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THE ROLE of SOIL MICROBiOCENOSIS IN THE COMPOSTING OF THE ORGANIC COMPONENT OF THE MUNICIPAL SOLID WASTE

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Abstract. In order to increase the efficiency of composting the organic component of solid municipal waste as a highly effective biotechnological method, and to compare the characteristics of the processes, it is suggested to use soil as an inoculum, as a microbiological additive - an extract from the soil. The original compost mixture is a multicomponent system, the decomposition and transformation of which depends on the functioning of a microorganisms complex, in particular, fungal and bacterial microflora. Since the main component of the organic fraction is cellulose, it is expedient, along with the definition of the total number of the microflora bacterial and fungal components, to determine the number of cellulose-decomposing microorganisms. An estimation of the change in the compost mixtures' microbial population has been made, which shows that bacteria dominate over fungi in compost mixtures. A similar microbial complex is observed in soils. The article presents the results of the study of the soil microbiocenosis qualitative and quantitative composition in order to use it as an inoculum in the process of composting the organic part of solid municipal waste. The influence of microbiological additive on the process of the organic waste composting for acceleration in mesophilic and thermophilic temperature regimes with controlled parameters was studied. The results of the conducted studies allow us to conclude that the organic waste composting with the microbiological additive is appropriate, both in the case of thermophilic and in the case of mesophilic regimes. The period of the compost maturation with the use of a microbiological additive is 6 weeks. It was shown that the microbiological complex accelerates the process of composting the organic component of solid municipal waste by 3.3 times for the thermophilic regime and by 2.1 times for the mesophilic conditions of composting process, which testifies to the efficiency of its use in the operation of the solid municipal waste processing in order to improve the general level of environmental safety.

Key words: soil, microbiocenosis, composting, waste, microbiological additive, mesophilic and thermophilic composting regimes.

РОЛЬ ГРУНТОВОГО МІКРОБІОЦЕНОЗУ В ПРОЦЕСІ КОМПОСТУВАННЯ ОРГАНІЧНОЇ ЧАСТИНИ ТВЕРДИХ МУНІЦИПАЛЬНИХ ВІДХОДІВ

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Анотація. Для підвищення ефективності процесу компостування органічної складової твердих муніципальних відходів, як високоефективного біотехнологічного методу, та порівняння особливостей перебігу процесів, запропоновано в якості інокуляту використовувати ґрунт, в якості мікробіологічної добавки – екстракт з ґрунту. Вихідна компостна суміш є багатокомпонентною системою, розкладання і перетворення якої залежить від функціонування цілого комплексу мікроорганізмів, зокрема, грибної та бактеріальної мікрофлори. Оскільки основним компонентом органічної фракції є целюлоза, доцільно поряд із визначенням загальної чисельності бактеріальної і грибної складових мікрофлори, визначати чисельність целюлозоруйнівних мікроорганізмів. Проведено оцінку зміни мікробного населення компостних сумішей, яка свідчить, що в компостних сумішах бактерії домінують над грибами. Аналогічний мікробний комплекс спостерігається і в ґрунтах. У статті представлено результати дослідження якісного та кількісного складу грунтового мікробіоценозу з метою його використання в якості інокуляту в процесі компостування органічної частини твердих муніципальних відходів. Вивчено вплив мікробіологічної добавки на перебіг процесів компостування органічних відходів з метою прискорення в мезофільному і термофільному температурних режимах з керованими параметрами. Результати проведених досліджень дозволяють зробити висновок про доцільність компостування органічних відходів з мікробіологічною добавкою як у випадку термофільного, так і у випадку мезофільного режимів. Період дозрівання компосту при використанні мікробіологічної добавки становить 6 тижнів. Показано, що мікробіологічний комплекс прискорює процес компостування органічної складової твердих муніципальних відходів у 3,3 рази за термофільного режиму та в 2,1 рази за мезофільних умов проведення процесу компостування, що свідчить про ефективність його використання в процесах переробки твердих муніципальних відходів із метою підвищення загального рівня екологічної безпеки.

Ключові слова: ґрунт, мікробіоценоз, компостування, відходи, мікробіологічна добавка, мезофільний і термофільний режими компостування.

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Introduction. Formulation of the problem

The management of solid municipal waste (SMW) is the subject of an annual regional report on the state of the environment [1], statistical surveys [2], special studies [3], environmental programs. Description of the problem is mainly limited to data on the number and area of landfills, volumes placed in specially designated waste sites (mostly industrial). But such an array of information on waste disposal in specially designated areas does not allow to fully characterize the environmental consequences of the existing waste situation in the Odessa region and determine the resource potential of such waste.

In recent years, the countries of the European Union (EU) have gained considerable experience in utilizing SMW and, in the course of time, have improved their methods of handling, taking into account the features of the territory and ecological and economic feasibility [4,5]. In the EU, over 90 directives in the field of environmental protection have been adopted, the main principles in the field of waste management are defined in [6], which form the general EU strategy for management of SMW flows. Recycling, in particular, composting and receiving biogas as an energy source, is the main methods used by the EU government to dispose of SMW [7].

The most environmentally appropriate solutions for management of TMV reprocessing are recognized as minimization and prevention of environmental pollution. The international recycling system is aimed at minimizing waste by sorting and recycling feedstocks, the rest goes to recycling and composting, combustion and stockpiling of residues. Since up to 40% of the SMW relates to easily degradable organic wastes (food waste, market waste, urban greenhouses, municipal power supply, sewage systems, household waste [8]), the removal of this part of waste from waste land due to composting and waste conversion on the secondary material resource will significantly reduce the environmental burden on actually deployed and potentially planned landfills.

Aerobic composting is one of the best available technologies for an integrated waste management system by minimizing anthropogenic environmental impact, complying with the latest domestic and foreign developments, economic and practical acceptance of technology.

But composting is characterized by relatively low popularity in comparison with other methods of waste utilization due to a number of its disadvantages, such as a long production cycle and sometimes the obtaining of a product of unstable quality. Because of this, many studies on SMW processing are devoted to methods of accelerating the process of composting, which can be achieved in various ways, such as the development of high-efficiency composting machines and the change of biotic (vermicomposting, use of specialized cultures and communities of microorganisms) or abiotic (temperature, pH, etc.). parameters of the process.

Analysis of recent research and publications

Attention to the technologies of rationalization of methods for the preparation of manure and other organic waste was drawn in the early twentieth century. On the basis of the formed stratified composting method in piles in the 30s, a composting technique with stratified formation of semi-buried piles was proposed (Indore method) [9,10]. Some exploration work was aimed at developing various ways to speed up the composting process with a change in the abiotic parameters of the process [11,12].

Among modern researchers of the composting process as a rational method of waste management, there are innovative works of M.V. Gatsenko [13], M.K. Linnik [14], A.A. Lyashenko [15], V.V. Shatsky [16], in which a lot of attention is paid to the issues of composting technology, mechanization of the preparation of the substrate, optimization of the controlled parameters of the process, design of piles, composition of the substrate and the ratio of the main nutrients in it.

The feedstock for composting – the organic fraction of the SMW – typically has a low density of anaerobic microorganisms that spontaneously colonize waste during collection, transportation, and storage. This amount of microorganisms is not enough for the composting process. To start and speed up the fermentation process, it is necessary to inoculate the raw material with an active anaerobic microbial community from other sources. Fermented sludge from wastewater treatment plants, ground extracts, sludge from industrial wastewater treatment systems, manure, etc. are used as inoculum [17]. According to the literature, fermented sewage sludge contains all the necessary groups of microorganisms and is a versatile inoculum to start the process of fermentation of various organic wastes to produce biogas [18]. Other experiments with composting organic SMW and food waste at ambient temperature (20±2°C) and in a moderately thermophilic mode (50°C) showed that the soil of the SMW landfill is the best inoculum compared to fermented sewage sludge, since provides a higher rate of methanogenesis [19]. The soil of the SMW landfills is widely available, however, for use as an inoculum, its previous activation is needed by dilution, incubation with an organic substrate at the desired temperature, as well as the separation of solid particles of sand and clay.

According to the results of studies [20], the structure of microbial complexes is an integral component of the detailed characteristics of soils. Soil as a habitat and a waste product of microorganisms is a complex system, including physiological and taxonomic species that provide biological circulation of substances, soil formation processes and their resistance to natural and anthropogenic factors. Heterotrophic organisms that inhabit the soil (in particular, organic and organogenic horizons), provide a complex transformation of detritus, participate in the processes of decomposition and resynthesis of organic substances in it.

The microbial biomass of the soil is represented by the biomass of soil microorganisms (bacteria, fungi, protozoa) in the soil. Its content substantially depends on the type of ecosystem, as well as the complex of hydrothermal conditions and ranges from 1 to 5% of the total content of soil organic matter [21]. These data are confirmed by studies [22], according to which microbial biomass contains from 0.27 to 4.8% of the total carbon content and 0.5 to 15.3% of nitrogen.

One of the important factors on which the temperature sensitivity of organic matter to mineralization depends is the physiological activity of the soil microbiota and it determines the effectiveness of the utilization of the substrate. Therefore, it is advisable to use microbial soil complexes containing cellulolytic microorganisms and bacterial colonies as a microbiological additive for composting in natural conditions. Bacteria and micromycetes are among the most active pulp decomposing microorganisms, however, bacteria play a major role in the decomposition of cellulose wastes during the composting process [23].

In the work it is envisaged to establish the technological features of the inclusion of a microbiological additive to compost mixtures with the food component of SMW, which makes it possible to determine the operating parameters of the technological operations of waste management. It is also proposed to establish the patterns of influence of microbiological additives on the biogenic and abiogenic parameters of composting processes, which allows regulating the process of utilization of the food component of SMW, which has not been done before and reflects the scientific novelty of the work. It is provided that the bacterial consortium isolated from the soil exhibits high cellulose activity, which allows accelerating the composting processes and improving the quality characteristics of the finished compost.

The purpose of this study was to study the role of soil microbiocenosis in the process of composting the organic part of SMW and the possibility of accelerating the process of composting plant waste by introducing microbiological additives. It was assumed that their addition to the composition of the feedstock will lead to the activation of microbial activity in the initial stages of the composting process.

In the course of this study, it was necessary to perform the following **tasks:**

1) to investigate the composition of soil microbiocenosis for use as an inoculum and feedstock for the preparation of a microbiological additive;

2) to investigate the effect of microbiological additives on the processes occurring during composting of the organic part of SMW in mesophilic regimes;

3) to investigate the conditions of the processes of composting with the addition of a microbiological additive by the main abiotic and biotic indicators and by the indicators of maturity.

Analysis of recent research and publications

Soil samples were collected in the background relative to the soil of the SMW dump site(MSW-1 «Dalnitsky quarries», taking into account typical signs (typical for the region black southern earth less humus), uniformity of vegetation and meteorological conditions. So, in total, three soil samples from the fields of the Ovidiopolsky district were used, which were taken in an envelope (zig-zag) pattern from a depth of 5–10 cm. After transportation in a plastic container, the samples were subjected to laboratory analysis using standardized methods. Soil samples were freed from inclusions, sifted through a sterile sieve, and the sample of 50 g, which was subject to tenfold dilution (1:1000, 1:10,000, 1:100,000), was selected by the quartering method.

All indicators of a complete bacteriological analysis of the soil were determined by the generally accepted methods of quantitative introduction of the prepared average soil sample into the corresponding media [24], temperature control of the samples, visual inspection and quantitative count of cultures. The total number of bacteria was determined by the deep culturing method on the plain agar medium. The presence of Escherichia coli (coliform bacteria analysis) was determined by culturing in modified medium Kessler. To determine the titre of *Clostridium perfringens*, iron sulfite agar (Wilson-Blair medium) was used. Identification of proteus was carried out according to the method of Shukevich.

A mixture of food, agricultural and landscape gardening wastes was used as a raw material for composting in a weight ratio of 1:1:1. Deciduous waste was used as a filler. The feedstock was crushed to a size of 10–15 mm, dried in air for two hours and loaded into the reactor for composting. To increase the efficiency of the composting process and compare the features of the processes, an extract from the soil was used as a microbiological additive.

The experiment was carried out in three stationary reactors with a volume of 3 dm^3 with forced aeration for 6 weeks. A mixture was introduced into each reactor, composted, in the amount of 1.2 (2/3 of the reactor volume) with a moisture content of 72%, which was mixed with 100 g of soil as an inoculum. 100 ml of distilled water was added to reactor 1 (control), and 100 ml of a microbiological additive was added to reactors 2 and 3, which is an aqueous extract of the soil obtained by incubating the soil with water from the water module 10 for 20 minutes while stirring. An extract from the soil was used as a microbiological additive to increase the efficiency of the composting process.

Reactors 1 and 2 were isolated from exposure to ambient temperature. The reactor 3 was placed in a thermostat with a set temperature of 55°C for the purpose of thermophilic composting. Composting was continued for 6 weeks, while the mixture was composted, stirred daily and moistened to maintain a moisture level of about 70–75%. Each week, we conducted a selection of samples weighing about 10 g for research.

The parameters of the composting process were controlled with a change in temperature, pH and the number of microorganisms in the mixture composted, as well as CO2 emissions from the reactor [25]. The maturity of the compost, which was obtained, was determined by the germination index [26] and the ratio of the total carbon and nitrogen in the mixture, composted [27].

The temperature inside the mixture, composted, measured using an alcohol thermometer, which was fixed in the lid of the reactor, the lower end of which was in the mixture, composted. Once a week, the gas fraction was collected from the reactors using disposable plastic syringes per 50 cm^3. The amount of carbon dioxide in the sample was determined using a gas chromatograph «Hromatek Crystal 5000.2». The determination of total organic carbon was carried out by the Tyurin method, and total nitrogen by the Kjeldahl method [27]. The pH of the aqueous extract was determined using a laboratory pH meter Hanna 221X. The number of microorganisms was determined by culturing on solid nutrient medium in Petri dishes by the method of Koch. The coefficient of germination was determined by the number of seeds of radish seed that germinated, with ten and the length of seedlings in water extracts from composts compared to control (distilled water). The quality control of the finished product was determined by the C/N ratio and the total nitrogen content in the dry matter.

Results of the research and their discussion

The results of the study of the soil microbiocenosis for use as an inoculum and raw material for the further preparation of a microbiological additive in the composting process showed a relatively high quality of soil samples and proved the presence of common microbiological properties of the same type of soil from different sampling sites. Thus, the microbial grouping of typical low-humus black earth is 24.5–30.8 million CFU/g of soil, which is a high indicator of the total number of microorganisms in the soil. Such soils are the most biogenic and are characterized by a high content of bacteria, which are able to assimilate the nitrogen of organo-mineral compounds (6.4–7.9 million CFU/g of soil). Using the averaged data on the total number of microorganisms in the samples studied, we can estimate the soil according to the degree of its enrichment with microorganisms [28] and assign it to group I with a "very rich" rating with average values of 27,700,000 CFU/g of soil containing the total number of microorganisms in the soil.

As for the qualitative composition of the soil samples, it is worth noting that the soil is a multicomponent system, the decomposition and transformation of which depends on the functioning of a whole complex of microorganisms capable of producing such exoenzymes as cellulase, phosphatase, chitinase, dehydrogenase, etc. The main groups of such organisms are fungal and bacterial microflora, therefore, for a more detailed understanding and explanation of the composting process, the total number of bacteria and fungi was taken into account.

Since the main component of the organic fraction is cellulose, it is advisable, along with determining the total number of bacterial and fungal components of the microflora, to determine the number of cellulose microorganisms. An assessment of the change in the microbial population of compost mixtures has been carried out, which suggests that bacteria in the studied samples dominate the fungi (Fig. 1).

Based on various morphological and biochemical characteristics, it was determined that most microorganisms isolated in pure culture belonged to the genus Bacillus. The entire bacterial community is divided into three main groups: gram-positive cocci, gram-positive bacilli and gram-negative bacilli. The first group is represented by bacteria of the genus *Micrococcus*, *Planococcus* and *Staphylococcus*. All gram-positive bacteria belong to the genus Bacillus. Gram-negative bacteria, found in specimens, were representatives of the genus *Enterobacter* and *Flavobacterium*.

Among the representatives of mushroom flora, mainly *Euroocomycetes* and *Ficomyces* were found. In samples of two soil extracts anaerobic cellulose-decomposing bacteria of the genus *Clostridium perfringens*, insignificant number of bacteria of the genus *Proteus* were found; in all three samples of the series of experiments, no bacteria of the *E. coli* group was detected, which in general indicates a high sanitary-hygienic index of the soils examined and proves the possibility of their use as an inoculum in the compostingprocess.

Thus, enrichment of the microbial consortium of compost mixtures in the initial stage of cellulose-decomposing organisms can help reduce the time of waste composting: mesophilic bacteria are the dominant organic waste debris at the initial stages of composting. During the thermophilic phase, they are replaced by thermotolerant bacteria. The domination of bacteria is due to their ability to grow rapidly, using proteins and other available substrates, as well as tolerance to high temperatures.

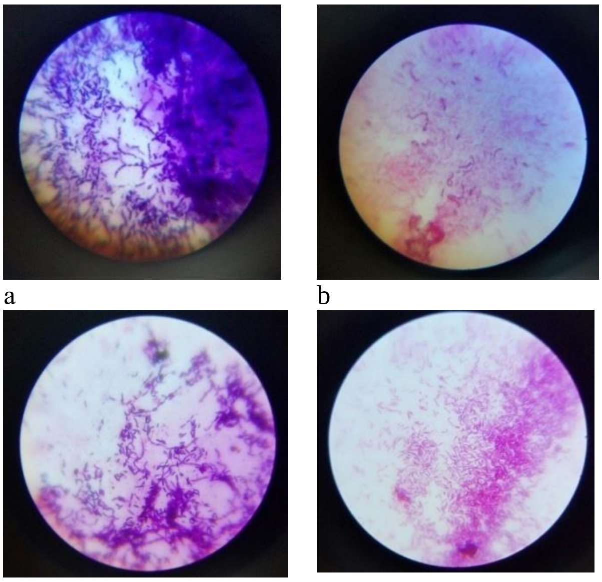

Fig. 1. Representatives of microbial complexes (a – Myxococcoles, b – Bacillus mycoides, c –B. subtilis, d– B. pasteurii), 1000-fold increase

Destruction of cellulose is carried out by bacteria, fungi and actinomycetes under various aeration conditions, at different temperatures and at various pH values of the medium. The development of microorganisms on cellulose involves biosynthesis and the removal of cellulases. The regulation of the process of biosynthesis and excretion of enzymes is controlled by the mechanisms of induction and catabolistic repression. Cellulase synthesis inducers can be cellulose, cellobiose, lactose, etc. The reagent of biosynthesis of cellulases is glucose most often. Some organisms synthesize cellulolytic enzymes when they grow on any substrate, others, for example, bacteria belonging to the genus *Achromobacter, Pseudomonas, Vibrio, Cellulomonas*, use cellulose only when there are no other sources of carbon.

The process of destruction of fiber begins with hydrolysis. Bacteria are able to break down cellulose under anaerobic and aerobic conditions. Most of the anaerobic cellulose bacteria identified in the soil extracts belong to the genus Clostridium.

Other anaerobic bacteria can also decompose cellulose: *Acetovibriocelhdolyticus, Bacteroidessuccinogenes, Anaerocellumthermophillum, Thermotoganeapolitana, Halocellacellulolytica.* All of these bacteria form the extracellular complex of cellulases, and the products of cellulose fermentation are ethanol, acetic, formic and lactic acids, molecular hydrogen and carbon dioxide, and extracellular cellulose is decomposed into celobiose. Cellulose is decomposed to actinomycetes, representatives of the genera *Streptosporangium, Microbiospora, and also the species Streptomycescellulosae, Micromonosporachalcea, Thermoactynomycescellulosae, Thermomonosporacurvata*.

Therefore, in the future, it was necessary to evaluate whether inoculation of compost mixtures with biological additives affects the composting process of solid waste. The conditions of the experiment are presented in the flowchart in Figure 2.

In general, the completeness of the composting process is characterized by two concepts – "stability" and "maturity" of compost, which, despite their conceptual differences, are simultaneously used to determine the degree of decomposition of organic substances in the composting process. Were selected parameters that allow to evaluate both the intensity of decomposition of organic substances (temperature, organic matter content, soluble organic carbon and ammonium nitrogen) and its stability (respiratory activity and cellulolytic activity, number of bacteria and micromycetes) and maturity (pH, phytotoxicity).

The results of studies of changes in the pH of the mixture, composted with a microbiological additive, are presented in Fig. 3.

Initial pH value of raw materials was subacidic, close to neutral (6.3). After the composting started, the pH value in the mesophilic regime in the reactor 2 decreased to 5.1 before the second week, at the fifth week it rose to 8.1, then decreased to 7.6. This can be explained by the formation of organic acids in the process of fermentation, and then their neutralization. Under the thermophilic conditions in the reactor 3 after the first week, the composting of the pH of the medium became alkalescent (8.3), which can be explained by the release of quaternary ammonium bases and salts, and then gradually decreased, stabilized at the value of 7.1. Thus, in reactors with a microbiological additive when mesophilic composting at the initial stage of composting, the pH was deviated to the side of the subacidic parameters, with the thermophilic -

in the direction of alkalescent ones. The pH values observed in reactors 2 and 3 at the end of the composting process are optimal for growing plants and meet the requirements of mature compost. Stabilization and even a slight decrease in the pH level observed at the last week is likely to result from the formation of humus-like substances, as indicated indirectly by the stabilization of organic matter and soluble organic carbon during this period.

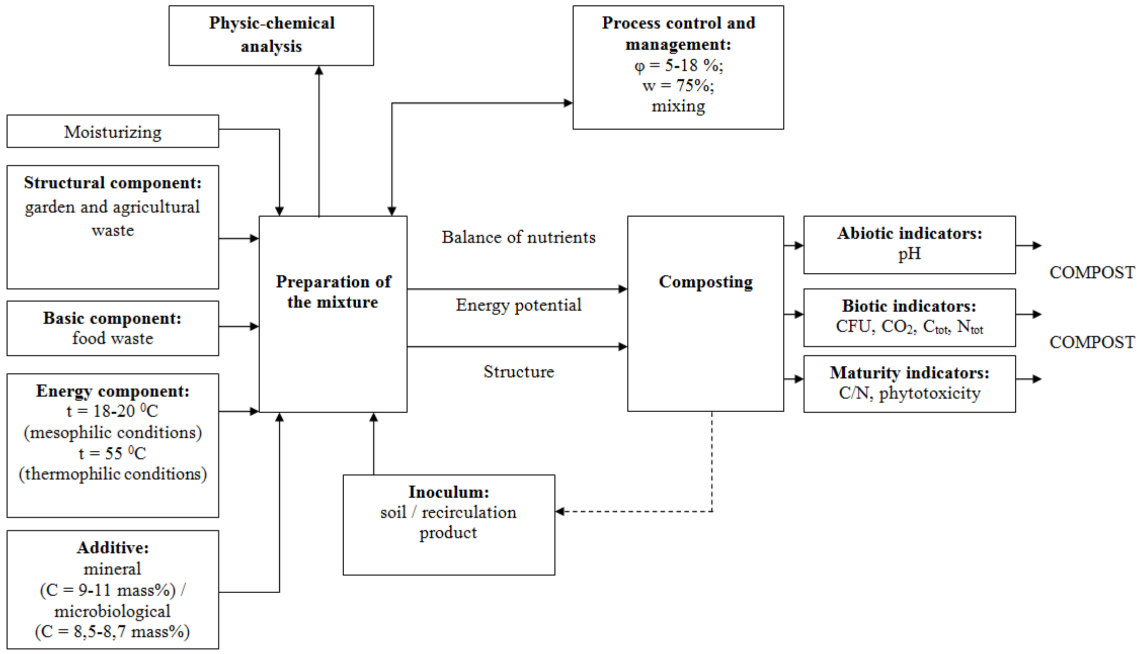

Fig. 2. Block diagram of preparation of compost mixture and control of composting process

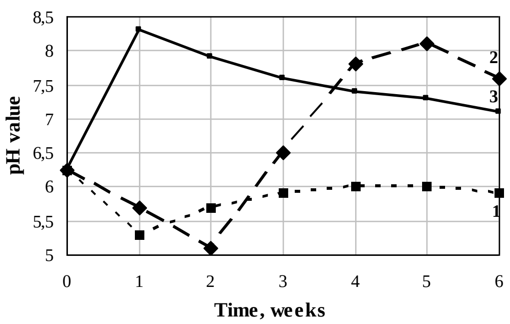

Fig. 3. Change of the pH of the composted mixture in microbiological reactors in the mesophilic (2) and thermophilic modes (3) in comparison with the control sample (1)

The results of the control of the number of colonies of microorganisms are quite consistent with the notions of the curves of growth of culture in periodic conditions. The rate of destruction of organic matter is directly dependent on the number of microorganisms and the composition of the microbial colonies of the mixture, which is composted. In reactor 2, accelerated growth of mesophilic microflora was observed, since the temperature in them was 23–25°C. In reactor 3, thermophiles reached a significantly larger number, since temperature conditions were more suitable for their growth (55°C). Thus, the addition of bio-additives based on soil extract increases the number of microflora in the compost samples by 2–3 times compared with the control. Since bacterial colonies correspond to composting for the decomposing of the organic part of the mixture, their increase in various modes of composting is expected to activate the formation of compost. By the end of the composting process, there is a significant increase in the number of bacteria, in particular, cellulose-decomposing. So, if at the beginning of composting their number was $1.2–2.3 \cdot 10^6$ $CFU \cdot g^{-1}$, then at the end of the process it was 2–4 times higher. The number of cellulose fungi, on the contrary, sharply decreased from $0.7–1.9 \cdot 10^4$ $CFU \cdot g^{-1}$ at the initial stage of composting to their complete elimination at the end. The likely reason for this dominance of bacteria is an increase in temperature, which creates unfavorable living conditions for most fungi.

The activity of microorganisms can be judged by the intensity of their respiration (oxygen consumption or release of carbon dioxide) presented in Fig. 4 The time dependence of the change in CO_2 concentration in the reactor space is indicative of changes in the activity of the microbial community during the composting process.

The activity of microorganisms is much higher in a reactor that is in thermophilic conditions (reactor 3). In reactors 2 and 3, the peak activity is for the period from the second to the third week. Peaks of respiratory activity coincide with an increase in the rate of destruction of organic matter. In the first weeks of composting microorganisms actively decompose easily accessible compounds, which leads to an increase in CO_2 production. It is during this period that high rate of mineralization of organic matter and the maximum decrease in the content of soluble organic carbon is observed (Fig. 5).

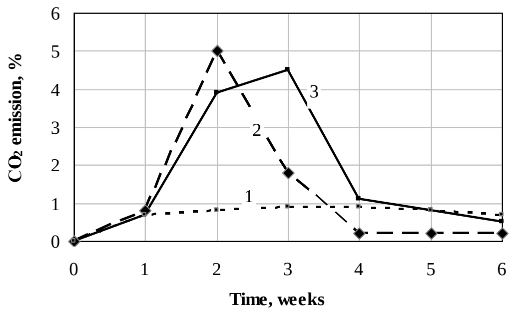

Fig. 4. Change of CO_2 emissions from reactors during composting process of the composted mixture in reactors with microbiological additive in mesophilic (2) and thermophilic modes (3) in comparison with control sample (1)

Since the peaks of activity in mesophilic and thermophilic conditions do not coincide, we can assume that in thermophilic conditions in the third week, bacterial colonies begin to more actively decompose complex organic compounds. At the final stage, the reduction and stabilization of the level of activity indicates that all available substances in the composted mixture are mineralized by microorganisms. Thus, the introduction of the microbiological additive stimulates the increase in the activity of the community of microorganisms in the initial stages of composting – within three weeks, which indicates that it is during these terms that the destruction of the organic part of the composted mixture is actively taking place.

The nature of the change in the number of total Carbon from the time of composting, shown in Fig. 5 is approximately the same for all three reactors: in the first 4 weeks mineralization of a large amount of organic matter (about 7%), then Carbon is consumed insignificantly (3–4%). Maximum rates of consumption of organic substances in all reactors were observed after the second week, and the introduction of a microbiological additive doubles the rate of Carbon expansion, which confirms the role of the soil microflora in destroying the organic part of the composted mixture in both temperature regimes.

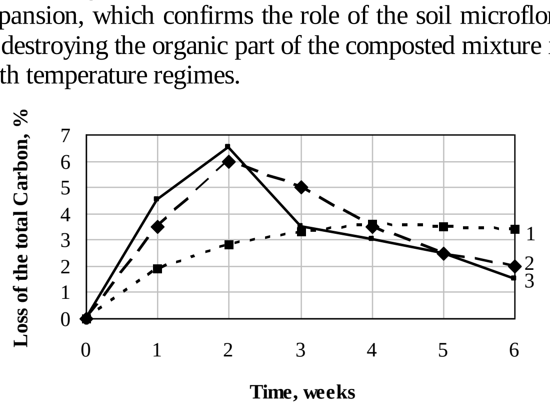

Fig. 5. Change in the rate of loss of the total Carbon in a composted mixture in reactors with a microbiological additive in the mesophilic (2) and thermophilic modes (3) as compared to the control sample (1)

The total losses of the total Carbon (Fig. 6) were somewhat higher in reactors 2 and 3 (21–22%) than in reactor 1 (about 12%). Thus, the overall losses and the rate of loss of the total Carbon are more pronounced when using a microbiological additive in both the thermophilic and mesophilic regimes, which suggests a greater efficiency of the composting process, which is obviously influenced by bacterial colonies of bio Additives – respectively thermophilic and mesophilic.

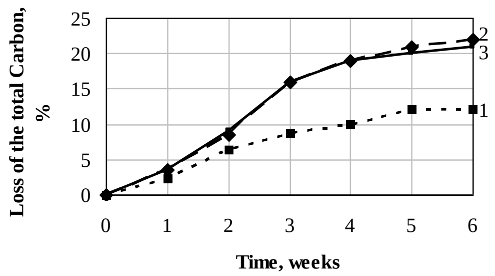

Fig. 6. Changes in the rate of loss of the total Carbon in the composite mixture in the reactors with mineral additive in the mesophilic (2) and thermophilic modes (3) as compared to the control sample (1)

The change in the content of the total nitrogene characterizes the dynamics of mineralization of nitrogen-containing substances. As can be seen from Fig. 7, the initial content of nitrogen in reactors is different: the largest amount is observed in reactors 3 and 2 (2 and 1.5 g/kg), which can be explained by the presence of bacterial colonies (possibly tuber bacteria), against 0.5 g/kg Nitrogen in a control reactor without the addition of a microbiological additive. The nature of the change in the content of the total Nitrogen in the composted mixture is virtually identical for all reactors (Fig. 7).

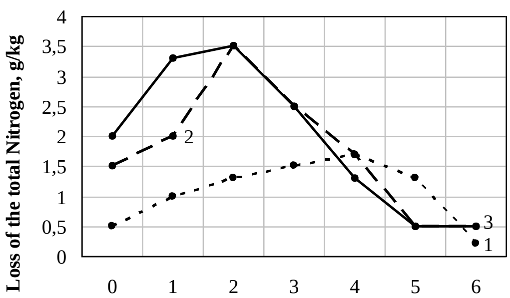

Fig. 7. Changes in the rate of loss of the total nitrogen in a composted mixture in reactors with a microbiological additive in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample (1)

The maximum nitrogen loss rates in all reactors were observed after the second week, and in reactors 2 and 3 they were greater (3.5 g/kg per week) than in reactor 1. Similar changes in the content of total nitrogene at the beginning of composting were associated with active the decomposition of nitrogen-containing compounds and evidence of the presence of unstable substances. Subsequently, in all experimental variants, there was a decrease in the total Nitrogen level, which by the end of the sixth week amounted to 0.2–0.5 g/kg. In general, at the end of composting, all samples tested showed a total nitrogen content below the level that is advanced to mature compost. However, it should be noted that the level of Nitrogene in mature compost varies in a sufficiently wide range and depends on the time of composting and composition of the source components. In our variant, the composting mixture did not contain substances that are characterized by high levels of Nitrogen (manure, sewage sludge, legume crops, etc.), which explains the reduced amount of nitrogene in the finished compost.

Total losses of nitrogen in reactors 2 and 3 were the largest (about 13 g/kg of dry mass, which is compacted). In the control reactor, the losses of Nitrogen were lower (8 g/kg of dry mass, which is compacted). Thus, the losses of Nitrogen are slightly increased with thermophilic composting, however, both in the thermophilic and mesophilic modes, in the case of the introduction of a microbiological additive, the destruction of organic matter is almost 2 times greater than in the control sample.

Maturity of compost is estimated by the mass ratio in it of total Carbon and total nitrogen (C/N). According to international standards, quality compost should have C/N below 25. Fig. 8 shows the dependence of the change of C/N on the duration of composting. The ratio of C/N reaches the minimum values after the second week of composting and then does not change significantly. The final ratio of C/N in all obtained compost is less than 25, which indicates a reduction in maturation of the compost when the microbiological additive is applied, approximately twice, taking into account the rate of its change.

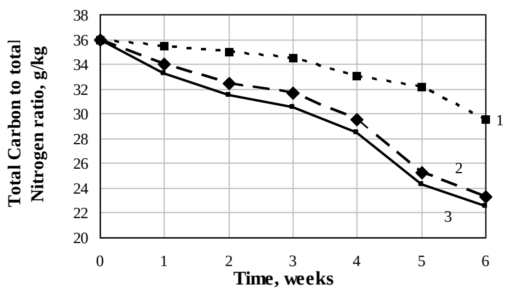

Fig. 8. Changes in the ratio of total Carbon to total Nitrogen in a composted mixture in microbiological reactors in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample

An analysis of the experimental study suggests that the intensity of destruction of the organic part of the mixture of municipal waste that is composted depends on the bacterial colonies derived from the soil extract and doubles both in the mesophilic and in the thermophilic conditions. The activity of thermophilic microorganisms is somewhat higher, however, taking into account the energy costs of heating the composted mixture, it is possible to recommend composting in mesophilic mode with the addition of dietary supplements as a resource-saving means of composting organic waste.

The results of the study indicate that the index of seed germination of radish is gradually reduced with an increase in the length of composting (Fig. 9). Compost with germination index less than 80% is considered phytotoxic, more than 80% – mature.

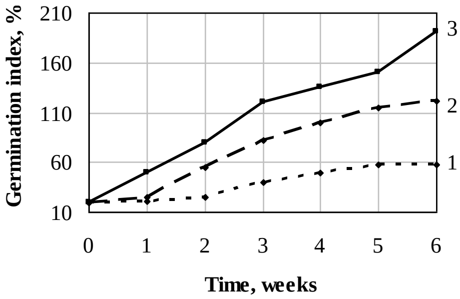

Fig. 9. Changes in the germination index in the composting process in a composted mixture in reactors with a microbiological additive in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample (1)

After 6 weeks compost composting in reactors 2 and 3 is characterized by a germination index of more than 100%, indicating that the compost is not only free from phytotoxins, but also has a stimulating effect on germination. Experimental data of the research allow us to conclude that maturation of the compost in thermophilic conditions is completed faster than in the mesophilic, and the duration of maturation of the compost when the microbiological additive is accelerated by 3.3 times under the thermophilic conditions and 2.1 times by the mesophilic ones. Thus, the temperature regime affects the maturity of the compost in the stage of germination and the evaluation of the phytotoxicity of the compost, but not the intensity of destruction of the organic matter, since in the mesophilic regime, the mesophilic microflora takes on the destructive role in approximately the same degree as in the thermophilic - thermophilic microflora.

Conclusions

The results of the conducted research allow to draw the following conclusions.

1. Aerobic composting is a highly effective ecologically-manageable biotechnological method for treating the organic part of the TMB.
2. Microbiological characteristic of soil complexes proves the expediency of using the soil as an inoculum during composting, for launching and accelerating the process of biofermentation.
3. The microbiological additive from the soil extract can be used for composting both in the thermophilic and mesophilic modes.
4. The bacterial complex accelerates the composting process of the organic component of the TMV by 3.3 times in the thermophilic regime and 2.1 times in the mesophilic conditions of composting process, which testifies to the efficiency of its use in the processes of TMB processing in order to increase the overall level of environmental safety.

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