E3S Web of Conferences **411**, 02050 (2023) https://doi.org/10.1051/e3sconf/202341102050
APEC-VI-2023

Evaluation of the efficiency of biocomposting of bottom silt deposits using different conditions of aerobic fermentation

A S Bobko[1*], *V V* Tervonen[1], and *N A* Chechkova[1]

[1]Petrozavodsk State University, 33, Lenin Ave., Petrozavodsk, Rep. Karelia, 185035, Russia

Abstract. The efficiency of biocomposting of bottom silt deposits was evaluated in laboratory conditions. The biocomposting process is reproduced taking into account the main technological parameters and using lowland peat, microbial concentrate and vermiculture as basic components. The composition of the microbial concentrate includes strains of the genera Bacillus spp., Clostridium spp., Pseudomonas spp., causing biosolubilization of a complex organomineral substrate - bottom sediments. The productive line Eisenia foetida Savigny (Lumbricidae) was used as a vermiculture. The evaluation of the efficiency of biocomposting was carried out according to agrochemical characteristics. The greatest effect on the preservation of biogens was obtained during the fermentation of bottom sediments with the participation of microbial concentrate. An increase in the content of N to 1.10%, P – to 0.54%, K – to 0.42% was achieved. The use of vermiculture caused an increase in organic matter – up to 42.1% and humus – up to 14.6%. The results of the experiment allow us to consider biocompost and vermicompost obtained using bottom sediments as a source of elements necessary for plant growth and development.

1 Introduction

The rapid increase in the world's population is gradually leading to a threat to food security. Since traditional methods of cultivating agricultural plants are unable to provide enough food, various chemical fertilizers are used to increase yields and increase the growth rate of plants. Their excessive and improper use leads to a new problem of soil degradation, as a result of contamination with nitrates, nitrites, phosphates, etc. Organic fertilizers can act as an alternative to chemical fertilizers [1].

As a rule, biofertilizers contain live mono- or polycultures of directed microorganisms with the functions of soil formation, plant nutrition and ensuring the phytosanitary condition of the soil [2]. During aerobic composting, microorganisms, due to diverse enzyme systems, cause decomposition of organic waste and form CO_2, H_2O and contribute to the formation of a humus-like decomposition product, which is effectively used by plants as a nutrient medium. The main options for the biologization of fertilizers are:

* Corresponding author: Bobko.2001@list.ru

- Treatment with enzymes-hydralases that destroy polymer molecules to oligomers.
- Introduction of bacteria of the genus Pseudomonas, Bacillus or Clastridium. The genus Pseudomonas is characterized by the presence of biodegradation plasmids, inactivating toxic compounds that adversely affect the condition of plants. The genus Bacillus and Clastridium are biosolubilizers of phosphate and silicate compounds. The biosolubilization process makes it possible to obtain soluble salts from insoluble forms of phosphorus and silicon, which can be used by plants for growth and development. Thus, microorganisms perform the main mineralizing function in the creation of biofertilizers.
- The use of vermiculture to produce biohumus, which is a natural product of processing organic waste by earthworms, characterized as a source of high-molecular natural organic compounds, namely humic acids and their salts–humates - natural growth stimulants.

In connection with the processes of biologization, fertilizers have a number of advantages over chemical fertilizers, namely:

- The optimal ratio of nitrogen and carbon, as a result, soil degradation does not occur.
- Mineral substances due to the biosynthetic activity of microorganisms are converted into dissolved and bioavailable forms of plants.
- Readily available forms of mineral and organic substances lead to acceleration, development and increase in plant yield.
- The absence of chemical pollution, as a result of the activity of microorganisms having plasmids of degradation of chemical compounds.
- Are characterized by the ability to equalize the acid-base balance of soils.

These advantages make biofertilizers an effective and promising element for the agricultural industry. However, to achieve these qualities, it is necessary to have the right combination of components and agents involved in the creation of biofertilizers. In connection with the above, the search and evaluation of the most optimal biocomposting regulations remain relevant, including on the basis of a comparative analysis of fermentation conditions, including the influence of microorganisms on the acceleration of composting processes, the development of composting modes, the use of alternative organomineral substrates.

The purpose of this study was to evaluate the effectiveness of biocomposting of bottom silt deposits using various aerobic fermentation options.

2 Materials and methods

The efficiency of biocomposting of bottom silt deposits was evaluated on the basis of the bioconversion laboratory of the Research Center for Aquaculture of the Institute of Biology, Ecology and Agrotechnologies of Petrozavodsk State University. For fermentation, a module based on bottom sediments (55 g), peat (500 g), microbial concentrate (55 ml) and compost worms (55 g) was used. The quantitative ratio of the module components was established on the basis of previously conducted studies to assess the effectiveness of biocomposting using microorganisms and vermiculture. All fermentation variants were performed under aerobic conditions at ambient temperature. The general scheme of the experiment is presented in Figure 1.

Composting was performed in specially prepared aerated containers, the substrate was laid with a layer of 20-25 cm. During fermentation, the bookmarks were turned over, controlling the process temperature, humidity, acidity, ambient temperature and aeration. pH 7.1 - 7.5 was considered optimal, respectively, with an acidity close to neutral at which microorganisms actively develop; the humidity level was in the range of 50-60%. Humidity was controlled throughout the experiment by irrigation of the soil with standing tap water. Aeration was controlled to ensure the metabolism of aerobic microorganisms involved in composting and removal of excess carbon dioxide and water formed during the vital activity of microorganisms due to the air flow. Aeration was performed by loosening the soil taking into account changes in the oxygen demand of microorganisms during composting. During composting, the ambient temperature corresponded to room values and was in the range of 19-20 °C. Changes in temperature, acidity and soil moisture were recorded using the universal tester "ETR306" for soil. The main characteristics of the tester included the ability to measure soil acidity in the range from 3.5 to 8 units and soil moisture from 0 to 100%. The result of humidity measurements was estimated in relative units from 0 to 100%, where indicators from 80 to 100% meant moistened soil, and from 0 to 30% - over-dried; soil with humidity indicators from 40 to 70% was considered optimal.

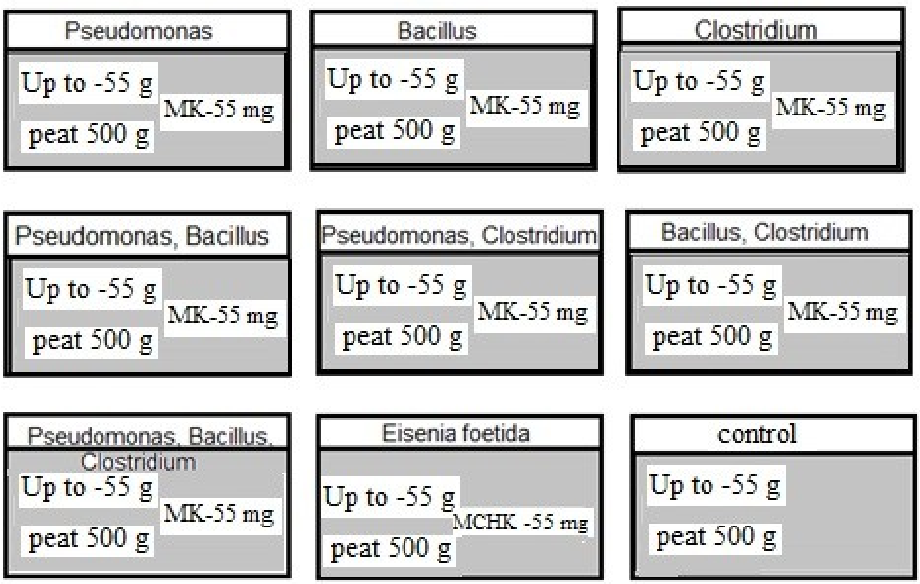

Fig. 1. Experimental scheme: DO – bottom sediments, MC – microbial concentrate, MC - mass of compost worms.

The degree of readiness of bio-organic fertilizer was determined by physico-mechanical, organoleptic (uniformity, friability, absence of odor) and chemical properties. Organic matter was determined according to GOST 26213-91, total nitrogen - according to GOST 26107-84, mobile compounds of phosphorus and potassium - according to the Chirikov method in the modification of TSINAO according to GOST 26204-91, humus - according to the Tyurin method in the modification of Nikitin according to GOST 26213-91 Soil. All measurements were performed in 3 repetitions. Composting was considered completed when soil moisture was established in the range of 50-70%, pH close to a neutral medium and accumulation of the final product – humified compost containing stable humic organic compounds, low molecular weight decomposition products of nitrogen-containing and carbon-containing organic matter and biomass from micro- and macroorganisms. If the above conditions are met, the duration of the full technological cycle was 60 days.

Bottom sediments were used as a source of organomineral substrate containing single-component nitrogen compounds (ammonium salts, nitrates, urea, amino acids), macronutrients (K, Ca, Mg, Fe, S, P salts) and trace elements (Zn, Cu, Na salts). The main characteristics of the peat used are indicated in Table 1.

Table 1. Characteristics of the peat used.

Type of peat	Features		
	Degree of decomposition R,%*	**Ash content of dry matter, A^c, %****	**Acidity, pH**
Lowland	34	7.1	6.8

Note: **- the degree of decomposition shows the percentage of structureless substance that has lost its cellular structure; **- the percentage of mineral components.

As a microbial concentrate, starter cultures of Bacillus spp., Pseudomonas spp. and Clostridiums spp. were used, isolated from the microflora of bottom sediments using the Methodology for studying biogeocenoses of inland reservoirs (1975). The use of these microorganisms in the experiment is based on literature data confirming their participation in biosolubilization, decomposition of residual organic raw materials and humification during composting [3-5]. The crops were carried out from tenfold dilutions of bottom sediments. A 100 mg bulk of bottom sediments was pre-prepared, which was mixed with 100 ml of sterile saline. Next, 1 ml of liquid was taken and transferred to a test tube with 9 ml of sterile saline. Such a sequence of dilutions was performed tenfold. Of the last three dilutions, 1 ml of liquid was sown in a "deep" way using melted and cooled to 45 ° C meat-peptone agar. As a nutrient medium for the isolation of clostridium, sulfite agar was used, which provides nutritional needs for the growth of clostridium and their identification by a sulfite-reducing trait: the ability to reduce sulfite to sulfide, which forms a black precipitate with iron ions. Morphological and tinctorial properties of the isolated cultures were used for morphological typing. Identification to the genus was performed according to a number of phenotypic traits regulated in the determinants of Bergi bacteria [6]. The accumulation of bacterial biomass was carried out using a medium containing peptone (10 g/l) and agar (20 g/l). All work on the accumulation of bacterial biomass was carried out in the thermostat TSO-200 SPU (Russia) at a temperature of 37 ± 0.2 ° C. Microbial concentrates were prepared from storage crops, the sowing dose was at least 108 CFU/ml.

As a vermiculture, Eisenia foetida Savigny (Lumbricidae) was used – a productive "line" of earthworms obtained by breeding natural precursors that are ubiquitous and have a wide range of adaptations to given cultivation conditions [7-8]. Eisenia foetida belongs to the lumbricides representatives of the Annelida type or annelids. Annelida includes the subtype Clitellata or girdle ringlets. The Clitellata subtype includes the class Oligochaeta or small-scale worms. According to the systematics of oligochaetes [9-10], the class includes the order Haplotaxida or haplotaxides and the suborder Lumbiicina or earthworms, which includes seven main taxa: the genus Eiseniella, the genus Eisenia, the genus Bimastus, the genus Eophila, the genus Octolasium, the genus Allobophora and the genus Lumbricus. The breeding stock of the compost worm was provided by LLC "Biohumus" (Chelyabinsk). The cultivation of worms was carried out using a starting vermiplock in the form of a closed-type cultivator. The cultivator was a structure in the form of a ridge 2 m long, 1 m wide and 0.5 m high, lined with breathable fabric. To fulfill the purpose and objectives of the study to assess the effectiveness of biocomposting of bottom silt deposits, two starting vermiploads were used for the cultivation of E. foetida: one for the accumulation of biomass of the mother stock of worms, the second for the accumulation of biomass in order to obtain vermicompost.

3 Results

The efficiency of biocomposting of bottom silt deposits using various variants of aerobic fermentation was evaluated according to agrochemical characteristics (Table 2): minimal loss of organic matter, maximum preservation of biogenic nutrients N, P, K and maximum degree of humification. In all variants of the experiment, the biocompost obtained on the basis of bottom silt deposits, lowland peat and microbial concentrate was a homogeneous loose product with a smell of earth and in terms of the content of biogens exceeded the humified compost. In the biocompost obtained using different variants of microbial concentrate, the nitrogen content varied from 0.30% (Pseudomonas-Bacillus) to 1.10% (Clostridium), phosphorus – from 0.12% (Clostridium) to 0.54% (Pseudomonas-Clostridium), potassium from 0.10% (Clostridium) to 0.42% (Pseudomonas-Clostridium). In the presence of microbial clostridium concentrate, the nitrogen fraction was 1.8 times higher than the agrochemical characteristics of the vermicompost obtained during the vermicultivation of bottom sediments and peat. In the presence of a pseudomonas-clostridial complex, the proportion of biogenic phosphorus and potassium in the biocompost increased to 0.54% and 0.42%, respectively, which turned out to be significantly higher (4 times) than similar indicators of vermicompost.

In the vermicompost obtained using bottom sediments, lowland peat and worms, nitrogen accounted for 0.61%, phosphorus - 0.12%, potassium - 0.10%. At the same time, the humus content in the vermicompost turned out to be higher than in other composting options and exceeded the control values of the degree of humification of the initial substrate by 2 times.

According to the physical properties, the water-holding capacity of the vermicompost slightly exceeded the moisture content of the vermicompost obtained using bottom sediments, peat and microbial concentrate, and the control values were 1.2 times (bottom sediments and peat). It should also be noted that in the composition of the vermicompost based on fermented bottom sediments and lowland peat, more nutrients available to plants were found not only in the form of humus, but also organic matter (42.1%). With the participation of microbial concentrate in aerobic fermentation processes, the largest proportion of organic matter was established for the biocompost with the Pseudomonas-Bacillus-Clostridium microbial consortium – 36.4%.

Table 2. Agrochemical characteristics of compost and vermicompost.

Name of indicators	**Compost based on**								
	DO, Peat and MK							**DO, Peat and MKH**	**DO, Peat**
	Pseudomonas	***Bacillus***	***Clostridium***	***Pseudomonas Bacillus***	***Pseudomonas Clostridium***	***Bacillus Clostridium***	***Pseudomonas Bacillus Clostridium***	***Eisenia foetida Savigny (Lumbricidae)***	**Control**
	average values (n = 3)								
Humidity, %	62.4	58.2	64.1	62.2	62.4	63.1	62.2	69.3	57.3
Organic matter, %	18.6	20.2	27.1	17.4	32.9	25.1	36.4	42.1	14.2
pH	6.1	5.8	6.6	6.3	6.9	6.8	7.1	7.0	7.6
Nitrogen, %	0.62	0.54	1.10	0.30	0.60	0.97	0.84	0.61	0.34
Phosphorus (P,05), %	0.16	0.32	0.12	0.31	0.54	0.36	0.31	0.12	0.12
Potassium (K,0), %	0.11	0.24	0.10	0.27	0.42	0.21	0.27	0.10	0.16
Humus content, %	8.5	10.3	11.3	10.9	12.7	12.9	13.8	14.6	7.2

Note: PRE–bottom sediments, MK – microbial concentrate, MKH – mass of compost worms.

4 Discussion

The positive effect of microbial concentrate consisting of mono- and polycultures of microorganisms of the genera Bacillus spp., Clstridium spp., Pseudomonas spp. on the processes of aerobic composting has been experimentally confirmed. and vermicultures of Eisenia foetida Savigny (Lumbricidae). The effective action of microorganisms is mainly associated with an increase in phosphorus and potassium in the target product, which is possible due to the biosolubilization of these compounds from such a complex organomineral substrate as silt bottom sediments. The activity of biosolubilizing bacteria is mediated by specific enzymes – silicases, which belong to the family of carbon anhydrases, a class of zinc-dependent metalloenzymes [11]. Nitrogen accumulation in the biocompost is largely due to the activity of diazotrophs of the genus Clostridium spp. Despite the fact that clostridia belong to obligate anaerobes, according to literature data [12], it is the vital activity of anaerobes that favorably affects the pH reduction of the composted mass and the preservation of ammonium nitrogen in it. It is believed that the creation of a balance between active aerobic and anaerobic microorganisms in the compost mass is one of the ways to increase the contribution of anaerobic processes that do not require oxygen supply and can affect the reduction of costs for compost aeration and increase the energy efficiency of the composting process as a whole.

The positive effect of vermiculture is based on an increase in the content of organic matter and humus in the target product - up to 42.1 and 14.6%, respectively. The basis of the substrate for worms was only bottom silt deposits and lowland peat. According to the literature data [13], in the process of vermicomposting for 3-5 months, it is possible to obtain up to 60% of the vermicompost and 40% of the mass of worms from the initial substrate.

In the case of compost from bottom sediments and peat, all agrochemical indicators were lower than the data obtained for biocompost and vermicompost. Especially negative is the pH indicator, which clearly indicates the leaching of the control substrate during fermentation, which negatively affects the efficiency of composting. Probably, one of the reasons for the change in the acidity of the fermentation medium to 7.6 may be associated with an increased concentration of calcium, the concentration of which in the composition of bottom silt deposits can often be increased due to the allochthonous and autochthonous mechanism of formation [14].

5 Conclusion

As a result of the performed studies, primary data were obtained on the effect of microorganisms of the genus Bacillus spp., Clostridium spp., and Pseudomonas spp. and the productive line Eisenia foetida Savigny (Lumbricidae) on the effectiveness of composting. For this purpose, the possibility of using mono- and polycultures of microorganisms and vermiculture to accelerate the maturation of compost consisting of bottom silt deposits and lowland peat has been determined; the agrochemical value of the obtained biocompost and the possibility of its use for agricultural crops as fertilizer and for the production of artificial soil-like substrates, soils and nutrient soils for closed ground are analyzed. An important point of the performed research is the use of bottom silt deposits as organomineral raw materials for the production of biofertilizers. The content of a set of micro- and macroelements in bottom silt deposits allows us to consider biocompost and vermicompost obtained using bottom sediments as a source of elements necessary for plant growth and development, with their normalized introduction into the soil. The results of the performed studies are primary and in the future, the effect of the obtained biofertilizers will be confirmed in a series of laboratory experiments using plant test objects.

Acknowledgement

The work was carried out with the support of the Grant of the Head of the Republic of Karelia for 2022, project No. KGRK-21/H3-12.

References

1. N.O. Igiehon, O.O. Babalola, Biofertilizers and sustainable agriculture: exploring arbuscular mycorrhizal fungi, Appl Microbiol Biotechnol, **101**, 4871–4881 (2017)
2. T. Mahanty, S. Bhattacharjee, M. Goswami, Biofertilizers: a potential approach for sustainable agriculture development, Environ Sci Pollut Res, **24**, 3315–3335 (2017)
3. O. Pepe, Dynamic of functional microbial groups during mesophilic composting of agro-industrial wastes and free-living (N 2) Mixing bacteria application, Waste Management, **33**, **7**, 1616-1625 (2013)
4. Y. Yin, Impact of copper on the diazotroph abundance and community composition during swine manure composting, Bioresource technology, **255**, 257 (2018)
5. L.L. Zhang, Dynamic changes of the dominant functioning microbial community in the compost of a 90-m^3 aerobic solid state fermenter revealed by integrated inetaoniics, Bioresource Technology, **203**, 1-10 (2016)
6. R. Krieg Noel, T. Staley James, R. Brown Daniel, P. Hedlund and Brian, Bergey's Manual of Systematic Bacteriology II (Springer, NY, 2010)
7. A.B. Sorokin, *Application of the bioresource Eisenia foetida in agriculture of the subtaiga zone of Siberia*, Materials of the IV International scientific and practical conference "Vermicomposting and vermicultivation as the basis of ecological agriculture in the XXI century: achievements, problems, prospects" Minsk, 95-100 (2013)
8. N.N. Tereshchenko, The effectiveness of the use of microorganisms isolated from earthworm coprolites to increase the yield of grain crops. Siberian Bulletin of Agricultural Science, **5**, 10-17 (2013)
9. A.S. Babenko, Ecology of soil invertebrates: textbook (NTL, Tomsk. 2006)
10. G.P. Ostroverkhova, Invertebrate Zoology (Tomsk University, Tomsk, 2005)
11. C. Eckert, H. C. Schroeder, D. Brandt, Perovic-Ottstadt, Histochemical and Electron Microscopic Analysis of Spiculogenesis in the Demosponge Suberites domuncula, J of Histochemistry and Cytochemistry, **54**, **9**, 1031-1040 (2006)
12. V.V. Mironov, A.A. Sedykh, A.V. Mironov, K.In. Palyutkina, Biothermocomposting of organic waste, Bulletin of VNIIMZH, **4**, **36**, 37-45 (2019)
13. A.S. Vasko, Agrochemical characteristics of unconventional organic fertilizers, Agrochemical problems of using organic fertilizers based on industrial animal husbandry waste, 172-175 (2006)
14. I.A. Dauwalter, Geoecology of bottom sediments of lakes (MSTU, Murmansk, 2012)