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COMPOSTING AS A WAY OF UTILIZATION OF AGRICULTURAL ORGANIC WASTE

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Abstract: Composting is an aerobic, biological waste treatment in which decomposition of organic waste (OW) happens under the influence of microorganisms. Many parameters such as temperature, pH value, C / N ratio, oxygen, and others affect the treatment. The achievement of the optimum values of parameters is accomplished by mixing various fractions of OW and applying various systems for controlling the amount of oxygen and moisture content. The final product obtained after the treatment is a compost that can be further used as an organic fertilizer in agriculture, thus returning nutrients such as N, K, and P into the soil. Currently, mineral fertilizers are used for soil mineralization, which includes the salts of N, P, and K, and their production is provided through the utilization of new resources. Agricultural waste such as wheat straw, animal excrements, and waste from processing wine are some of the types of OW that can be composted, and they also contain N, P, and K as the basis of the composition of mineral fertilizers. By treating them, multiple benefits could be achieved: the OW problem could be solved, the nutrient circle closed, but it could also lead to a reduction in the use of mineral fertilizers. The paper describes the composting process as a possibility of utilizating OW. A mathematical model for a selection of the optimal mixture of agricultural and municipal OW is presented.
Keywords: biological treatment, organic waste, compost, nutrients

INTRODUCTION

Composting is a complex biological process where the decomposition of OW is carried out under the influence of different microorganisms during several phases. The composting process can be used for the treatment of different types of OW such as agricultural, municipal and industrial waste. When mixing two or more fractions of OW the process is known as co-composting. The major advantage of this process is the possibility of utilizing an obtained compost as an organic fertilizer in agriculture.

The composting process is divided into three phases. The first phase is mesophilic. In this phase, easily degradable organic matter (OM) breaks down under the influence of mesophilic microorganisms, and it lasts for several days. After that, in the thermophilic range, degradation of complex OM starts and the temperature increases which leads to heat release in the maturation phase, the rest of the complex OM breaks down, and this phase lasts the longest. At the end of the degradation process, the stabilization of the obtained product occurs [1].

Many factors such as C/N ratio, pH value, moisture, and oxygen content affect the composting process. The optimal C/N ratio is from 20 to 30, the pH value from 5.5 to 8, the moisture content from 50% to 60%, with enough oxygen to perform the process [2]. Higher or lower values than those have a negative impact, which allows the process to slow down and leas to the death of microorganisms. At the end of the process, parameters need to be in the following range: C/N ratio from 10 to 15, moisture content 30%, pH value from 7 to 8.5. The compost obtained with these parameters is stable and can be used as an organic fertilizer.

Because of the complex degradation process of OM and the influence of many parameters, much research has been carried out with the aim of optimizing the composting process and obtaining a stable compost at the end of the process. The research conducted in Taiwan showed that it is possible to get a stable compost at the low value of the C/N ratio of 19.6 and the moisture content of 60% when food and garden waste are composted [4]. The study conducted in China investigated the influence of the amount of maize silage in a mixture of municipal waste and wastewater sludge. The results showed that the share of 15% maize silage leads to the C/N ratio stability and the reduction in moisture [5].

Similar research was conducted in China when the parameters such as the C/N ratio, oxygen, and moisture content and their influence on compost stability were observed in the process of composting swine manure and maize silage. The obtained results showed that oxygen significantly influences the stability, the C/N ratio the maturity and moisture the quality of the compost (if the parameters of the process are: C/N 18, moisture content 65 – 75% and oxygen 0.48l/min kg OM)[6].

Besides these experimental models, a mathematical model for optimization of the composting process has also been developed. The study conducted in Bosna, which dealt with the validation of a mathematical with an experimental one model showed that two parameters have an important influence on the composting process: initial moisture content and oxygen [7].

Compost, which is the final product, can be used in agriculture as an organic fertilizer because of its favorable properties and nutrient content, those significantly reducing the application of mineral fertilizers. In this way, the environmental requirements are linked to the agricultural requirements leading to the sustainability of agricultural systems. By using compost as a fertilizer many benefits can be achieved: reimbursement of macronutrients N, P, and K, improvement of the structure and stabilization of soil, OM mineralization [8].

Many studies were performed on the possibility of using compost as a fertilizer. The research conducted in Brazil showed that the compost obtained from grape pomace has an optimal content of OM and the nutrients that are necessary for plants to grow. However, the problem of the compost application exists, because of the presence of tannins and organic acids [9]. Another, study on the influence of compost obtained from poultry manure on maize growth showed that the application of 8 t/ha improved all physiological parameters for maize growth [10].

This paper presents the potentials and characteristics of OW on the territory of the City of Niš, with the focus on the five fractions of OW from agriculture: grape pomace, cow manure, poultry manure and swine manure, wheat straw, and municipal waste. By using a previously developed mathematical model for OW selection, the optimal mixture was obtained, based on which the quantity of compost was calculated.

EXPERIMENTAL RESEARCH

In this experimental research, OW from agriculture and compostable municipal waste were observed. Fractions of OW from agriculture are wheat straw, cow manure, swine manure, poultry manure, and grape pomace, while fractions of municipal waste are food waste and garden waste. Characteristics of the observed OW fractions C/N ratio, pH value, and moisture content are shown in Table 1.

In order to get an optimal mixture and achieve optimal conditions for composting the process, a mathematical model was developed [11]. A multi-criteria optimization was used, which observed several parameters that have an influence on the process: C/N ratio, pH value, carbon, and moisture content. Also, in the model, the ranking of parameters was conducted, and it was taken that the pH value is more important than carbon content. Boundary conditions in the mathematical model were: the C/N ratio in the range between 25 to 35 and, the moisture content between 50% to 60%. The criteria taken were the maximum carbon content and maximum pH value.

By using a previously developed model, an optimal mixture for composting was obtained, and the boundary conditions were satisfied. The composition of the optimal mixture, contained 20% wheat straw, 40% cow manure, 18% poultry manure, 20% grape pomace and 2% municipal waste. Swine manure did not enter the optimal mixture. The values of the obtained parameters were: C/N ratio 29.6, pH value 6.7 and the share of carbon in the optimal mixture 39.5%.

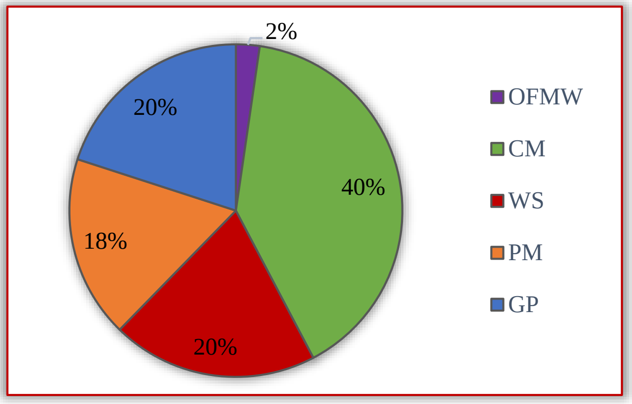

Figure 1. Optimal mixture composition

If this optimal mixture is applied to the available quantities on the territory of City of Niš (Table 2), it can be concluded that there are not enough quantities of OW fractions for achieving the optimal mixture. A new calculation was conducted with the aim of introducing more quantities of OW fractions in the optimal mixture. In the second iteration, the missing quantities of OW were replaced with similar ones and a new optimal mixture was obtained. The boundary conditions are the same: C/N ratio between 25 to 35 and moisture content between 50% to 60%.

Table 1. Characteristics of organic waste fractions [11,12,13,14,15]

Characteristic OW Fraction	C/N	Moisture [%]	pH
Biomass			
Wheat straw	88.7	10.8	7.1
Grape pomace	16.8	56.1	3.5
Animal excrements			
Swine	12.4	66.3	5.5
Cow	24.5	78.2	7.9
Poultry	7.6	78.2	7.3
Rest			
Municipal waste	15.4	65	6.7

Table 2. Available quantities of OW from agriculture and municipal waste [16]

OW Fraction Biomass	Area [ha]	Quantity per inhabitant, throat, ha[t/year]	Total quantity [t/year]
Wheat straw	3,889	3.39	13,183.7
Grape pomace	801	2.76	2,212.8
Animal excrements	Number of throats		
Swine	15,292	1.45	22,168.8
Cow	2,870	19.86	56,998.2
Poultry	128,065	0.0645	8,324.2
Rest	Number of inhabitants		
Municipal waste	260,237	0.06865	17,866

RESULTS AND DISCUSSION

A previously developed mathematical model for determining an optimal mixture composition was implemented for the available quantities of agricultural and municipal waste on the territory of the City of Niš. The aim of the research was to determine how much quantities of OW are available and what is the amount of compost that can be obtained from them. By taking the quantities of individual fractions and based on the percentages in the optimal mixture with the requirement to treat whole amount of wheat straw, it was found that the corresponding quantities of the other fractions are: 26,367.4 t/year cow manure, 11, 667.5 t/year of poultry manure, 13,183.7 t/year of grape pomace and 1,516.1 t/year of municipal waste. On the basis of the available quantities shown in Table 2, it can be seen that the quantities of individual fractions that enter the optimal mixture, poultry manure and grape pomace, are missing. One can attempt to replace the amounts of missing fractions by others, similar fractions that the mathematical model did not take in account at all or in small percentages. Based on the shown characteristics (Table 1) and the available quantities of OW, (Table 2), the necessary quantities of missing fractions were replaced. Poultry manure was replaced with swine manure and grape pomace with municipal waste. In this way, the new mixture with similar characteristics as the optimal one was obtained, and the parameters remained in the given range. From the aspect of the neutralization of OW, using this model, the problem would be solved completely with 100% of wheat straw, poultry and grape pomace, 46.3% annual production of cow manure, 21.9% production of swine manure, and 69.8% of municipal waste. Based on the previously described model and the quantities that enter in the optimal mixture, the theoretical amount of compost obtained from the treatment can be calculated. The amount of 40,460.7 t/year of compost was obtained from 13,183.7 tons of wheat straw, 26,367.4 tons of cow manure, 8,324.2 tons of poultry manure, 4,859.5 tons of swine manure, 2,212.8 tons of grape pomace and 12,487 tons of municipal waste.

CONCLUSION

The composting process is a good way of solving the problem of OW that comes from agriculture and municipal waste. When selecting the fractions of OW for composting, their characteristics and quantities that are available on the territory of the City of Niš were observed. Due to a high C/N ratio and low moisture content, wheat straw is taken as the fraction with the role of maintaining these parameters optimal. By applying the previously developed mathematical model, an optimal mixture was obtained. It includes 20% of grape pomace and wheat straw, 40% of cow manure, 18% of poultry manure and 2% of municipal waste. The parameters were: C/N ratio 29.6, pH value 6.7 and the share of carbon 39.5%. Because of the lack of quantities of individual fractions that enter in the optimal mixture and the surplus of other fractions, and due to their similar characteristics, it is possible to replace certain fractions and still remain within the specified conditions. From the OW utilization perspective, the application of this model would completely solve the problem of wheat straw, grape pomace, and poultry manure, and partly that of cow manure and municipal waste, with the swine manure problem being the least affected. As an overall conclusion, based on the previous results it can be said that this developed mathematical model is optimal in terms of process parameters, OW fractions, and the amount of compost obtained at the end of the process.

Note:
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