STUDY RESULTS OF MASS AND NUTRIENT LOSS IN TECHNOLOGIES OF DIFFERENT COMPOSTING RATE: CASE OF BEDDING POULTRY MANURE

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Abstract. Currently increasing attention is paid to intensification of different technologies of farm waste processing, animal and poultry manure in particular. It is the authors' opinion that acceleration of the composting process should not have negative effect on the ready product quality. The aim of the study was to estimate the loss of mass and nitrogen and phosphorous in two intensive composting technologies – bio-fermentation in chamber- and drum-type installations and the open ground passive composting. It was established that the loss of mass in these technologies varies from 15 to 27 %, the loss of total nitrogen varies from 3 to 25 %, that of phosphorous – from 0 to 7 %. The experiments proved the duration of the bio-fermentation process in each studied technology: in chamber bio-fermentor – 7 days, drum bio-fermentor – 3 days, passive composting in piles – 2.5 months in summer time. The methods to reduce the nutrient loss in the studied technologies are offered.

Key words: technology, composting, bio-fermentation, poultry manure, nutrients, nitrogen, phosphorous, loss, ecology.

Intoduction

Over the past few years, the need to enhance environmentally safe production in the world becomes increasingly important. Many developed countries, such as Germany, the USA, Canada and the Netherlands, set a goal to decrease the environmental load as one of the priority objectives of their long-term development. Not the least role in this loading is played by agro-industrial production [1]. The main environmental hazard associated with the agricultural sector of economy accounts for production of livestock and poultry manure – around 85 % of the total environmental risks from agricultural production [2].

The recent emerging trend to construct large-scale livestock complexes without coordinating their operation with the plant growing farms makes us re-examine the technologies of animal and poultry manure utilization in place in the Russian Federation [3].

Along with traditionally used passive composting in piles the ever increasing number of farms start to apply other, more intensive technologies of waste processing, including biofermentation in chamber and drum type installations [4].

The Department of Egineering Ecology of Agricultural Production of IEEP in 2012-2015 evaluated the most promising technologies of animal/poultry manure utilization. This work resulted in identification of BAT candidates. In this work the degree of environmental load in the region from manure processing technologies under consideration was assessed.

Materials and methods

The objective of the investigation was to determine the effect of the intensity level of organic waste processing on the ready product quality in general, and on the loss of mass of the composting mix, and the main biogenic elements – nitrogen (N) and phosphorus (P) – in the course of bioconversion, in particular.

The following technologies were considered – passive composting in piles, bioferementation in a chamber type installation, and biofermentation in a drum type installation.

Initial raw material was bedding poultry manure.

The experimental investigations were carried out in 2014-2015 in the laboratory of waste bioconversion of IEEP. The physical parameters and chemical composition of initial, intermediate and ready products was determined in the analytical laboratory of IEEP with the use of state-of-the-art instruments and equipment.

Fig. 1 shows the diagram and the picture of the experimental ground for field-edge composting. Fig. 2 and 3 show the breadboard models of the experimental biofermentation installations of the chamber and drum type, correspondingly [5; 6].

In the framework of the investigations the method of static full factorial experiment was used, the optimization factor of which was reduction of nutrient loss during bioconversion.

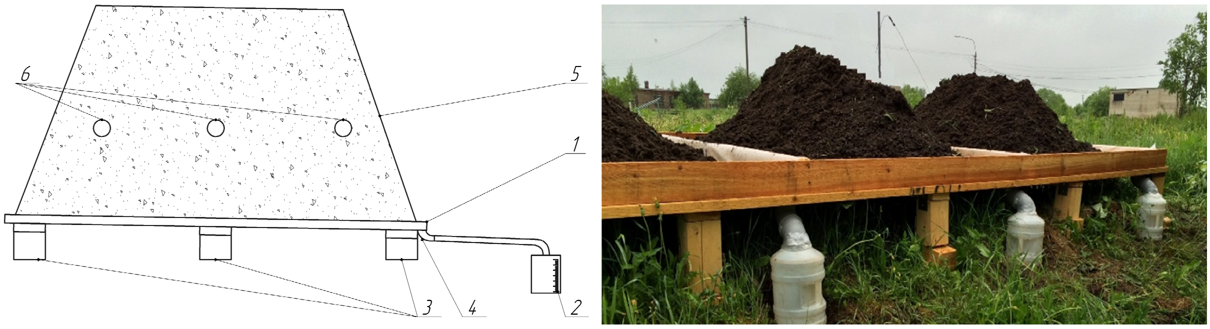

Fig. 1. **Experimental ground for field-edge composting:** 1 – base; 2 – vessel to accumulate and measure effluents; 3 – support; 4 – moisture trap; 5 – compost mix; 6 – sampling and temperature measurement points

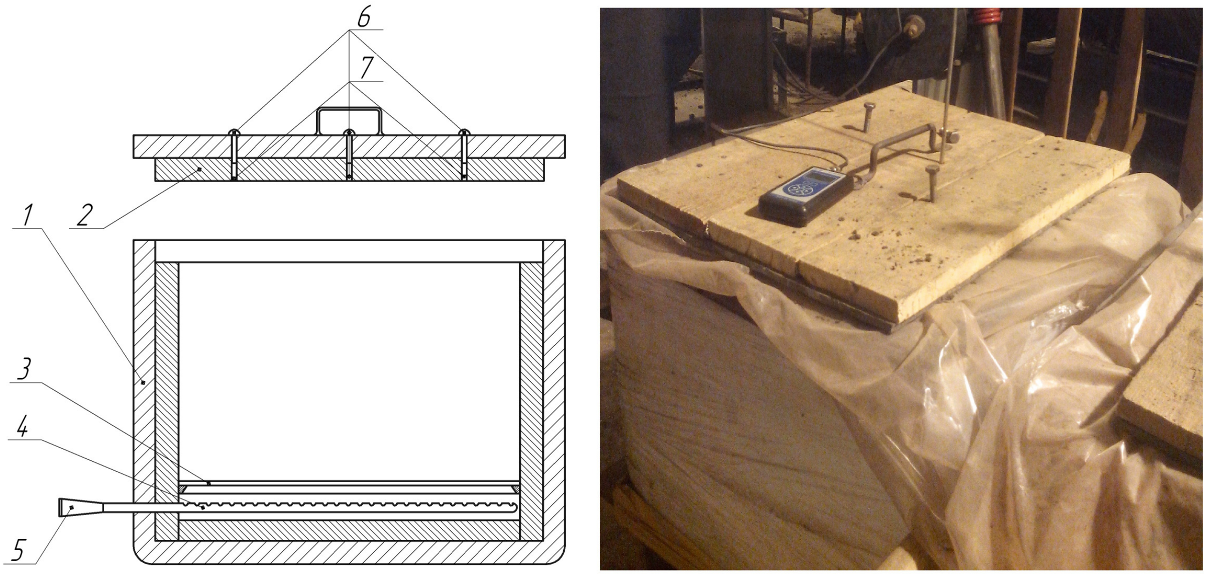

Fig. 2. **Breadboard model of an experimental biofermentation installation of the chamber type:** 1 – biofermentor chamber; 2 – removable lid; 3 – perforated plate; 4 – perforated zigzag pipe; 5 – air compressor nozzle; 6 – plugs; 7 – holes for temperature and oxygen content measurements

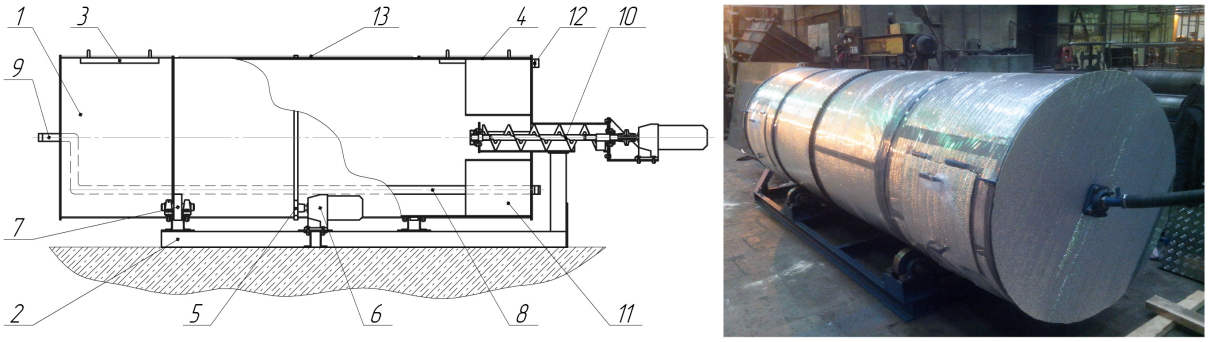

Fig. 3. **Breadboard model of an experimental biofermentation installation of the drum type:** 1 – rotating cylindrical drum; 2 – frame; 3 – charge hole; 4 – checking hole; 5 – power unit; 6 – motor reduction unit; 7 – mounting assemble; 8 – aeration pipe; 9 – air duct for outside air supply; 10 – discharging auger conveyor; 11 – blades; 12 – exhaust duct; 13 – heat insulation

Dynamic pattern of temperature, mass, moisture content and chemical composition was determined in the real time mode. The initial parameters were set according to the experiment planning matrixes. To improve the accuracy of the acquired data the randomized matrixes were used in the experiments. The data obtained during the experimental investigations were processed by the methods of statistical analysis. In the experiment the following equipment was used: ТЦМ 9410/М2 thermometer with ±0.5 ºC sensitivity; strain sensor 3410-2000-C3 with 0.02 % error; laboratory scales Pioneer with 0.005 % error; pH-meter/ionometer ЭКСПЕРТ-001 3(01) with 0.02 % error, spectrophotometer ПЭ-5400 В with the accuracy of 0.001 %, as well as atomic absorption spectrophotometer Shimadzu AA-680, with 0.001 % error.

Due to the specific features of particular technology application, the composting on the field-edge ground was carried out in the open; biofermentation in the chamber and drum type installations – inside the building. The investigations took place in summer time.

Results and discussion

The earlier studies show that the minimal critical mass of the composted mix, which provides a stable bioconversion process, is from 150 to 200 kg for the composting in piles and from 75 to 100 kg for biofermentation in closed installations [7-9]. With due account for these scientifically substantiated values and available equipment the initial mass of the processed mix for the experiments was taken as follows: in composting on the field-edge ground the average mass of the piles was 887 kg; in biofermentation in the chamber and drum type installations – 155 kg and 2511 kg, correspondingly.

A number of scientific publications prove that the temperature mode is the key indicator of the bioconversion process behavior [10; 11]. Temperature variation in the composting process is directly linked with the processing efficiency of organic substances in the composted mix by microorganisms.

Analysis of the temperature data, in its turn, allows to estimate the efficiency and rate of the bioconversion process.

Microorganisms participating in the composting process may be divided in three classes according to their temperature ranges for growth:

- psychrophiles (optimum growth temperatures – below 20 ºC);
- mesophiles (optimum growth temperatures – from 20 to 45 ºC);
- thermophiles (optimum growth temperatures – from 45 to 70 ºC) [12].

For proper temperature monitoring it should be taken into account that the composting mass is characterized by non-uniform distribution of heat throughout the volume of the processed mix.

The process of pile composting is the longest and most labor consuming of the processing techniques under consideration. It includes a number of technological operations: mixing of components, shaping of piles, keeping the mix in piles, its aeration and storing of the ready compost. Depending on the use of moisture absorbing materials the dimensions of the piles vary. The time of keeping the manure and compost in piles after the temperature in all parts of the compost has reached from 50 to 60 ºC should be no less than two months in warm periods and no less than three months in cold periods. In case the animal and poultry manure is composted with bark and saw dust the duration of the process increases by 1.5 to 3 times [13].

The temperature dynamics pattern in the mix under the passive pile composting is shown in Fig. 4.

High dynamics of temperature rise in the pile is explained by the favourable external factors – optimal moisture content and carbon to nitrogen ratio in the initial mix as well as the raised ambient temperature. The mix reached maximum temperature of 39 ºC on the 9^{th} day, when the ambient air warmed up to 29 ºC. Subsequent changes in the pile temperature are directly linked with the variations of ambient temperature and atmospheric precipitations. Starting with the 49^{th} day of the experiment the temperature of the mix declined and reached its minimum of 14 ºC on the 69^{th} day. This was the evidence of decreased activity of mesophiles and, as a consequence, the end of bioconversion. Chemical analysis of the ready product proved that the biofermentation process had completed successfully [14].

The process of accelerated fermentation in the closed installations is characterized by shorter processing time: 7 to 9 days and 3 to 4 days in chamber and drum installations, correspondingly, and as a consequence, highly intensive dynamics pattern of the composted mix temperature [15; 16].

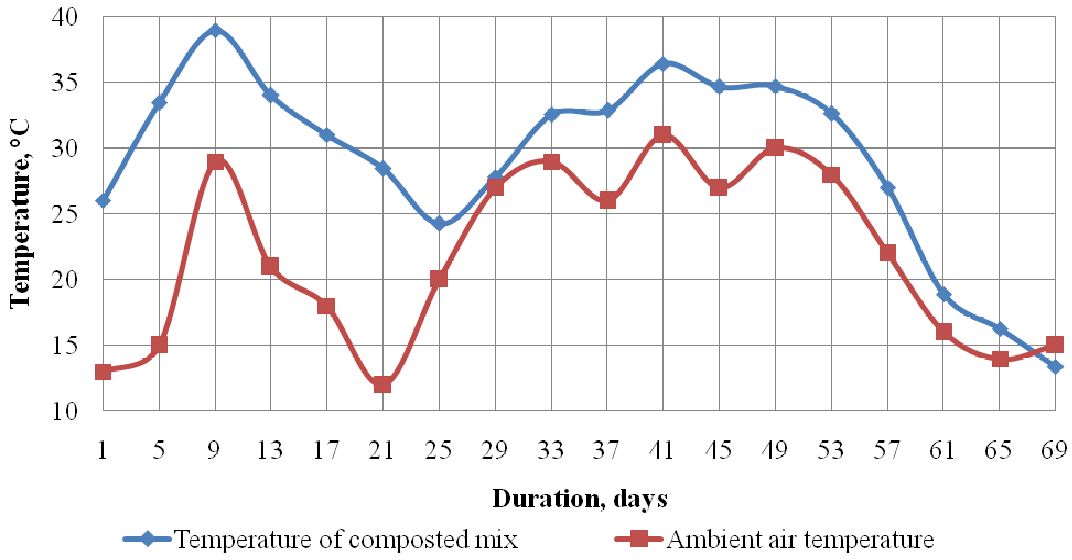

Fig. 4. **Graph of the temperature dynamics pattern under the passive pile composting**

The temperature pattern of the mix in biofermentation installations of the chamber and drum type is shown in Fig. 5.

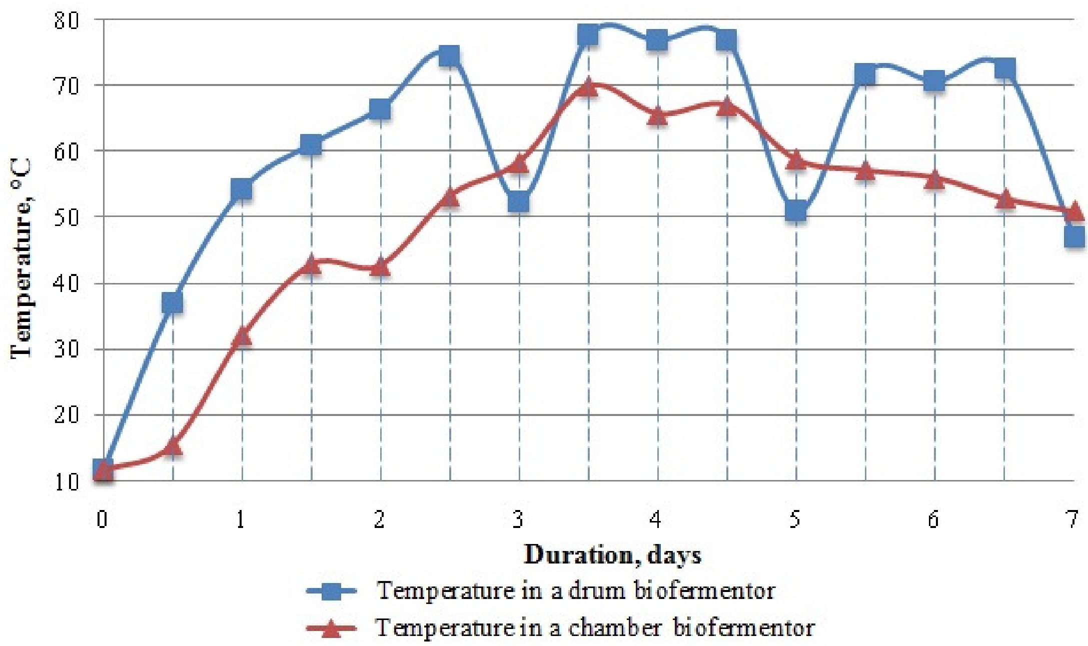

Fig. 5. **Graph of the temperature pattern during biofermentation in the chamber and drum type installations**

The biofermentation process in installations of closed type is characterized by high dynamics of temperature rise: on the second or third day after the experiment started the temperature of the mix in biofermentation installations reached 60 ºC, achieving the maximum values on the fourth day – 70 ºC for chamber type installations and 78 ºC for drum type installations. The average temperature, which the fermented mix reaches in the chamber type installation within seven days of bioconversion, is 49.1 ºC, whereas in the drum type installations it reaches 63.2 ºC. Thus, the value of the average temperature of thefermented mix in the installations of the drum type is higher by 26.7 % [17; 18].

Over the analysed period of bioconversion in different closed installations (seven days), in the installation of the chamber type one full cycle of bioconversion took place, whereas over the same time period during bioconversion in the drum type installation three full cycles took place. In this way, the process of bioconversion of bedding poultry manure in biofermentation installations of the drum type is three times more intensive against the bioconversion process in biofermentation installations of the chamber type.

To assess the accuracy of the experimental data, it was decided to find the confidence intervals for the following indicators:

- mass loss;
- total nitrogen loss (N);
- total phosphorus loss (P).

Estimation of expectation was found by the following formula:

$$\bar{y}_k = \frac{\sum y_{ik}}{3}, \quad (1)$$

where $\bar{y}_k$ – expected mean of loss at the end of bio-conversion, %;
y_{ik} – loss in the i-th experiment at the end of bioconversion, %;
3 – number of degrees of freedom.

Mean square deviation is found by the following formula:

$$\sigma_k = \sqrt{\frac{\sum (y_{ik} - \bar{y}_k)^2}{2}}. \quad (2)$$

To determine the confidence interval Student's distribution was used:

$$\bar{y}_k - \frac{\sigma_k}{\sqrt{3}} \cdot t_{1-\frac{p}{2}} < My_k < \bar{y}_k + \frac{\sigma_k}{\sqrt{3}} \cdot t_{1-\frac{p}{2}}, \quad (3)$$

where $t_{1-\frac{p}{2}}$ – Student t-test under conditions:

- $p = 0.05$ (confidential interval is 95 %);
- number of degrees of freedom is 2.

Homogeneity of variance was checked by Cochran test:

$$g = \frac{\max \sigma_k^2}{\sum \sigma_k^2}. \quad (4)$$

The outcomes of the experimental study of biofermentation technologies of various intensity were processed by the method of mathematical statistics in STATGRAPHICS Centurion XV (Table 1).

Table 1

Outcomes of the experimental investigations of bioconversion technologies of various intensity

Indicator	**Passive pile composting**	**Biofermentation in chamber type installation**	**Biofermentation in drum type installation**
Duration of the fermentation process including warming up of the mix to the operational temperature, days	69	7	3
Mass loss, %	14.8 to19,9	15.5 to 22.2	19.4 to 26.9
Total nitrogen loss (N), %	21.2 to 27.1	13.4 to 19.8	3.2 to 8.9
Total phosphorus loss (P), %	3.4 to 7.0	0 to 1.8	0 to 1.6

Conclusions

1. To carry out the experimental investigations the breadboard models of laboratory installations were substantiated and designed.
2. The accuracy of the investigations was proved by the temperature mode and duration of the mix processing that complied with the existing standards: under passive composting in piles the bioconversion lasted for 69 days; under processing in the chamber biofermentor – 7 days, and under processing in the drum biofermentor – 3 days.
3. The mass loss during passive pile composting was from 14.8 to 19.9 % that is 0.7 to 2.3 % less than during biofermentation in the chamber type installation (15.5 to 22.2 %) and 4.6. to 7.0 % leass than during biofermentation in the drum type installation (19.4 to 26.9 %). Such variance results from the effect of atmospheric precipitations and smaller loss of the moisture content in the composted mix as it achieves lower average temperature: 27.6 ºC (field-edge composting), 49.1 ºC (biofermentation in the chamber installation) and 63.2 ºC (biofermentation in the drum installation).
4. The loss of total nitrogen was 21.1 to 27.1 % in passive pile composting, 13.4 to 19.8 % in biofermentation in the chamber installation and 3.2 to 8.9 % in biofermentation in the drum installation. Higher nitrogen loss in the field-edge composting is explained by the greater interaction between the composted mix and environment against the closed installations and the longer processing time.
5. The loss of phosphorus was 3.4 to 7.0 % in passive pile composting, 0 to 1.8 % in biofermentation in the chamber installation and 0 to 1.6 % in biofermentation in the drum installation. This indicator is linked with the leakage of this biogen with precipitations or with mechanic loss of a part of composted material. As the field-edge composting took place in the open air this indicator is substantially higher against the biofermentation technologies in the chamber and drum installations.
6. Further investigations of the considered bioconversion techniques using other types of livestock waste are scheduled with the aim to obtain more reliable data.

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