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Experimental Study in Composting the Sludge of Food Industry with Municipal Wastes

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Abstract : This article shows that sludge resulting from the aerobic treatment of Düzce Pakmaya Facility can be composted either with domestic organic wastes or by themselves in closed aerobic reactors. The economic raw materials in Düzce and cities in the vicinity of Düzce which can be used for the composting are determined and mathematical postulates were developed. Proving the accuracy of these mathematical postulates with laboratory analyses, it was proved that how the composting process is conducted can be determined beforehand by mathematical postulates with maximum ±9% deviation. The result of the composting of sludge both with domestic organic wastes and by themselves were examined separately and evaluated according to the compost formation criteria. The main aim of this study is to combine solid wastes that are getting a problem day by day and treatment sludge. And also, turn the raw materials that pollute the environment into beneficial products to make a pilot scale approach to the solid waste problem.

Keywords: Composting, organic waste, sludge, solid waste.

1. INTRODUCTION

One of the most serious problems the humanity is confronted with today is the disposal of wastes resulting from various activities. This problem is of greater importance for our rapidly developing country, for the amount of solid wastes increases in parallel with an increase in the population upon an increase in the level of life [8,11].

Having cleaner cities and finding sound and economical solutions to solid wastes that might be detrimental to health also entail benefiting from the existing experiences, along with addressing the issue scientifically. Particularly the irregular disposal of municipal wastes produced in settlements and the wastes due to sludge cause serious health problems, while a large number, and quantities, of wastes cause a much more serious environmental problem [10,12].

There are food resources, such as carbon, nitrogen and phosphorus, in sludge and municipal organic wastes. It can be ensured that these wastes be recycled to be reused in the nature using appropriate technologies and methods when they are detrimental to the environment. All these technologies and methods are briefly called composting [19].

In many developed countries, it has been prohibited to store organic wastes and sludge in landfills. It has been preferred to establish new composting facilities instead of landfills because the existing landfills are about to become full and they have preferred to establish composting facilities as there are no locations to construct new landfills. In this way, they do not have any problems like the lifetime of landfills and they process the existing wastes and make them economically serviceable [22].

This study encompasses the composting of the aerobic sludge of Pakmaya factory alone and together with municipal organic wastes. This study aims both to find a solution to the solid waste problems through biological ways by converting the municipal organic wastes and sludge that contribute to the contamination of the nature into useful products and to have a pilot-scale approach to the recycling of the resulting products in a stable way.

2. MATERIAL AND METHOD

The sludge we use for composting is the sludge resulting from aerobic treatment. The other main substance we used in composting is the food leftovers (organic wastes) resulting from the refectory of the Pakmaya factory. Besides this sludge, auxiliary substances were used to adjust the rate of moisture and to adjust the C/N ratio. When choosing these auxiliary substances, the agricultural policy covering Duzce and the surrounding provinces was taken into consideration in order for the compost production to be as economical as possible. Since a high quantity of hazelnut and corn production takes place in the locality, the hazelnut husk that remained after hazelnuts had been processed and used in the factory, corn silage, and hay were selected as the auxiliary raw materials.

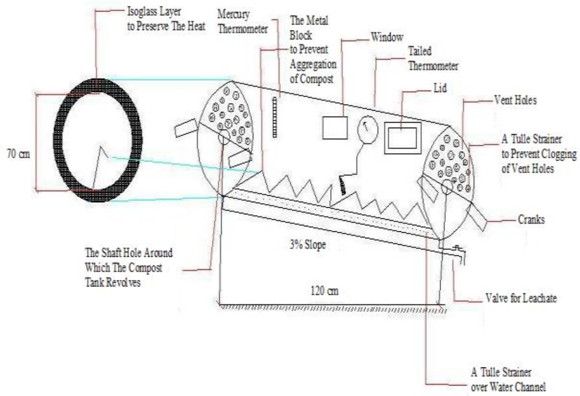

Fig 1. Detailed drawing of the compost tank

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The compost production was performed in a round tank that could turn around its own axis and was designed in closed form in order for the mixing process to be easy. The details of the tank are presented in Figure 1.

2.1. Details of the Compost Tank

The compost tank was designed to be cylindrical so that it could easily turn around a horizontal shaft by being fixed on the pillars. It was wrapped with isoglass in order to preserve the heat to result from the microorganism activities. A lid that could move with a hinge (collapsible) was designed on its top. The lid was planned to be hinged in order to prevent the material in the tank from spilling during the rotation process, to put the materials in it easily and to get the resulting compost from the tank easily. A window was designed so that the interior of the compost tank could be easily seen. It will be possible to see the interior of the compost tank without opening the lid of the compost tank. In this way, entry of cold air, which is due to continually opening the lid, will also be prevented.

A metal block was placed into the compost tank. The metal block was designed to prevent the grouping of the resulting compost during the rotation process, thereby preventing it from becoming unventilated. It was planned to bore small holes with a diameter of 3 cm in the section above the half level of the border parts, thereby providing entry of air into the compost tank. To prevent the compost material from getting out of these holes during the rotation process, it was planned to stick a tulle strainer from the interior of the compost tank.

A tap was designed for the compost tank. The tap was designed to ensure the controlled removal of the water resulting from the decomposition to occur in the compost tank. It was considered to give a 3% slope so that the water to occur could easily flow through the tap. A water channel was planned under the compost tank in order to carry the leachate to the tap. Aluminum tulle was considered over the channel where we would take the leachate. In this way, clogging of the holes on the channel by small particles was prevented.

A thermometer was placed in the compost tanks prepared, while a mercury thermometer was placed outside. The purpose of placing thermometers in the compost tanks was to measure temperature easily by preventing the cooling of compost tanks by continually opening their lids as the pointers of these thermometers were outside. In this way, the temperature of the compost formation could easily be followed together with the outdoor temperature.

Some 2 cranks were planned each for the borders of the compost tank so that the compost tank could easily complete the rotation process on the horizontal shaft.

2.2. Pre-composting Activities

Initially, the sludge of the aerobic treatment of the yeast factory was analyzed within the standard methods. The other substances to be used together with the sludge in composting were also analyzed in accordance with the standard methods.

The results of the analysis are given in Table 1.

	%M	%C	% N	C/N	pH	$\%PO_4$	Conduc. (µs/cm)
Sludge	75.8	32.71	2.88	11.36	8.15	1.19	729
Hazelnut H.	25.5	36.95	0.70	52.78	8.22	0.19	666
Corn S.	24.3	44.18	1.03	42.89	3.98	0.25	1939
Hay	19.7	36.58	2.36	15.50	8.30	0.92	1782
Municipal org. wastes	60.1	56.73	1.14	64.73	5.00	0.11	1565

Table 1. The results of analysis of aerobic sludge of the yeast factory, hazelnut husk, corn silage, hay and municipal organic wastes

Mixtures were determined to find the optimal mixture for the compost tanks. When preparing the mixtures, C/N, % moisture and pH, which affected the yield of composting, were taken into consideration.

For mixture 1 (the mixture, the main substance of which is aerobic sludge only)

1.1: 60% aerobic sludge, 20% hazelnut husk, 15% corn wastes, 5% hay

1.2: 50% aerobic sludge, 30% hazelnut husk, 10% corn wastes, 10% hay

1.3: 50% aerobic sludge, 35% hazelnut husk, 10% corn wastes , 5% hay

1.4: 50% aerobic sludge, 35% hazelnut husk, 5% corn wastes , 10% hay

1.5: 50% aerobic sludge, 40% hazelnut husk, 5% corn wastes , 5% hay

For mixture 2 (the mixture, the main substances of which are aerobic sludge and municipal wastes)

2.1: 20% aerobic sludge, 30% municipal waste, 30% hazelnut husk, 10% corn silage, 10% hay

2.2: 30% aerobic sludge, 20% municipal waste, 30% hazelnut husk, 10% corn silage, 10% hay

2.3: 25% aerobic sludge, 25% municipal waste, 30% hazelnut husk, 10% corn silage, 10% hay

2.4: 20% aerobic sludge, 25% municipal waste, 25% hazelnut husk, 15% corn silage, 15% hay

2.5: 25% aerobic sludge, 35% municipal waste, 30% hazelnut husk, 5% corn silage, 5% hay

Regarding the ideal mixtures prepared, the C/N, % Moisture and pH values are presented in Table 2.

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Table 2. C/N, % Moisture and pH values with respect to the mathematical acknowledgements for mixtures 1 and 2

Parameter	Mixture 1				
	I.M. 1	**I.M. 2**	**I.M. 3**	**I.M. 4**	**I.M. 5**
C/N	24.58	27.35	29.21	27.85	29.71
%Moisture	55.21	49.95	50.24	50.01	50.30
pH	7.55	7.77	7.765	7.98	7.98
Parameter	**Mixture 2**				
	I.M. 1	**I.M. 2**	**I.M. 3**	**I.M. 4**	**I.M. 5**
C/N	43.36	38.02	40.35	40.41	44.25
%Moisture	45.24	46.81	46.02	43.16	49.83
pH	6.82	7.14	6.98	6.77	6.87

As it is known, the results of ideal mixtures (in theory) differ from the results in real life (in practice). Two ideal mixtures optimal for composting were each taken from both mixtures, their laboratory-scale mixtures were prepared, and they were analyzed within the standard methods. The purpose of making these analyses was to see the degree of accuracy of the ideal mixtures.

For the maximum yield of the composting process, the C/N ratio should be 30%, the moisture content should be 50% and pH should be neutral or close to neutral (pH=7) [12].

Mixtures 3 and 5 with a C/N ratio closest to 30% were selected from mixture 1, whereas mixtures 2 and 3 were selected from mixture 2. At the same time, the moisture contents of the mixtures selected from mixtures 1 and 2 were also close to 50%, while their pH values were within the optimal interval.

For the homogeneous preparation of the mixtures in the laboratory, it was ensured that the raw materials be weighed at the rates required and mixed by means of a kitchen mixer. As the kitchen mixer also performed the chopping process while mixing, size diminutions occurred in the grain size. In this way, homogeneous mixtures were obtained. The comparative results of the laboratory-scale mixtures and the mathematical acknowledgements are presented in Table 3.

Table 3. Comparison of ideal mixtures and laboratory data

Mixture 1						
	Ideal mixture			**Laboratory data**		
	C/N	**%M**	**pH**	**C/N**	**%M**	**pH**
3	29.21	50.24	7.76	32.34	51.22	8.10
5	29.71	50.30	7.98	28.65	51.32	8.32
Mixture 2						
	Ideal mixture			**Laboratory data**		
	C/N	**%M**	**pH**	**C/N**	**%M**	**pH**
2	38.02	46.81	7.14	36.23	47.18	7.21
3	40.35	46.02	6.98	41.87	46.0	7.01

As also seen in Table 2.3, there are differences between ideal mixtures and laboratory data. However, these differences are not at a very high rate. The ideal mixtures we had prepared showed accuracy with a maximum ±9% deviation. Following the verification analyses, one of the ideal mixtures we had prepared might be selected to prepare the optimal mixtures for the composting process. Ideal mixture 3 was selected for the 1st mixture tank, whereas ideal mixture 2 was selected for the 2nd mixture tank.

The mixtures began to be prepared with the specified percentages. Nevertheless, it was noticed that hazelnuts and hazelnut shells were present in the hazelnut husk. For the diminution of the grain sizes of hazelnuts and hazelnut shells, they were crushed with a hand cylinder and the process of grain size diminution was performed.

Grain size is among the factors that influence composting. Microorganisms use the oxygen on the surface of the grain. As the surface area of small grains is larger, aerobic degradation is higher in small grains [13].

Following the breaking (adjustment of the grain size) process, it is required to mix the substances to be composted. It is required that this mixture be homogeneous because the more homogeneous this mixture is, the higher the compost yield will be [1]. The mixing process was carried out by a spiral mechanical mixer.

The mechanical mixer does not solely perform the mixing process. With its sharp knives, it also performs cutting, that is to say, the process of grain size diminution. The mechanical mixer is underfed, and as it provides progress against the gravity, it enables us to obtain a nearly homogeneous mixture, while it ensures the prevention of large particles before they enter the mixture, thanks to the sieve placed on the exit (top). Until the materials accumulated in the sieve finished, the mechanical mixer had repeatedly been underfed by the materials concerned and it was ensured that the grain size be diminished and they pass through the sieve. The mechanical mixer could not be used to break the hazelnut shells because as the mechanical mixer provided an upstream flow and as the hazelnut shells were round and slippery, this prevented the hazelnut shells from ascending and breaking. Therefore, the hazelnuts and the hazelnut shells in the hazelnut husk were broken with the hand cylinder and then put into the mechanical mixer.

The Pakmaya factory in Duzce produces pile compost from sludge. After the compost tanks had been filled, one kilogram of compost each was taken from the existing composts of the Pakmaya factory and inoculated to the compost tanks. It was thought that the composting process would function more quickly thanks to inoculation. After mixtures had been prepared at the specified rates, the mixtures were put into the compost tanks and the composting process was launched [29]. External view of the compost tank is presented in Figure 2.

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Fig 2. External view of the compost tank

3. DISCUSSION

The composting process in the compost tanks was carried out between October and November. During the composting process, temperature, pH, C/N and conductivity were regularly measured. During the composting process, variations in these parameters were also observed in time. Temperature was measured for four times per day and the temperature data were reached by calculating their arithmetic mean. The temperature was measured at 8 a.m., 12 a.m., 4 p.m. and 7 p.m. The outdoor temperature was measured, along with that of the compost tank. In this way, the effect of the outdoor temperature on the compost temperature was observed. The relationship of the compost tanks with the outdoor temperature during the composting process is presented in Figures 3 and 4

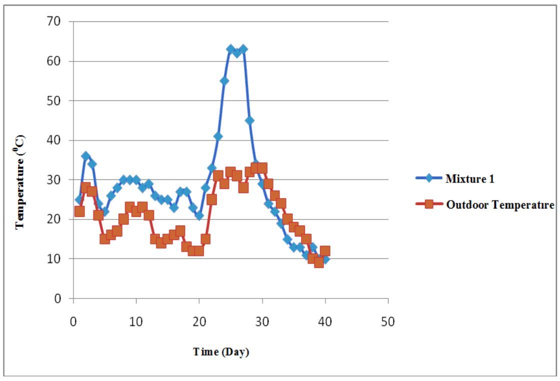

Fig 3. Relationship between the outdoor temperature and the temperature of the compost tank for mixture 1

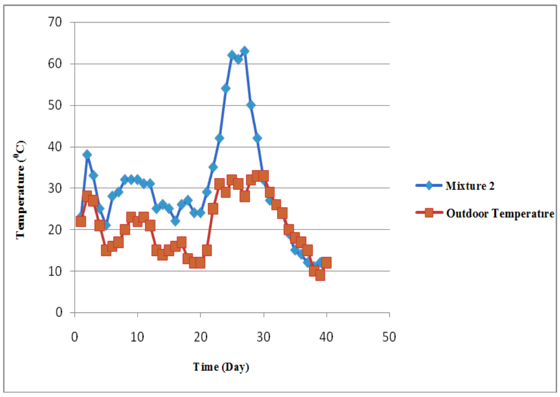

Fig4. Relationship between the outdoor temperature and the temperature of the compost tank for mixture 2

As it will also be understood from the graphs, the outdoor temperature highly varied by day. Accordingly, noticeable variations in temperature occurred in the temperatures of the compost tanks. However, the temperatures of the compost tanks were always higher than the outdoor temperature, which indicates that the compost bacteria were active despite the negative impacts of the weather. As the weather warmed up, a favorable medium was created in order for the compost bacteria to maintain their activities in the optimal way and the temperature increased upon the increase in their activities. The microorganism activity decreased with a decrease in the existing organic substance and the temperature decreased accordingly.
The initial pH of the compost tank (mixture 2) containing municipal organic wastes was lower than that of the compost (mixture 1) tank containing sludge only. However, an increase in pH was observed in both tanks in the first week. This is because the nitrogen found in the medium could not be used by the compost bacteria and left the medium as ammonia [17]. The pH-day graph of the mixtures is presented in Figure 5.

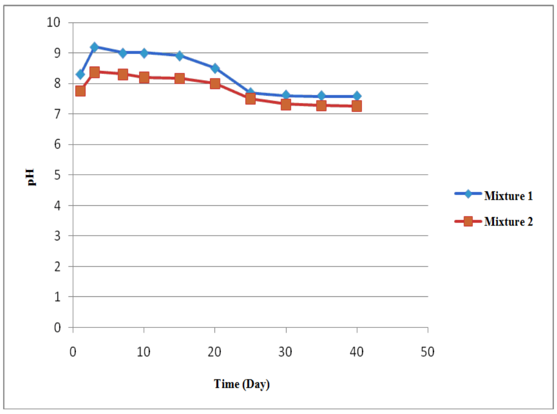

Fig 5. Distribution of variations in pH of mixtures 1 and 2 by day

Compost formation accelerated with increasing weather temperatures. It was observed that although pH increased in the compost formation in the first week, pH decreased as the compost formation accelerated. The formation of acetic acid due to the decomposition of organic substances during the composting process plays a role in the decrease in pH [9,12]. In both tanks, the maximum decline in pH occurred after 20 days.

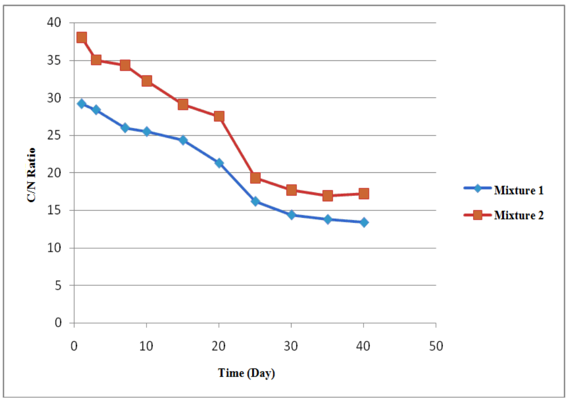

Fig 6. Distribution of variations in C/N of mixtures 1 and 2 by day

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When we look at Figures 3. and 4, it is seen that the compost tanks reached the maximum temperature on the 25th day as the weather warmed up.

It was observed that the C/N ratio in the tank containing the municipal wastes was initially 38.02, while it decreased to 17.52 at the end of the 40th day. It was seen that the C/N ratio in the tank containing sludge only was initially 29.21, whereas the C/N ratio measured on the 40th day reached the value of 13.4. In both mixtures, the C/N ratios decreased as a result of the microorganism activities. When the optimal temperature value was attained, the maximum decrease in C/N was observed.

The electrical conductivity of the mixture containing the municipal wastes was initially lower than that of the compost tank containing sludge only. However, at the end of the composting process, their electrical conductivities converged each other. It is thought that the salts resulting from the decomposition of both compost materials increased electrical conductivity [2].

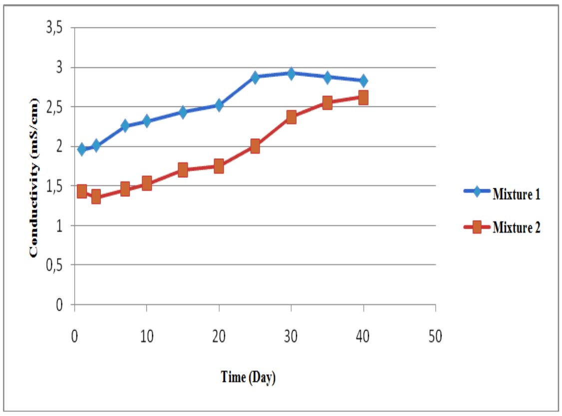

Fig 7. Distribution of variations in the electrical conductivities of mixtures 1 and 2 by day

Temperature is a function of the process and plays an essential role in composting. Owing to the heat release as a result of the biological activity, a rapid increase is seen in the temperatures in the reactor [25]. Nevertheless, the outdoor temperature directly affects the compost tanks. Since our study coincided with the autumn months, the increase in temperature took place at a later date than the normal timing because even though the activity continues in the compost tanks, it cannot break the cold of the outdoor medium. That is, it cannot exceed the threshold level of temperature required for the survival of the thermophilic bacteria. Therefore, either the compost activities to be performed in the autumn and winter months should be carried out in an indoor medium to preserve the temperature or externally-controlled temperature intervention should be made to the compost mechanisms. In this way, positive compost results can be reached.

The C/N ratio has long been used as the sign of stability and maturity. The C/N ratios below 20 were expressed as stable compost by Keller (1961). In their studies, Aydin and Kocasoy [4] and Tosun [30] used (C/N)final/(C/N)initial parameter as the compost stability indicator. In the study by Aydin and Kocasoy, [4] the (C/N)final/(C/N)initial ratio ranged from 0.55 to 0.7, whereas Tosun stated that it should be at the interval of 0.45-0.6. The final C/N ratio of the compost tank consisting only of sludge was 13.4, while the final C/N ratio of the compost tank prepared together with sludge and municipal wastes was 17.52.

In our both compost experiments, our values were below the C/N ratio considered necessary by Keller. The (C/N)final/(C/N)initial ratio of the compost tank consisting only of sludge was 0.46, whereas the (C/N)final/(C/N)initial ratio of the compost tank prepared together with sludge and municipal wastes was 0.45. Our values were below the values found in the study by Aydin and Kocasoy, while they were observed to be between the values found in the study by Tosun. Considering the C/N ratios in the previous studies, we may state that both compost studies we performed showed the character of mature compost at the end of the 40th day.

In order for the composts obtained from the compost tanks to be used in soil, they should provide the limitations laid down in Article 14 of the Regulation on the Control of Soil Pollution (RCSP) published in the Official Gazette No. 25831 dated 31.05.2005. The water content of the compost tank consisting only of sludge was 25%, whereas the water content of the compost tank prepared together with sludge and municipal wastes was 31%.

In Article 14 of the RCSP, it is required that the water content rate of the compost put on the market not exceed 50%. Thus, it is seen that the water content of the compost end-product in the reactors complied with the article concerned.

In the RCSP, in the event that the C/N ratio is greater than 35, it is required to feed the compost with nitrogen in order for the compost reaction to take place under optimal conditions. As the C/N ratios in the composts obtained from both compost tanks in this study are smaller than 35, there is no need for nitrogen addition.

In both compost mechanisms, temperatures turned out to be above 60˚C after the 20th day and remained at these temperatures at least for 2 days. In the section where the compost reached 60-70˚C, basically all pathogenic organisms apart from several spores die within 2 to 3 days [32]. In both studies, it was determined that the compost products were stable and not detrimental to human health.

4. CONCLUSION

In conclusion, this study revealed the applicability of aerobic compostability of the sludge of food industry alone and together with municipal organic wastes.

The results of analysis of the composts performed demonstrate that they comply with the RCSP and can easily be used in soil. A solution was produced through a pilot-scale approach to urban solid waste problems.

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