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# Acquisition of organic-mineral fertilizers based on compost from plant raw materials

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**Abstract**
The acceleration of the possibility of the composting process of plant waste with mineral additives has been studied. The proposed method has proven itself during both thermophilic and mesophilic composting. There was no change in the ripening period of the compost obtained with the presence of mineral additives compared to the microbiological fertilizers. The received organic mineral fertilizers were enriched with a fairly high amount of nitrogen, phosphorus, potassium, and magnesium compounds.

**Keywords:** organic-mineral, plant raw materials, acceleration

## Introduction

Land degradation is one of the most acute problems of modern nature use. With the depletion of humus and biophilic elements in the soil, the organic and mineral nutrition of the soil biota is severely disrupted, the conditions of oligotrophy increase, the general biological activity and fertility of the soil decreases, it causes erosion, chemical and bacterial pollution [1]. The seriousness of this problem is aggravated by the lack of organic fertilizers, without which it is impossible to imagine the fertility of the soil [2].

According to the monitoring of landfills for disposal of solid waste, vegetable waste has a significant share (25-30%) of the total volume of solid waste, and it includes 1. landscape gardening (15-17%) 2. food (10-13%) waste [3]. The most environmentally friendly method for processing this type of waste is compost. Composting is a method of decontamination of domestic, agricultural, and some solid industrial waste based on the decomposition of organic matter by microorganisms. The final product of decomposition is a hygienically clean non-toxic substance, which is successfully used firstly as means of stimulating the regeneration of soil ecosystems, and secondly as an organic fertilizer can be used.

However, composting has gained relatively low popularity compared to other waste disposal methods due to disadvantages such as long production cycles and sometimes unstable product quality. Therefore, many studies in the field of BST (solid industrial waste) processing have been devoted to ways to accelerate the composting process. This can be achieved in various ways, for example, by creating highly efficient composting machines and changing the biotic (vermicomposting, use of communities of microorganisms) or abiotic (temperature, pH, etc.) parameters of the process.

This study aimed to study the availability of mineral additives to accelerate the co-composting process of plant waste. It was assumed that their inclusion in the composition of raw materials would lead to the activation of microbial activity in the initial stages of the process. The main factors affecting the composting process are temperature, aeration, humidity, and pH.

Temperature is one of the most important parameters that ensures the efficiency of composting. It changes significantly during composting due to the heat effect that occurs as a result of the oxidative destruction of covalent bonds in decomposable substances. Usually, four main temperature stages are distinguished in any composting process: mesophilic, thermophilic, cooling stages, and final ripening of compost.

Studies have shown that the microorganisms of the thermophilic phase play a key role in the decomposition of organic substrates, they decompose more than 2/3 of lignin during composting, while in the mesophilic phase, microorganisms mainly process easily decomposable substances, and in the cooling and ripening phases, the remaining humid substances are decomposed. Based on this, scientists hypothesized that thermophilic microorganisms can process most of the organic matter decomposed by mesophilic microorganisms at other stages. In other words, the mesophilic stage, as well as the cooling and ripening stages, are not essential parts of the composting process, and therefore the composting time can be significantly reduced if the composting mixture is artificially heated to maintain suitable conditions for the growth of thermophiles [4].

Another important parameter of aerobic composting is aeration. There are three types of aeration of compost mixtures: forced aeration, passive aeration; and finally natural aeration methods.

According to a study in which the optimal aeration rate was determined, the most effective way to aerate a compostable mixture from agricultural waste is forced aeration with an air entrainment rate of 0.41 l/min kg of dry compost material [5].

The water content of compostable mixtures is important to obtain high-quality compost. Typically, the composting mixture has a water content of 35-65%, and the process proceeds fairly efficiently. Maintaining these values is especially important in forced ventilation, as water and exhaust gases are removed together. To ensure the high efficiency of the process, the humidity of the composted mixture should not be fallen below 50%.

The pH value of the mixture is another indicator of the efficiency of the composting process. Typically, composted mixture pH values range from 4.5 to 8.1, from a slightly acidic environment (due to the synthesis of carbonic acids) to a slightly alkaline environment (due to the formation of ammonium ions). As a rule, these values are closely related to the activity of microorganisms which involved in composting.

**Experimental Part**

A 1:1:1 mixture of food (potatoes, cabbage leaves), agriculture (weeds), and fallen leaf waste was used as raw material for compost preparation. Fallen leaf litter was taken as filler. The raw material is shredded to a size of 15 mm, air-dried for 3 hours, then mixed with soil and placed in a reactor. To increase the efficiency of the composting process, microbiological fertilizer was prepared separately and solutions of mineral salts (calcium nitrate, potassium pyrophosphate, and magnesium sulfate) were used.

The experiment was carried out in four stationary reactors with a volume of 3 dm3 (with forced ventilation for 6-7 weeks). The conditions for the experiment are given in table 1.

**Table 1:** The conditions of the experiment

| Number of a container | Vaccinator | Additive | Environmental temperature 0C |
|---|---|---|---|
| 1 | Land | Microbiological fertilizer | 16-20 |
| 2 | Land | Microbiological fertilizer | 45 |
| 3 | Land | Mineral | 16-20 |
| 4 | Land | Mineral | 45 |

Each reactor was mixed with 100 g of soil with a moisture content of approximately 80% in a volume of 0.4 kg. Then microbiological fertilizer was added to reactors 1 and 2. Solutions of mineral salts were introduced into the 3rd and 4th reactors in the following quantities:

$Ca\ (NO_3)_2{*}4H_2O$ – 44.48 g/kg, $KH_2PO_4$ *34.7 g/kg, $MgS0_4{*}{\cdot}7H_20$ -6.96 g/kg

Reactors 1 and 3 are isolated from the influence of ambient temperature. Reactors 2 and 4 were placed in a thermostat with a temperature of 45°C to carry out the thermophilic composting.

Composting takes 7 weeks; the composting mixture is stirred weekly and moistened daily to maintain a moisture level up of 70-75%. About 10 g of samples are taken for analysis every week.

The control of composting process parameters was controlled by changing the temperature, pH, the number of microorganisms in the composted mass, and CO2 emission from the containers. The maturity of the obtained compost was determined by the germination index and the ratio of total carbon and total nitrogen (C/N) in the composted mass.

The temperature of the composting mixture was measured using an alcohol thermometer attached to the lid of the reactor, the lower end of which was deep into the composting mixture.

Using 50 cm3 plastic syringes the gas fraction was sampled weekly from the reactors. A syringe was attached to the tube to remove gases from the reactor, then the reactor was shaken to remove gases from the volume of the composted mixture, and after 5 minutes a sample of the gas fraction was taken in a volume of 50 cm3. The amount of carbon dioxide in the sample was determined using a gas chromatograph.

Samples of approximately 6 g of the composted mixture were placed in glass containers and dried to constant weight to determine moisture content, total carbon, and total nitrogen. The samples brought to constant weight were crushed in a porcelain dish, passed through a 0.25 mm sieve, and then we determined total organic carbon according to Turin and total nitrogen according to Keldal. Wet samples weighing 6 g were placed in 200 mL conical flasks, mixed with 45 mL of distilled water, and shaken for 1 h, then filtered and used to determine pH, an abundance of mesophilic and thermophilic microorganisms, and germination coefficient.

Germination rate (compared to distilled water) was determined by the number and length of germinated corn seeds.

**Discussion of Results**

The initial pH of the raw material was close to neutral (6.35). After composting started, the pH in Reactor 1 decreased to 5.1 in the second week, increased to 8.1 in the fifth week, and then dropped to 7.6). After the first week of composting in container 2, the pH became slightly alkaline (8.3), then gradually decreased and stabilized at 7.1. In the reactor with microbiological fertilizer, the mesophilic composting changed to an acidic environment, and in the case of thermophilic to a weak alkaline environment. In the reactor with mineral additives, the situation was reversed: in the thermophilic phase, the environment first became acidic, and then became neutral; In the mesophilic phase, the pH first dropped to 7.6 and then to 5.4. Then the pH was approximately equalized in both composts.

In the mesophilic phase, the pH is weakly acidic, and in the thermophilic phase, the pH is weakly alkaline. Predominant growth of mesophilic microflora was observed in containers 1 and 3 because the temperature in them was at 23-25 °C. In containers 2 and 4, the number of thermophiles increased, because the temperature conditions were suitable for their development. (60-68 °C).The activity of microorganisms can be evaluated by their respiration intensity (oxygen consumption or carbon dioxide release). The dependence of the CO2 gas concentration on time demonstrates the change in the activity of microorganisms during the composting process in the reactor space. The activity of microorganisms is much higher in reactors (reactors 2 and 4) under thermophilic conditions. In reactors 3 and 4, the activity of microorganisms increases more rapidly than in reactors 1 and 2, respectively, and reaches maximum values after the first two weeks of composting, but begins to decline more rapidly after 3-4 weeks. Peak activity in reactors 1 and 2 occurs between the second and third weeks. Thus, the application of mineral additives promotes the rise of the activity of microorganisms in the initial stages of composting. The dependence of the change in the amount of total carbon on the composting time is almost the same for all four reactors: in the first 4 weeks, more organic matter is mineralized.

The change in total nitrogen content in the composted mixture is almost the same in all reactors. The only difference is that in reactors 3 and 4, a mineral supplement containing nitrate ions was introduced, so after the first week, the amount of nitrogen in the composted mass is higher than the amount of nitrogen in the raw material. The maximum nitrogen loss in all reactors was observed after the third week, in reactors 3 and 4 they were higher than in vessels 2 and 1 (3.0 and 2.5 g/kg per week, respectively) (4, 0, and 3.5 g/kg). The total loss of nitrogen was the highest in the 4th reactor. Nitrogen loss was lower in the remaining reactors. Thus, nitrogen loss occurs in the presence of mineral additives in thermophilic composting.

However, at the end of composting, the total nitrogen content in reactors 3 and 4 was 28 and 26 g/kg, respectively, which is 40% more than the total nitrogen content in reactors 1 and 2.

Compost maturity is assessed by the mass ratio of total carbon to total nitrogen (C/N). According to the European standard, the C/N ratio of quality compost should be below 15. The C/N ratio reaches minimum values after the second week of composting and does not change significantly thereafter. At the same time, the C/N ratio practically does not depend on temperature, but it significantly drops when nitrogen is introduced with mineral additives.

The germination index of corn seeds gradually increases as the composting period increases. Compost with a germination index of less than 80% is considered phytotoxic, and more than 80% is mature. After 6 weeks of composting, the composts in containers 2 and 4 are characterized by a germination index of more than 100%, which indicates that the composts are not only free from phytotoxins but also have a germination-stimulating effect. Based on this data, it can be concluded that the ripening of compost in a thermophilic environment is completed faster than in a mesophilic environment, and the ripening time of compost with the presence of a mineral additive is practically the same as the ripening time when using a microbiological additive."

The final C/N ratio of all obtained composts is less than 15, the C/N ratio of compost with MBQ (microbiological manure) is close to 14, and the C/N ratio of compost with mineral addition is about 12.

## Conclusion

The proposed method for composting plant waste with mineral additives was proven during both thermophilic and mesophilic composting. There is not a lot of difference in the ripening time of compost while using mineral supplements compared to compost containing microbiological fertilizer. The fertilizer obtained by this method combines the properties of organic and mineral fertilizers: on the one hand, it improves the structure of the soil and prevents depletion of the fertile layer, on the other hand, it contains components necessary for mineral nutrition. Plants, especially P205 (-20 mg/100 g of dry composted mass when thermophilic and -15 mg/100 g of dry composted mass during mesophilic composting), MgO (0.035% in thermophilic and 0.0056% in mesophilic composting, K2O (1.0 % in thermophilic and 0.55 in mesophilic composting), Ca+2 (0.072% in thermophilic and mesophilic composting -0.0053%). Thus, the number of mineral components in thermophilic composting is greater than the number of mineral components in mesophilic composting, and the ripening period is reduced by 1-2 weeks.

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