

Study of the Conditions for Accelerating the Composting Process when Adding Microbial Communities

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ABSTRACT

The study of the composting process is a very urgent task. The rapid growth in food production leads to the formation of waste, which should be safely disposed of in a natural way – composting. Composting the vegetable component of food waste can significantly reduce the proportion of waste falling into landfills and utilize the food waste from the hotel and restaurant industry. Additional enrichment of the compost mixture of food waste with the «Baikal EM» microbiological additive accelerates the maturation process and enhances the efficiency of the finished compost. Such compost does not contain viable weed seeds or pathogenic microflora and can be used as a fertilizer. In contrast to the control, a sufficient level of germination index is observed for the studied samples and they are not phytotoxic. The finished compost can be used as a fertilizer in agriculture for growing crops. The results obtained indicate that the index of germination of radish seeds increases along with the duration of fermentation of the composted mixture. Communities of microorganisms contained in the «Baikal EM» additive accelerate the natural process of composting, taking an active part in the destruction of the components of the vegetable mixture. The pH value of the finished compost, both under thermophilic and mesophilic conditions, is close to neutral indicators. High values of CO₂ emissions from reactors were recorded in the second week under thermophilic and for 3 weeks under mesophilic conditions. The finished compost that fermented under thermophilic and mesophilic conditions can be used as fertilizer, but considering that additional energy is required to create thermophilic conditions, it is advisable to compost the food waste mixture with the addition of the microbiological additive «Baikal EM» under mesophilic conditions.

Keywords: biotechnology, ecological biotechnologies, composting, biologically active additive, microorganisms, phytotoxicity, microbiological processes, food waste.

INTRODUCTION

An urgent problem of the modern world is the accumulation of waste, the vast majority of which is food waste. Every day, an average Ukrainian produces about 1–1.5 kg of waste, where about 40–70% is food waste or its packaging. The food waste from the industry has a significant impact on the environment. Another important source of food waste includes restaurants and catering establishments, which have a significant impact on the environment. Among all known methods

of food waste of plant origin, composting is safe, but this process has a number of disadvantages. [Filimonau et al. 2019, Nilsson 2011].

Research and improvement of the composting technology is an urgent problem for the scientists around the world, who use various composting methods in their research, such as adding mineral and microbiological impurities, ozone-hydrogen peroxide to the compost mixture, and determine various methods for assessing the maturity of compost [Gliniak et al. 2019, Warman 2013].

The disadvantages of using the composting method include: it is quite long in vivo, while its acceleration is quite energy-intensive and leads to extra costs and additional environmental impacts [Mitchell 2011, Villar et al. 2017]. Such impacts are not desirable for the environment; therefore, the search for new ways to speed up the composting process and improve it is relevant. One of these methods is the addition of microbiological additives and maintaining the temperature [Sagdeeva et al. 2018, Sokolova et al. 2019].

During the preparation of the compost mixture inoculum - southern chernozem little humus was added to the food waste. According to the literature [Liu et al. 2018], the soil is inhabited by microorganisms, which are the driving force of the ecosystem and a cycle of nutrients occurs due to them. Therefore, the use of soil in the preparation of the compost mixture should improve the process and speed up composting.

Purpose of the work

In order to investigate the process of composting food waste under mesophilic temperature conditions with the addition of the «Baikal EM» microbiological additive. The task of the work involved:

- studies of changes in the rate of loss of total carbon and nitrogen;
- studies of the dynamics of changes in the ratio C/N;
- comparative characteristics of mesophilic modes;
- studies of the dynamics of changes in the index of seed germination;
- studies of the dynamics of changes in the pH of the waste food mixture;
- studies of changes in the CO₂ emissions from a reactor.

METHODS AND TECHNIQUES

Experiments were carried out at constant humidity and stirring in mesophilic and thermophilic modes. The food waste mixture that was studied consisted of the peelings of potatoes, carrots, zucchini and cabbage leaves in a weight ratio of 1: 1: 1: 1. The study was conducted with the addition of soil – low-humus southern chernozem type – to the food mixture. The temperature of the composted mixture was determined using

an alcohol thermometer, the end of which was immersed in the test mixture.

Each week, a gas mixture of 50 cm³ was sampled using disposable plastic syringes. A syringe was attached to the pipe for removing gases from the reactors. The gas mixture was sampled 5 minutes after shaking the reactor. In order to determine the amount of carbon dioxide in the sample, a «Chromatec Crystal 5000.2» gas chromatograph was used [Hasan et al. 2019]. Raw material humidity, total Carbon and total Nitrogen were determined by drying the mixture samples to constant weight. The dried samples of the composted mixture were crushed in a porcelain mortar and sieved through a sieve with a hole size of 0.25 mm.

The determination of total carbon was carried out according to the method of Tyurin, and the total nitrogen was determined by using the Kjeldahl method. The samples of the mixture weighing 5 g were placed in 250 cm³ flasks, 50 cm³ of distilled water were added and shaken for 1:00. They were filtered using a folded filter to determine pH, meso- and thermophilic microorganisms and germination coefficients [Rastogi et al. 2020]. The pH value of the aqueous extract of the mixture was determined using a «Testo 206-pH3» laboratory pH meter. The determination of the number of microorganisms was carried out according to the Koch method [Sagdeeva et al. 2018, Zhi-Qiang et al. 2017], namely, by plating on solid medium in Petri dishes. The activity of microorganisms can be estimated by the intensity of oxygen consumption and carbon dioxide emission. By plating on solid medium, namely meat peptone agar, the number of bacteria in the growing communities of microorganisms was determined, as well as dynamics of composting process. The number of microorganisms was counted daily. The number of myxomycetes was obtained 7 days after plating on the solid Chapek medium (g/1). This medium is used for isolation, determination and cultivation of saprophytic species of yeast and mold fungi. The number of cellulose-destructive microorganisms that were grown for 10 days on Hutchinson's medium was obtained with the limit dilution method [Sagdeeva et al. 2018, Warman 2013].

MATERIAL AND RESULTS OF RESEARCH

For the study, a mixture of food waste was selected in a weight ratio of components 1: 1: 1: 1, in the following composition:

- peelings of potatoes;
- peelings of carrots;
- peelings of zucchini;
- cabbage leaves.

Additionally, the soil was added to the food mixture - southern low humus chernozem soil and a microbiological additive – the «Baikal EM» preparation, containing more than 60 strains of microorganisms.

Preliminarily, the mixture was ground to a size of 10-15 mm and dried for 2 hours in air. The fermentation process was carried out for 40 days in the mesophilic temperature mode at 18-20°C and in the thermophilic mode at 50-60°C. During the study, the reactors were isolated from environmental influences. A constant humidity of 72% was maintained and the mixture was stirred.

At the initial stages of composting, microorganisms actively decompose the readily available compounds; this process is accompanied by the release of CO₂. During this period, active mineralization of organic substances and a decrease in the content of dissolved organic carbon occur.

The change in the rate of loss of total carbon in the composted mixture with the microbiological additive in the meso- and thermophilic modes compared to the control is shown in Figure 1.

From the data presented in Figure 1, it can be concluded that when using a microbiological additive in both meso- and thermophilic modes, the total consumption and the rate of consumption of total carbon are more pronounced than in the control sample, which increases the efficiency of the composting process that is stimulated by mesophiles and thermophiles – bacterial communities of the «Baikal EM» additive.

The mineralization of nitrogen-containing substances is accompanied by a change in the total nitrogen content (Fig. 2).

Figure 2 shows the change in the rate of loss of total nitrogen of the composted mixture in the meso- and thermophilic modes compared with the control with the addition of the «Baikal EM» microbial additive.

After the second week of observation, the maximum rates of loss of total nitrogen were recorded, which is associated with the presence of labile

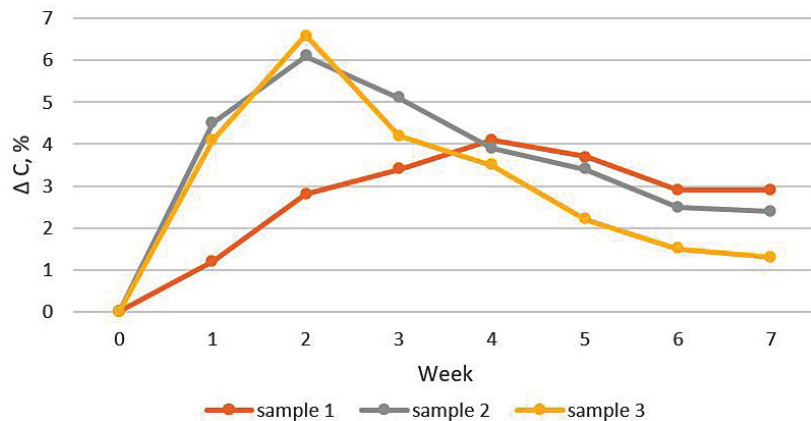


Figure 1. Change in the rate of loss of total carbon

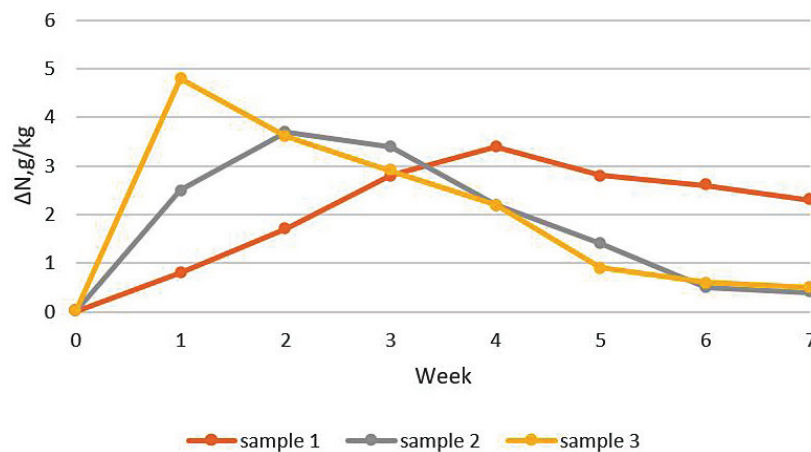


Figure 2. Change in the rate of loss of total nitrogen

substances and the active decomposition of nitrogen-containing compounds in the mixture at the beginning of the composting process. The compost maturity was determined by the germination index and the ratio of the total carbon and nitrogen content in the mixture, which was composted (Fig. 3).

In literature [Zhi-Qiang et al. 2017], the optimal value for the ratio of total carbon to nitrogen (C / N) is taken 25. The value above means that the mixture has not reached a sufficient degree of maturity and is considered phytotoxic.

An analysis of the results of experimental studies indicates that the «Baikal EM» microbiological additive affects the intensity of the destruction of the food waste mixture, increasing it in the meso- (sample 2) and thermophilic (sample 3) modes compared to the control (sample 1). It can be seen from Figure 3 that thermophilic organisms are more active, but to maintain the temperature regime, an additional expenditure of energy resources is required; therefore, following a resource-saving approach when composting food waste, it is advisable to add the «Baikal EM» microbiological additive and conduct the composting process under mesophilic conditions. The

main parameters by which the study was conducted and the composted mixture indicators, as well as their value, are presented in Table 1. According to the results of studies it was revealed that samples 2 and 3 exhibited a high level of compost maturity. The control sample, in which distilled water was used instead of the microbiological additive, was not mature and was phytotoxic.

The study of the index of germination of seeds of vegetable crops on the composts obtained in samples 2 and 3 was carried out by determining the number of germinated seeds of radish (*Raphanussativus*) and the length of seedlings in the aqueous extracts from compost compared to control (sample 1). The dynamics of changes in the germination index are shown in Figure 4.

The results of the study indicate that the index of germination of radish seeds gradually increases along with the duration of fermentation. After radish seed germination, compost in sample 1 is phytotoxic, because its germination index is less than 80% and contains viable weed and pathogenic microflora seeds. Samples 2 and 3 have a germination index of more than 80% and therefore are mature.

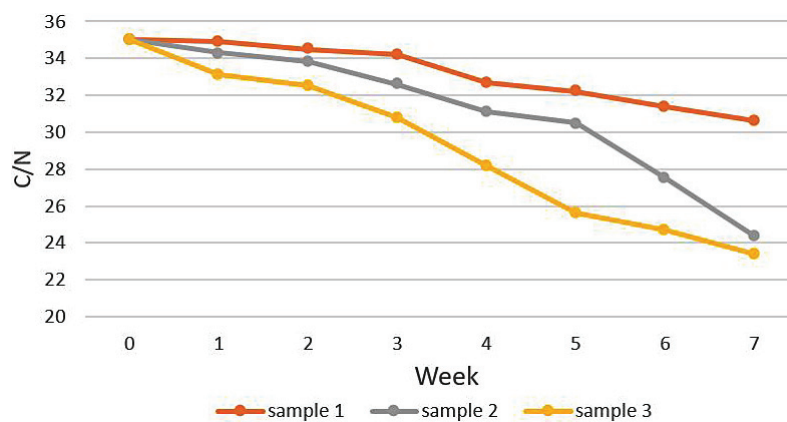


Figure 3. Dynamics of change in the C / N ratio

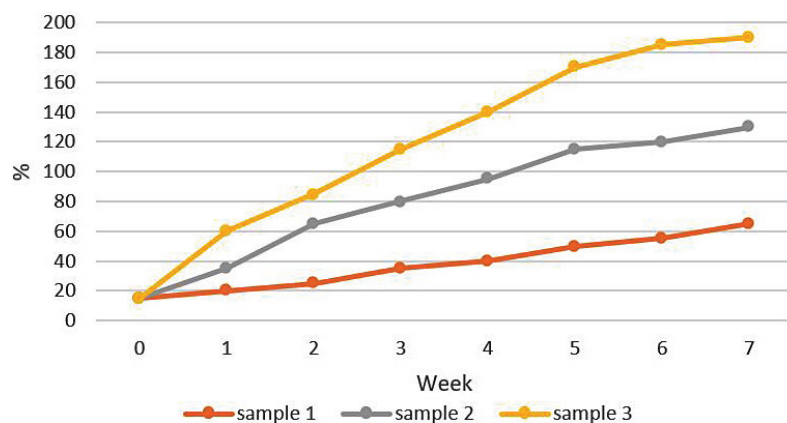


Figure 4. Dynamics of changes in the index of seed germination

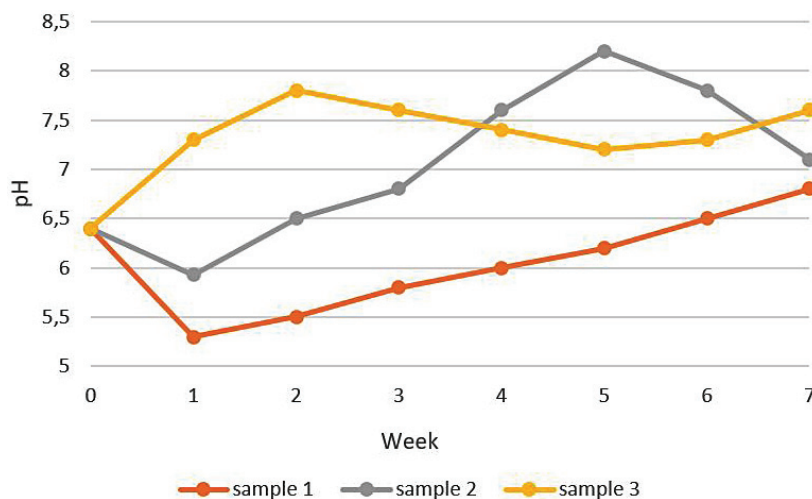
Table 1. Comparative table of the main indicators of the composted mixture

Indicator	Sample 1 (control)	Sample 2 (mesophilic mode)	Sample 3 (thermophilic mode)
Temperature, °C	19	19	55
Humidity, %	72	72	72
Duration, days	40	40	40
C/N	30.6	24.4	23.4
pH (initially), pH	6.4	6.4	6.4
pH (final), pH	7.1	6.8	7.6
Weight of fermented compost (from 1 kg of mixture), g	176	150	120

An important characteristic of compost mixtures is the range of communities of microorganisms and quantitative indicators of each type of microorganism. The highest activity of microorganisms was observed in sample 2 under thermophilic conditions with the addition of the Baikal EM microbiological preparation. However, in sample 3, which was under mesophilic conditions, an increased activity of the colonies was also recorded. In samples 2 and 3, with the addition of a microbiological additive, an increased activity of microorganisms was observed from 12 to 20 days. This allows us to conclude that the «Baikal EM» additive stimulates the activity of microorganisms in comparison with the control sample. In sample 2, an accelerated growth of mesophilic microflora was observed, which is associated with fermentation under mesophilic conditions at a temperature of 19°C. Unlike sample 2, in sample 3, which was fermented in the thermophilic mode, thermophiles reached a significantly larger number due to more favorable temperature conditions, namely, temperature (55°C). Compared to samples 2 and 3, the control, which did not contain the «Baikal EM» microbiological additive, was characterized

by half the number of meso- and thermophilic microorganisms. When composting vegetable raw materials, the parameter that undergoes significant changes in the process of biochemical reactions is the pH of the medium.

During the study, the dynamics of changes in the pH of the raw material was monitored, the results of which are shown in the graph (Fig. 5). The initial pH value of the raw material under study varied in the range of values close to neutral and amounted to 6.4 pH. In the reactors, which were in the mesophilic mode and with the addition of a microbiological additive, at the beginning of the study, a deviation of pH towards slightly acidic (sample 2) pH values was observed. In sample 3, which was studied in the thermophilic mode, the pH of the medium acquired a slightly alkaline value. In the control sample, the pH value was close to slightly acidic, but the final pH values in the control and the studied samples ranged from 6.8 to 7.1 pH. Composting is accompanied by the destruction of biopolymer substances and the conversion of compounds in the direction of low molecular ones. During the study, the changes in the content of organic substances in the food mixture

**Figure 5.** Dynamics of changes in pH of the food mixture

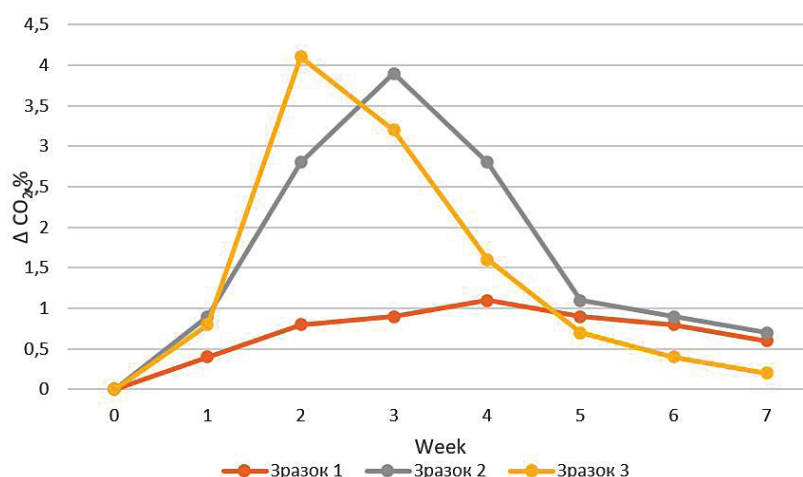


Figure 6. Change of CO₂ emission from the reactor during the composting process

were determined when the «Baikal EM» microbiological additive was added. The main results are shown in Figure 6, the analysis of which allows stating that the growth of activity of microorganisms is recorded, beginning with the second and third weeks of the study in thermo- and mesophilic modes, respectively. It should also be noted that under thermophilic conditions, microorganisms are more active, but in comparison with mesophilic conditions the difference is insignificant.

CONCLUSIONS

While analyzing the properties of the obtained compost, it can be concluded that the introduction of the «Baikal EM» microbiological additive is advisable for fermentation in mesophilic modes. Microorganisms are actively involved in the destruction of food waste and accelerate the natural composting process. The consumption of total carbon in the studied samples is more pronounced than in the control, which is associated with additional stimulation of the process by mesophylls and thermophylls. The consumption of total nitrogen was stimulated by the active decomposition of the nitrogen-containing compounds and the presence of labile substances in the studied samples. The C / N ratio in the samples that were composted under mesophilic conditions, in contrast to the control, are close to optimal values and amount to 24.4 and 23.4, respectively.

When determining the index of germination of radish seeds, it was found that both studied samples, compared to the control, are mature and do not contain pathogenic microflora and weed seeds. In the process of composting, an important

indicator that was studied was the pH value, which under mesophilic conditions deviated to slightly acidic, whereas under thermophilic conditions – to slightly alkaline pH values. However, at the end of the composting process, approximately the same pH values of the finished compost medium were recorded in all three samples. When studying the dynamics of CO₂ emission from reactors, an increased activity of communities of microorganisms was detected under thermophilic conditions compared with the control, and under mesophilic conditions the difference is insignificant.

Summarizing the above conclusions, it can be stated that the mixtures that were studied under meso- and thermophilic conditions can be used as fertilizer, since the compost is mature and does not contain seeds of harmful weeds and pathogenic organisms. The compost, which matured under thermophilic conditions, was characterized by a high number of thermophiles; this is due to more comfortable living conditions of microorganisms. However, taking into account that the creation of thermophilic conditions requires an additional waste of energy resources and considering the economic component, it is more expedient to carry out composting under mesophilic conditions with the addition of the «Baikal EM» microbiological additive.

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