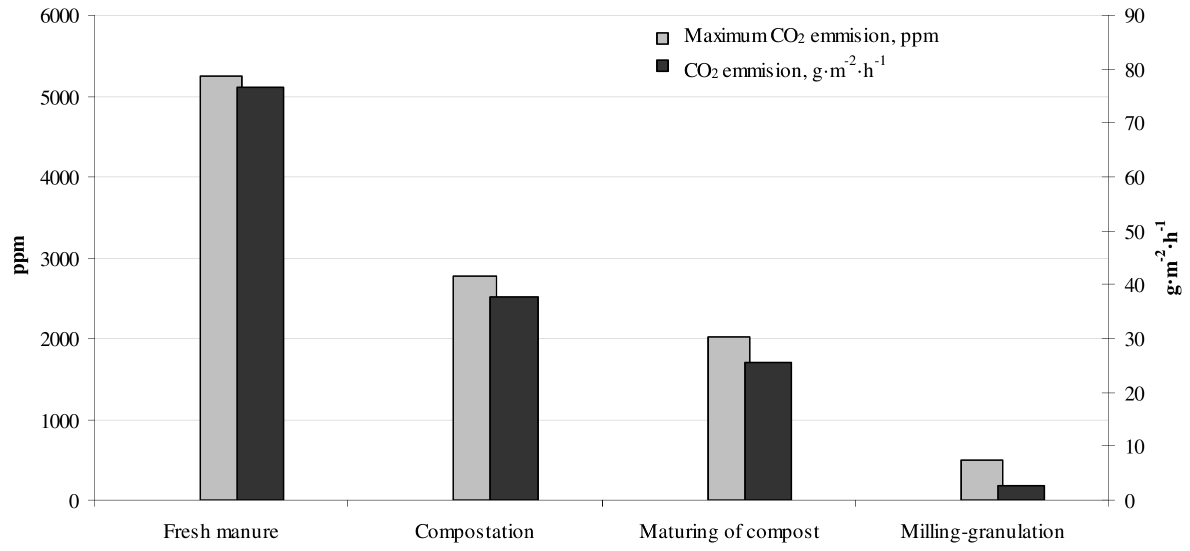

Fig.2. **Measured carbon dioxide (CO_2) emissions from technological operations of milled compost and granule production**

Measurements of CO_2 emissions showed that the spread of compostable livestock manure samples over 0.5 m^2 area and at the temperature 20 ºC the maximum CO_2 changed from 5240 ppm to 578 ppm, and CO_2 emission from composted manure varied from 76.7 to 2.75 $g \cdot m^{-2} \cdot h^{-1}$.

Conclusions

1. From 2011 to 2016, the number of holdings with up to 50 animals decreased by 41 %, however, the number of farms keeping 50 and more animal increased by 17 %.
2. Having performed calculations of emissions, it appeared that the total GHG emissions of manure management systems in CO_2 equivalents are about 862.06 kt CO2 e in 2017. The largest emissions of dinitrogen monoxide (N_2O) and carbon dioxide (CO_2) are from dairy cow manure, and the highest methane (CH_4) emissions were from poultry manure in Lithuania.
3. During the grazing period, total spread manure emissions in fields and soils amount was about 2282 kt CO2 e in 2017. About 86 % of these emissions generate dinitrogen monoxide (N_2O), and only about 8 % of methane (CH_4) and 6 % of carbon dioxide (CO_2) emissions in Lithuania.
4. Experimental measurements in the study object have shown that the maximum CO_2 emission of the final product, milled cattle compost and its granules, is 9 times lower, and CO_2 emission according to gas mass of manure area unit is up to 28 times lower than of fresh manure.

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