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Disinfection of solid fraction of cattle manure in drum-type bio-fermenter

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Abstract. In the context of increased intensification of production and disruption of established ties between livestock and crop farms there is an urgent need to introduce novel, more efficient, economically viable and environmentally sound techniques of animal and poultry manure processing. As a part of the ongoing work on implementation of best available techniques (BAT) in various sectors of Russian economy, agriculture included, the bioconversion technology of organic waste in a drum-type bio-fermenter was considered as one of BAT candidates, which is most adapted to the natural and climatic conditions of North-West Russia and feature the minimal environmental impact. The main purpose was to investigate the influence of bioconversion of solid fraction of cattle manure on selected microbial parameters and parasitic purity in the raw material, semi-finished and final products. The study was conducted in the IEEP Organic Waste Bioconversion Laboratory on a patented drum-type bio-fermenter. After 18 hours the digested material self-heated to 55 °C, i.e. the lower limit of the range of thermophilic microbial activity. By the 30th hour after the experiment started the temperature had reached the maximum level of 71 °C, then it dropped to 62–66 °C and stabilized in this range. 48 hours after the temperature reached 55 °C, the content of coliform bacteria reduced to acceptable limits, and that of *Enterococcus* dropped more than 10 times. After 120 hours the digested product was completely disinfected.

Key words: cattle manure, disinfection, biofermentation, microbial parameters, parasitic purity.

INTRODUCTION

Continuing population growth poses a challenge for agriculture to ensure the food security. In current situation it can be achieved only by making the production more intensive. However this process results not only in the bigger amount of produced food stuffs but also in the increased generation of waste, such as animal and poultry manure, the share of which in the total negative environmental effect from agro- industrial complex is up to 85% (Uvarov, 2016). This stimulates stipulates the active development and testing of new, more efficient technologies for animal waste recycling.

Russia is actively working on introduction of best available techniques (BAT) in the various sectors of economy, agriculture included. Practical application experience is one of the criteria for identifying a technology as BAT, but there are some other promising techniques for manure treatment, which have not been widely implemented so far as they are under-explored yet. With the aim to increase the number of BAT

candidates the team of authors assessed the potential of one of the most efficient and environmentally friendly technologies for animal waste recycling –manure treatment in a drum-type bio-fermenter, which is regularly used to produce fertilizers and bedding. (Uvarov & Briukhanov, 2015; Subbotin et al., 2016).

MATERIALS AND METHODS

The main purpose was to investigate the influence of bioconversion of solid fraction of cattle manure on selected microbial parameters (the presence of *Bacillus* and *Proteus* pathogens, *Salmonella*, *Staphylococcus* and Enteropathogenic *E. coli* types; the Index of coliform bacteria and *Enterococcus*) and the parasitic purity (the presence of pathogenic intestinal protozoa cysts; viable larvae and pupae of synanthropic flies; eggs and larvae of helminths) in the raw material, semi-finished and final products (Gannon et al., 2004; Cliver, 2009).

The study was conducted in 2015–2016 in the IEEP Organic Waste Bioconversion Laboratory on a patented drum-type bio-fermenter (Fig. 1) (Briukhanov et al., 2014). Bio-fermenter is a movable drum with insulating coating, mounted with rollers on the fixed frame. The power unit and motor reduction unit drive the drum. Bio-fermenter is equipped with the composted mass aeration system in the form of a perforated pipe placed inside the drum along its full length.

The finished product is discharged by an auger, with special blades evenly spaced around the inner diameter of the drum to direct the ready compost to it.

The breadboard model of bio-fermenter with the dimensions of 4,300 × 2,100 × 1,650 mm, effective capacity of 2.2 m^3, and the daily output of 0.7 m^3, allows to study the biofermentation process of different types of organic waste in real time mode.

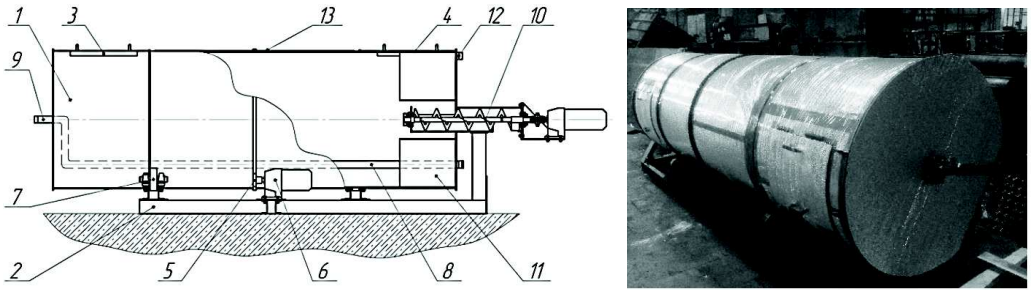

Figure 1. Breadboard model of an experimental drum-type bio-fermenter: 1 – rotating cylindrical drum; 2 – frame; 3 – charge hole; 4 – checking hole; 5 – power unit; 6 – motor reduction unit; 7 – mounting assemble; 8 – aeration pipe; 9 – air duct for outside air supply; 10 – discharging auger conveyor;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

Initial raw material was solid fraction of cattle manure from a dairy farm with the animal stock of 900 head, manure output of 90 m^3 per day and the system of mechanical manure separation into solid and liquid fractions in place.

The raw material, semi-finished and final products were analysed in Leningrad Interregional Veterinary Laboratory and the analytical laboratory of IEEP.

The experiment was conducted under a cyclic operation mode of the bio-fermenter with three replications. The method of static full factorial experiment was applied, the optimization factor of which was reduction of microbial parameters and parasites in the final product to acceptable level in the course of bioconversion.

The mass of fermented product of 1,470 kg was taken with due account for the reasonable minimum critical mass value required for the successful conversion, and the design features of the laboratory-scale bio-fermenter (The composting process, 1996; Mironov & Khmirov, 2002).

The study was conducted under previously substantiated operation mode of the bio-fermenter: air supply – 12.86 $m^3 h^{-1}$, aeration – 5 min h^{-1}, drum rotation frequency – 3 revolutions every 12 hours (Uvarov et al., 2016).

Samples were taken following the State Standard GOST R 54519-2011 'Organic fertilizers. Sampling methods'.

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 acquired data the randomized matrixes were used in the experiments. The data obtained were processed by the method of statistical analysis in MS Excel, Statgraphics Centurion XIV & Mathcad 13.1 (Valge, 2013; Valge et al., 2015).

In the experiment the following equipment was used: ТЦМ 9410/М2 thermometer with ±0.5°C sensitivity; strain sensor 3410-2000-С3 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.

RESULTS AND DISCUSSION

Previous studies have shown that bioconversion in the drum-type biofermenter allows to save most of the nutrients, otherwise lost during other processing methods, owing to the higher intensity of bioconversion process (Uvarov et al., 2016; Subbotin et al., 2016).

Fermentation process of solid fraction of cattle manure is characterized by high dynamics of the temperature rise. After 18 hours the digested material self-heated to 55 °C, i.e. the lower limit of the range of thermophilic microbial activity (Kovalev & Baranovskiy, 2006; Selimbasic et al., 2012). By the 30th hour after the experiment started the temperature had reached the maximum level of 71 °C, then it dropped to 62–66 °C and stabilized in this range (Fig. 2).

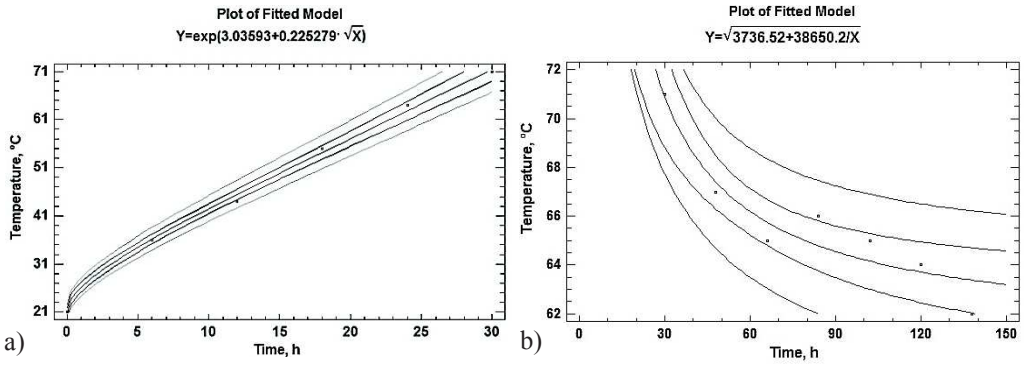

Figure 2. Heating (a) and maturation (b) of the solid fraction of cattle manure in the course of biofermentation.

Forty-eight hours after the temperature reached 55 °C (66 hours from the beginning of the experiment) the first sample was taken; after 120 hours (138 hours from the beginning of the experiment) – the second one. Results of laboratory analysis of the raw material, semi-finished and final products are presented in Table 1.

Table 1. Results of laboratory analysis of the raw material, semi-finished and final products of biofermentation of the solid fraction of cattle manure

Indicator	Experimental result, in 1 g			Permissible content in 1 g
	Raw material	Semi-finished product (48 hours fermentation)	Final product (120 hours fermentation)	
Microbiological indicators				
Bacillus pathogen	Detected	Detected	Not detected	Not allowed
Coliform bacteria Index	1,000	1–9	1–9	1–9
Proteus pathogen	Detected	Not detected	Not detected	Not allowed
Salmonella	Not detected	Not detected	Not detected	Not allowed
Staphylococcus	Not detected	Not detected	Not detected	Not allowed
Enterococcus Index	1,000	100	1–9	1–9
Enteropathogenic E. Coli types	Detected	Not detected	Not detected	Not allowed
Parasitic purity				
Pathogenic intestinal protozoa cysts	Not detected	Not detected	Not detected	Not allowed
Viable larvae and pupae of synanthropic flies	Not detected	Not detected	Not detected	Not allowed
Eggs and larvae of helminths	Not detected	Not detected	Not detected	Not allowed

The conducted investigation demonstrated that fermentation under the temperature above 55 °C for 48 hours reduced the Coliform bacteria Index to acceptable level, eliminated *Proteus* pathogen and Enteropathogenic *E. coli* types and resulted in 10 times lower *Enterococcus* Index.

Longer (up to 120 hours) fermentation period allowed achieving the elimination of *Bacillus* pathogen in the final product; *Enterococcus* Index was reduced to acceptable level.

At the same time the effect of biofermentation process on *Salmonella* and *Staphylococcus* as well as on pathogenic intestinal protozoa cysts, the viable larvae and pupae of synanthropic flies, the eggs and larvae of helminthes was not revealed as they were not present in the raw material.

CONCLUSIONS

1. Drum-type bio-fermenter is an efficient tool for disinfection of organic waste from some microbial cultures (Bacillus and Proteus pathogen; coliform bacteria; Enterococcus and Enteropathogenic E. coli types).
2. More research is needed to explore the biofermentation effect on some microbial cultures (*Salmonella* and *Staphylococcus*) and parasites (pathogenic intestinal protozoa cysts; viable larvae and pupae of synanthropic flies and the eggs and larvae of helminthes).
3. Improvement of bio-fermenter design parameters and operating modes will increase the potential of its application and achieve a shorter disinfection period by reducing the duration of heating and/or by increasing the processing temperature (Briukhanov & Uvarov, 2016).
4. One of the focuses of further research is the effect of the resulting final product on the structure and fertility of soil, as well as the possibility of its use as a bedding in cow barns.
5. In the future, the bioconversion of other types of waste in the drum-type biofermenter will be studied, such as poultry manure, solid fraction of pig manure, and some types of food waste.

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