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Traditional Composting, Bokashi and Takakura: Efficiency in the Degradation of Organic Waste

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Currently, around the world, cities, and populations tend to dispose of all organic waste without any reuse option. Kaza et al., (2020) point out that only 4% of waste is recycled in underdeveloped countries. The impacts generated by these organic residues are gases such as SO_2, NO_x, CO, CO_2, HC, benzene, chloroform, and methane, they produce too suspended particles in air and liquids with a high concentration of infectious biological and toxic elements called leachates; all can affect the health (respiratory and intestinal infections, conjunctivitis, etc.). In the city of Chachapoyas (Peru), 69 % of the waste are organic so is encouraged at the population the practice of compost production, it is due to potential of this in agricultural activities, avoiding too, the disposal of large volumes in landfills and the reduction of greenhouse gas emissions. The purpose of this research was determinate and compare the efficiency of the methods of composting: traditional, Bokashi and Takakura, to evaluate how is degrade the organic matter generated by this city in each case. For it, the three types of compost were characterized evaluate parameters such as final temperature (°C), humidity (%), pH, electrical conductivity (dS/m), Nitrogen (% dry material), Potassium (mg/L) and Phosphorus (mg/L), and the microorganisms present in each compost. The results showed a higher benefit for the Takakura composting method with 78.33 % in degradation, followed by 61.81 % in the Bokashi method and 45 % in traditional composting. Also, regarding the physicochemical characteristics showing that the Takakura method obtained the best values. Likewise, the number of bacteria and fungi showed ranges of good microbial activity in the compost for all forms.

1. Introduction

Today consumer society has led us to generate a large amount of urban waste that is abandoned in dumps or best of cases disposed of in a sanitary landfill. However, the effect of gases on the climate is causing increasing concern, so composting or anaerobic digestion may be an alternative solution (Leow et al., 2018), estimates made by Herrera et al., (2018) indicate that greatest amount of greenhouse gases originate in the final disposal, 532.5 t CO_2-eq/day; Another complication to the problem is the generation of leachates that affect soil conditions due to their high concentrations of organic matter, phosphorus, nitrogen, and biotoxins, (Gómez, 2018). The Peruvian reality is not so far from this problem, cities like Chachapoyas, which population have low incomes, evidence of a high organic fraction of 69 % (MINAM, 2018). This represents an excellent opportunity for the generation of composting and encourage environmental practices that lead to the development of sustainable cities, help to the control of the number of greenhouse gases released in landfills, and reduce the amount of leachate, become them in liquid fertilizers of great contribution to the soil (Haryanta et al., 2022). A review of the national reality outstanding that there are different types of composting plants implemented for the local governments as an alternative for the treatment of organic waste, these different contributions produced different kind of methodologies, such as, traditional composting, Bokashi, and Takakura; each one looking for the highest reduction efficiency and the best quality to be used as a nutritional supplement to the soil. The objective of this research was determined which composting method: traditional, Bokashi, or Takakura is more efficient. For such purpose, it was necessary to determine the physicochemical characteristics and identify the

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microorganisms present in the compost for each method and evaluate the degradation efficiency in the organic fraction of the solid waste generated in the city.

2. Methodology

The research used a sample of traditional composting through a process of degradation of organic waste (vegetables, fruits, sawdust, branches, among others) product of the action of microorganisms who alter or change the composition of the waste, using a pile of composting where the temperature, humidity and pH were controlled, and some irrigation and turning mechanisms were used in order to contribute to the aeration of the pile (Chaves-Arias et al., 2019). In the Bokashi method were used piles with two different substrates in each repetition (three); This method is characterized by having a higher frequency of flipping because reach high temperatures quickly and generates lower GHG emissions (Streitwieser and Cadena, 2018); It also degrades residues such as citrus peels, eggs, or raw meats and provides greater nutritional value to plants (Pandit et al., 2020). In the Takakura method, in addition to the substrates used, mountain microorganisms are added, which allows providing an advantage in degradation time compared to the traditional method (Mejía and Ramos, 2019). Table 1 shows the components of each dose that have was added to the substrate through the fermentative liquid; In this method, three repetitions are also used.

Table 1: Table of substrates for the doses of Bokashi and Takakura

Component	Traditional Method	Bokashi Method		Takakura Method	
	Dose Only	Dose 01	Dose 02	Dose 01	Dose 02
Rice powder	-	1.6 kg	1.2 kg	-	-
Charcoal	-	0.6 kg	-	-	-
Ash	-		0.05 kg	-	-
Chicken manure	-	1.6 kg	1.2 kg	-	-
Yeast	-	0.002 kg	0.0012 kg	-	0.5 kg
Chancaca honey _	-	0.05 L	0.1L	-	-
Salt	-	-	-	0.05 kg	1 kg
Fruit and vegetable peel	-	-	-	0.25 kg	0.25 kg
Mountain microorganisms	not	not	not	yes	yes
Sugar	-	-	-	1 kg	-
Yogurt	-	-	-	-	0.5 L
Soy sauce	-	-	-	0.5 L	-
Sawdust	1kg	-	-	1 kg	1 kg
Water	-			3 L	3 L

According to Román et al., (2013), the efficiency of the compost is determined by the degradation of the residues in the shortest possible time, without losing the quality to be used as fertilizer for the soil (p. 31, 97-98). The procedure of the three composting methods is similar (Figure 1), the difference is related to the substrate with the doses of fermentative liquid that are added experimentally before decomposition. The procedure of the three composting methods is similar (Figure 1), the difference is how add the doses of fermentative substrate liquid in the experiment before decomposition. It begins with the collection and transport of organic waste from seven food markets of Chachapoyas to the treatment plant, where they are classified and separated from impurities (plastics, glass, and metals). The required sample (104 kg) was extracted and distributed in thirteen stacks of 8 kg each, the traditional method used one bed and the Takakura method used six beds M_TK1 (R1, R2, and R3) and M_TK2 (R1, R2, and R3) and another six beds was used by the Bokashi method M_BK1 (R1, R2, and R3) and M_BK2 (R1, R2, and R3). Subsequently, the waste was crushed and combined with sawdust (1/3 proportion); In the case of the traditional method (M_TR1,) it was not added substrate to accelerate the process. Once the piles were formed, they were turned over and the parameters of humidity, temperature, and pH were controlled.

As shown in Figure 1, for Bokashi composting method, the waste piles were mixed in a ratio of 60 % of dry material to 40 % of wet material when the inputs were added to. In the control stage, these piles should not be exposed to the sun, so they were carried out indoors. The piles required turning 1 to 2 times a day so they temperature does not exceed 45 °C. For the Takakura method, the fermentative liquid required 10 to 15 days of maturation and the generation of microbial units with the application of the mountain microorganisms; Subsequently, the pile was prepared, the organic residues and the fermentative liquid were added in a 2:1 ratio between dry material (rice husks, bran, etc.) and earth.

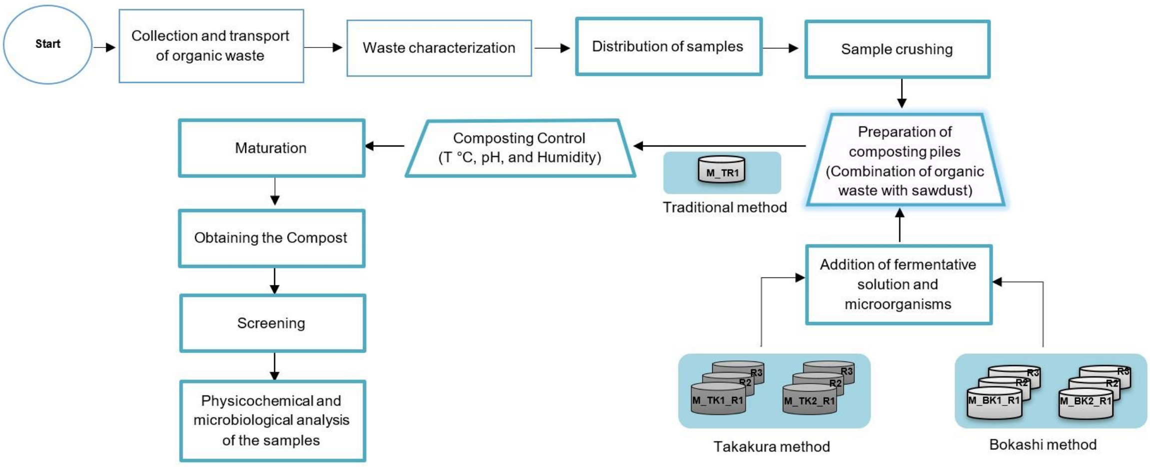

Figure 1: Stages of the composting process for each method in the investigation.

3. Results and discussion

In the production of composting, in the mesophilic phase, the temperature due to microbial activity does not exceed 45 °C and the pH can drop to 4.5. Then, in the thermophilic phase, the mesophilic microorganisms are replaced by others that grow at a higher rate. The temperature is elevated to 60 °C sanitizing the material from contaminants such as Escherichia coli, Salmonella spp, cysts, helminth eggs, fungal spores, and weed seeds. In the cooling phase, the temperature drops again (40-45 °C) due product of C and N consumption. In the main, the pH remains slightly alkaline and, finally, the maturation can take months at room temperature producing reactions for the formation of humic and fulvic acids (Román et al., 2013).

3.1 Physicochemical characteristics for each composting method.

For obtain results, the first step is determining the physicochemical characteristics from the final compost for each composting method as shown in Table 2.

Table 2: Physicochemical characteristics of the final compost for each method

Composting method	Physicochemical characteristics						
	T (°C)	Humidity (%)	pH (1-16)	EC (dS/m)	N (% DM)	K (mg/L)	P (mg/L)
M_TR1	16.5	50	9.72	5.01	3.16	12,551.82	94.98
M_TK1_R1	18.7	60	8.55	10.27	3.40	15,737.01	93.63
M_TK1_R2	19.2	59	7.89	10.65	3.55	14,018.99	127.11
M_TK1_R3	19.3	59	8.53	10.55	3.33	17,074.36	94.79
M_TK2_R1	19.4	60	8.14	8.46	3.41	12,029.34	95.60
M_TK2_R2	19.5	59	8.60	9.75	3.56	12,816.65	102.96
M_TK2_R3	19.4	60	8.03	15.70	3.44	14,351.91	118.07
M_BK1_R1	19.1	60	8.14	19.19	2.72	17,788.29	155.87
M_BK1_R2	19.2	48	8.29	18.97	2.65	16,141.69	115.85
M_BK1_R3	19.0	52	8.23	19.02	2.91	17,081.90	147.69
M_BK2_R1	19.0	52	8.45	18.96	2.04	21,712.53	137.11
M_BK2_R2	24.4	51	8.50	19.48	2.07	22,644.44	130.19
M_BK2_R3	23.8	52	8.69	19.68	2.53	24,824.36	153.75

The quality characteristics of temperature, humidity and pH were contrasted with the quality parameters expressed in the Farmer's Composting Manual. The final temperature was measured on day 38, at the beginning of the maturation stage, and contrasted with the ambient temperature of 17 °C, the closest value was from the traditional method with 16.5 °C; Regarding the Takakura method, the values were similar, with a difference of 0.8 °C between the maximum (19.5 °C) and minimum (18.7 °C) values; The Bokashi method presented a difference of 5.4 °C between the maximum and minimum value in the second dose. The humidity values collected from the analysis were contrasted with the ideal range of 45 % to 60 %, and it was found that the second dose of the Bokashi method is closer to the average of the ideal range. Similarly, the ideal range of pH

is between 4.5 and 8.5. Table 2 of the results shows that the Takakura and Bokashi method is close to the highest value of the range and in the case of the traditional method the value is out of the ideal.
For electrical conductivity and Nitrogen (N) results, they were compared with the Mexican Standard of the Technical Committee for National Standardization of the Environment and Natural Resources, (2018) , which contains the compost quality for agricultural use parameters. The electrical conductivity of the samples showed that the Takakura method is within the established range (0.5 to 12 dS/m) except for the TK2_R3 sample, which exceeds the maximum value of the range by 3.7 dS/m. For the Bokashi method was showed all the values of his results above the norm; This may be due to the composition of the residues that may contain salts or may for the mineralization process of organic matter that would affect the absorption of water if it is high, therefore, the germination of the seeds (Márquez et al., 2008). The percentage of nitrogen found in the samples determined that the traditional method and Takakura exceed the range of 1 % - 3 %, leaving the Bokashi method as the only one that meets the standard.
For the potassium and phosphorus data, which contains the requirements for soil improvers from organic waste; the results showed that for potassium all the methods met the parameter of > 2,500 mg/L. For phosphorus, no method met the standard value of being > 1,000 mg/L.

3.2 Characterization of Microorganisms

The count of mesophilic aerobic microorganisms, as well as molds and yeasts, present in each sample is showed in Table 3: the traditional, Takakura and Bokashi methods.

Table 3: Count of mesophilic microorganisms and molds and yeasts for each composting method

Traditional or Takakura Method (Rx= repeat)	Microorganism mesophiles (CFU/g)	Molds and yeasts (CFU/g)	Method Bokashi (Rx= repeat)	Microorganism mesophiles (CFU/g)	Molds and yeasts (CFU/g)
M_TR1	51×10^{7}	68×10^{5}	--		
M_TK1_R1	22×10^{7}	73×10^{5}	M_BK1_R1	34×10^{7}	26×10^{5}
M_TK1_R2	36×10^{7}	99×10^{5}	M_BK1_R2	37×10^{7}	26×10^{5}
M_TK1_R3	63×10^{7}	73×10^{5}	M_BK1_R3	48×10^{7}	45×10^{5}
M_TK2_R1	14×10^{7}	54×10^{5}	M_BK2_R1	17×10^{7}	40×10^{5}
M_TK2_R2	19×10^{7}	76×10^{5}	M_BK2_R2	44×10^{7}	35×10^{5}
M_TK2_R3	41×10^{7}	54×10^{5}	M_BK2_R3	12x108 –	48×10^{5}

3.3 Evaluation of the degradation efficiency of organic waste.

To evaluate the degradation efficiency of organic waste according to composting methods, Eq. (1) was used, the results of which are shown in table 4, evidencing the percentage degradation efficiency of organic waste:

$$Compost\ Efficiency = \frac{Initial\ Weight - Final\ Weight}{Initial\ Weight}\ x\ 100 \quad (1)$$

Table 4: Degradation efficiency of organic solid waste

Traditional or Takakura Method	Initial Weight (kg)	Final Weight (kg)	Degradation efficiency (%)	Average degradation by the method (%)	Method Bokashi	Initial Weight (kg)	Final Weight (kg)	Degradation efficiency (%)	Average degradation by the method (%)
M_TR1	8	4.4	45.00	45.00	--				
M_TK1_R1	10.5	5.0	52.38		M_BK1_R1	11.8	4.2	64.41	
M_TK1_R2	10.5	4.5	57.14	53.33	M_BK1_R2	11.8	3.9	66.95	64.97
M_TK1_R3	10.5	5.2	50.48		M_BK1_R3	11.8	4.3	63.56	
M_TK2_R1	11.5	5.1	55.65		M_BK2_R1	10.4	4.1	60.58	
M_TK2_R2	11.5	5.5	52.17	53.91	M_BK2_R2	10.4	4.5	56.73	58.65
M_TK2_R3	11.5	5.3	53.91		M_BK2_R3	10.4	4.3	58.65	

The results shows that the Bokashi method is the method presents a better percentage of efficiency in the degradation of organic matter with an average value of 64.97 % for dose 01 and 58.65 % for dose 02. The other methods have less percentage of degradation.

3.4 Determination of the efficiency of the three composting methods.

The selection index (IS) was proposed for each composting technique Eq. (2) in order to determine the efficiency of the three composting methods. According to the evaluation criteria: physicochemical parameters, characterization of microorganisms, and organic matter degradation efficiency are expressed in bad, acceptable, and good levels (Table 5).

$$IS = C_1 * P_1 + C_2 * P_2 + \cdots + C_{10} * P_{10} \quad (2)$$

Table 5: Levels of evaluation criteria

Criteria	Bad (01)	Acceptable (02)	Good (03)
C_{1}: Temperature (°C)	> 20	18 – 20	16 – 18
C_{2}: Moisture (%)	> 60	45 – 60	35 – 45
C_{3}: pH (1-16)	>9.0 _	8.5 – 9.0	6.5 – 8.5
C_{4}: Electrical conductivity (dS /m)	out of range	-	0.5 – 12
C_{5}: Nitrogen (% Dry material)	>3.5 _	2.0 – 3.5	1.0 – 2.0
C_{6}: Potassium (mg/L)	< 2500	-	> 2500
C_{7}: Phosphorus (mg/L)	< 1000	-	> 1000
C_{8}: Mesophilic microorganisms (CFU/g)	< 5 x 10^{10}	-	> 5 x 10^{10}
C_{9}: Molds and yeasts (CFU/g)	out of range	-	1 x 10^{3} – 1 x 10^{7}
C_{10}: Degradation efficiency of Res. Org. (%)	< 30	30 - 50	50 - 70

The weights have been established based on the physicochemical quality parameters of the compost, such as temperature, humidity, pH, electrical conductivity, etc. (Lauri et al., 2021). The presence of mesophilic microorganisms, fungi, and yeasts (Bonilla and Mosquera, 2007) and the degradation efficiency of organic waste are shown in Table 6 (Vallejo et al., 2020).

Table 6: Weighting table for evaluation criteria

Criterion	Weighted	Criterion	Weighted	Criterion	Weighted
Temperature	10	Nitrogen	5	Microorganisms	10
Humidity	10	Match	5	Molds and Yeasts	10
pH	10	Potassium	5	Efficiency (%)	30
EC	5	--	-	--	-

The efficiency percent obtained for each composting method was calculated through the selection of the indicator between the total selection index (IST), the latter is calculated considering that all the criteria have a value of 3 (good), which would give as result in a value of 300, all multiplied by 100 Eq. (3).

$$Total\ efficiency\ of\ the\ composting\ method\ (\%) = \frac{IS}{IST} * 100 \quad (3)$$

Table 7: Efficiency percentage for each composting method

Traditional or Takakura Method	Overall Efficiency (%)	Mean Dose (%)	Method Bokashi	Overall Efficiency (%)	Mean Dose (%)
M_TR1	68.33	68.33			
M_TK1_R1	78.33		M_BK1_R1	78.33	
M_TK1_R2	80.00	78.89	M_BK1_R2	78.33	78.33
M_TK1_R3	78.33		M_BK1_R3	78.33	
M_TK2_R1	81.67		M_BK2_R1	78.33	
M_TK2_R2	76.67	78.89	M_BK2_R2	75.00	75.00
M_TK2_R3	78.33		M_BK2_R3	71.67	

The results (Table 7) were favorable for the Takakura composting method with an average percentage of 78.89 for any of the doses, followed by the Bokashi method with 78.33 % for dose 01 and 75 % for dose 02, and finally the traditional method with 68.33 %.

4. Conclusion

In general, the study was able to identify that the physicochemical characteristics of the compost in the three methods meet the required quality requirements, except the phosphorus concentration according to the consulted regulations; For the results of the count of bacteria and fungi can be said that the sample of them comply with the established sanitization process, the degradation efficiency of all the samples has a percentage greater than 50%, except for the traditional method with 45 %. Finally, it was determined that the most efficient method on average is Takakura with 78.89 %, followed by Bokashi with 76.67 %, and finally the traditional one with 68.33 %.

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