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Impact of Improved Aeration on Decomposition Rate of Enriched Compost

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ABSTRACT

Agricultural activities tend to generate a substantial volume of animal and crop residues. Composting is the most economical and ecologically sustainable option to manage farmyard waste. However, it takes approximately three months to complete decomposition and contains lower plant nutrient percentages than inorganic fertilisers. This study aimed to reduce the decomposition time and improve the nutrient content of compost. Aerobic decomposition was enhanced by aeration inside the pile using a blower with 0.5 l/min/kg airflow. Paddy straw, poultry manure, goat manure, cattle manure and paddy husk ash were mixed in 3:1:1:1:1 ratio respectively as the raw materials and 3% of Eppawala Rock Phosphate was added to the mixture in weight basis. Six piles; (150 X 100 X 80 cm) were prepared, and three piles were aerated for six hours per day while other three piles were left to decompose under the ambient condition as the control. According to the results, aerated and control piles took 35 days and 65 days to complete the decomposition. Total N, available P, exchangeable K, C:N ratio, pH, EC and CEC were analysed in compost samples from aerated (after 35 days) and controls, and the results were, 20.5 g kg^{-1}, 1.8 g kg^{-1}, 10.4 g kg^{-1}, 7, 8.8, 4.3 mS cm^{-1}, 19.3 cmol kg^{-1} and 17.8 g kg^{-1}, 1.5 g kg^{-1}, 9.9 g kg^{-1}, 8.5, 8.8, 3.64 mS cm^{-1}, 21.3 cmol kg^{-1} respectively. Data were analysed using SAS 9.0 software with a 95% confidence interval. The results revealed a significant increment in total N, exchangeable K, C:N ratio, EC and CEC in aerated piles compared to controls. And the nutrient composition of both methods was significantly higher than the commercial compost. Therefore, it can be concluded that decomposition time can be effectively reduced and the nutrient level can be increased by artificial aeration and nutrient enrichment, respectively. However, further studies are recommended to study the economic feasibility.

KEYWORDS: *Decomposition, Enriched compost, Forced air circulation, Plant nutrients*

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INTRODUCTION

Sri Lanka is an agricultural country where crop cultivation and animal rearing are being practised as the leading agricultural activities. These farming activities tend to create a massive amount of farmyard waste materials throughout the year. However, once these wastes get accumulated on the farm, it causes many socio-economic and health problems to human, livestock and environment through contamination. The trash generated on the farm has to be disposed of efficiently and effectively to prevent environmental pollution and to improve the productivity of a farm.

Decomposition is the process of converting straw/manure into available nutrients for the plants. It can happen in two ways, anaerobic and aerobic decomposition. Of these, aerobic decomposition referred to as composting. Composting is a biological process of decomposition in which, organisms under controlled conditions of ventilation, temperature & moisture converts the organic portion into humus-like material, a stable, odour-free soil conditioner. It is a mixture of decayed organic materials decomposed by microorganisms in a warm, moist & aerobic environment & releasing nutrients into readily available plant use forms. It acts as an excellent soil conditioner, as well. It loosens the texture of heavy clay soil, making them better for root growth and improving retain water and nutrients and source of minerals and nutrients essential to plants [3]. It has been defined as a controlled microbial aerobic decomposition process with the formation of stabilised organic materials [1]. Composting is an effective and safe way to reduce the waste mass and volume, destroy pathogens, and stabilise nutrients and organic matter. The key parameters influencing the efficiency of the process are C:N ratio, moisture content, airflow rate, particle size and temperature [2]. Successful optimisation of these parameters may shorten the generation time of the process and result in quality product and answer to the above problems [5].

However, farmers are reluctant to use compost for reasons that align with it, such as longer generation time, higher cost for labour, and lower nutrient concentrations. A higher amount of compost manure must be added to the field to complete nutrition requirement (Mussari *et al.*, 2013) and due to that, the transport costs and labour costs are very high. Hence, this study aimed to introduce a compost generation method from agricultural farm residuals with less generation duration and rich nutrient mixture to popularise the organic farming in Sri Lanka.

METHODOLOGY

Background and experimental location

This study was carried out at the Faculty of Agriculture, Rajarata University of Sri Lanka. Farmyard manure (cattle, poultry and goat manure) was collected and mixed with paddy husk ash with the ratio of 1:1:1:1 in dry weight and rice straw mix to achieve 20:1 (19.89) C: N ratio. Paddy husk ash and Eppawala rock phosphate were mixed at the initial stage to enhance the nutrient level of compost.

Composting heap design setup

The compost heap was built using 48 kg cow dung, 42 kg goat manure, 24 kg poultry manure, and 108 kg paddy straw in 1:2:0.5:4.5 ratios. Raw materials were mixed well, and according to the total weight of raw materials, 7.5 kg Eppawala Rock Phosphate and 24 kg paddy husk ash were added. The total weight (wet basis) of one compost heap was around 255 kg. Approximate dimensions of a compost heap were 150 cm length, 100 cm width and 80 cm height, as shown in figure 01.

Compost piles were covered with black colour polythene. Six piles were built, and among them, three piles were aerated artificially using a blower, and the other three were allowed to aerate naturally. Artificially aerated compost piles were built enclosing a frame made from perforated pipes which is connected to a blower, as shown in figure 02. Frame dimensions were 1.2 m × 0.6 m. Polyvinyl chloride (PVC) pipes with 60 mm diameter were used as perforated pipes. Holes with 20 mm diameter create one side of PVC pipe system. The distance between two holes was 200 mm. Iron mesh pieces were used covered the holes to prevent the whole block. The air blower was connected to the center of one side length pipe to maintain the less variation of air distribution within the pile. An average flow rate of 0.5 l air per kg of compost per minute [9] was maintained. Frames were laid at the base of the compost piles.

The moisture content of the compost pile was maintained by more than 45 % (w/w) by adding water. The temperature was measured daily from three different heights within all six piles at 25 cm,75 cm and 125 cm from bottom to identify composting phases. The piles were mixed once a week and rebuilt them.

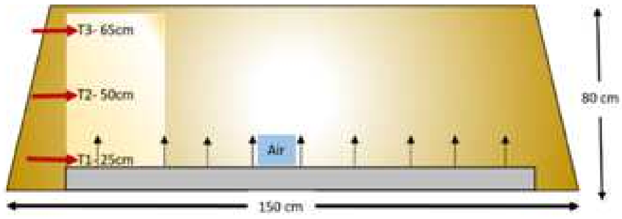

Figure 01: Compost heap arrangement

Sampling and analysis

Total Nitrogen, pH value, Total carbon, Potassium, Phosphorus concentration of raw materials were measured in several stages such as before mixing, just after building heaps, in the two-week intervals and at the end of the decomposition process. Samples were collected at three locations in each composting piles at 0.3 m, 0.55 m, and 0.8 m from the bottom. Air-dried subsamples were ground, then passed through a 0.25 mm sieve and stored in a desiccator for further analysis. The fresh samples were analysed for Organic Matter (OM), pH, NH_4^+-N, NO_3^--N, Electrical Conductivity (EC) and Cation Exchange Capacity (CEC). In contrast, Total Nitrogen (TN) and Total Organic Carbon (TOC) were determined by using air-dried samples. Table 01 shows the measured parameters and the methods used for the analysis [15].

Parameters	Method of analysis	Frequency
Total Organic carbon	Potassium dichromate and H_2SO_4 acid method	2 weeks
Total Nitrogen	Kjeldahl digestion method	2 weeks
NH_4^+-Nitrogen	Calorimetrically by using UV Visible spectrophotometer	2 weeks
NO_3^--Nitrogen	Calorimetrically by using UV Visible spectrophotometer	2 weeks
Phosphorus	Calorimetrically by using UV Visible spectrophotometer	2 weeks
Potassium	Flame photometer method	2 weeks
Electrical Conductivity	Multi Parameter Analyser	2 weeks
CEC	7.0 pH Ammonium Acetate method	2 weeks
pH	Multi Parameter Analyser	2 weeks
Temperature	Thermometer	12 hrs

Table 01: Analytical parameters of compost quality

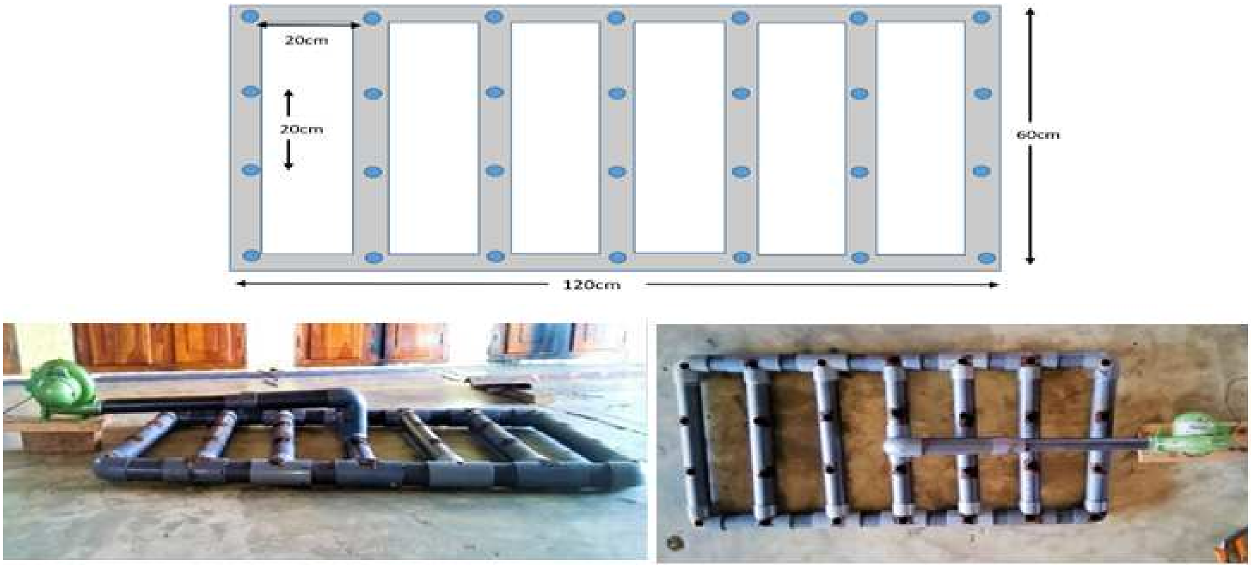

Figure 02: Aeration pipe system

Statistical analysis
Collected data were analysed statistically using pooled T-test to compare composting rate, nutritional levels and variability of temperature among the aerated, non - aerated and commercial compost.

RESULTS AND DISCUSSION
Properties of raw materials
Initial nutrient composition of raw materials (Poultry manure, Cattle manure, Goat manure, Paddy straw and Paddy husk ash) used in this study is shown in Table 02. According to the table, all the manure materials are rich in plant nutrients. Poultry manure contains the maximum amount of nutrients compared to the other raw materials except C:N ratio.

The temperature has been widely recognised as one of the most critical parameters in the composting process [12]. The rise and fall in temperature have been found to have a strong correlation with the microbial activity [13].. The temperature exceeding 55 ^{0}C is necessary to destroy the pathogens in composting mixture for at least three consecutive days [16]. Figure 03 shows the temperature change in the three composting mixtures at different layers during the composting process.

According to the figure, the temperature of the middle layer (60 cm) is higher than the other two layers. The temperature in the bottom layers was the lowest due to the evaporative cooling effect of the incoming air in both types of compost piles. Initially, due to the rapid breakdown of the available OM and nitrogenous compounds by microbial activities, the three composting piles' temperature increased rapidly up to 50 ^{0}C. At the 3rd day in both treatments, the temperature reached a maximum about 58^{0}C in aerated piles and 63^{0}C in non-aerated piles. The fifth day after the heap was built up, the piles' temperature went through three phases: mesophilic, thermophilic and curing & maturation. During the mesophilic phase, activities of mesophilic microorganisms in the compost piles cause to increase the temperature. During the thermophilic phase, the temperature exceeded the tolerance limit of the mesophilic microorganisms and promoted the thermogenic microorganisms' increment. In this study (according to figure 03), the thermophilic phase (>50^{0}C) ensued 3-7 days in both piles.

As the OM became more stabilised, the microbial activity and the OM decomposition rate slowed down, and the temperature in all composting piles gradually decreased to reach ambient temperature. According to the figure, in the aerated piles, the temperature dropped to room temperature within 33 days, hence, can conclude that the composting process completed within those days. After 33 days, the maturation phase was started. However, non-aerated piles reached room temperature after 65 days from the heap built up. That means the non-aerated pile required more than 65 days to complete the decomposition process.

Water content in the compost piles with aeration was decreased rapidly due to high temperature and air stream. Therefore, water was added to maintain the moisture content at a suitable microbial activity level during this period. A temperature drop was observed in each pile every seven days because the compost piles were mixed once a week in both treatments and added water after mixing.

Analysis of compost parameters
Table 03 shows the measured values of nutrient contents and the other parameters of the composting materials obtained from aerated and non – aerated piles at different time intervals (initial, 1st week, 3rd week and 5th week).

Raw materials	Nutritional value in dry weight(g/kg)						
	Total N	Total C	C:N	NH_4^+-N	NO_3^--N	Av. P	Exc. K
Poultry manure	31.70	300.3	9.47	0.44	22.21	1.40	14.53
Cattle manure	18.06	339.3	18.79	0.12	6.10	0.70	8.64
Goat manure	23.04	292.5	12.69	0.15	6.66	0.67	12.11
Paddy straw	9.18	354.9	38.64	0.06	1.85	0.33	5.04
Paddy husk ash	9.03						

Table 02: Initial nutrient composition of raw materials

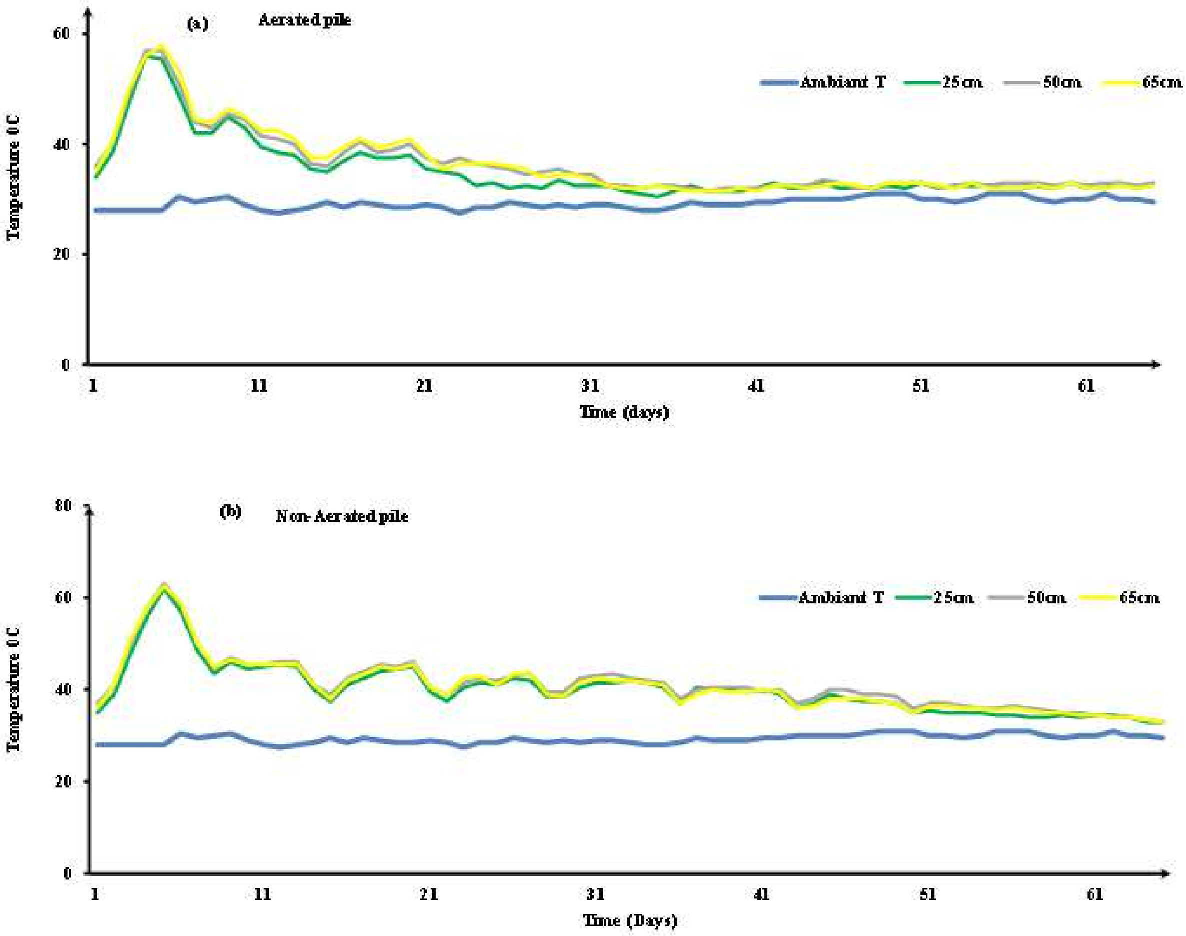

Figure 03: Temperature (^{0}C) in various depths of the (a) aerated compost piles, (b) non-aerated compost piles, during decomposition

Parameters	Treatment							
	Aerated				Non aerated			
	Initial	1st week	3rd week	5th week	Initial	1st week	3rd week	5th week
Total organic carbon (g/kg)	284.7	198.9	170.63	143.33	284.7	222.3	178.43	152.1
Total nitrogen (g/kg)	14.315	16.45	19.565	20.51	14.315	16.17	17.36	17.85
Ammonium-Nitrogen (g/kg)	0.34	0.09	0.09	0.09	0.34	0.14	0.16	0.17
Nitrate- Nitrogen (g/kg)	5.54	6.66	10.79	14.51	5.54	6.66	7.78	8.36
Exchangable Potassium (g/kg)	6.35	8.93	10.01	10.42	6.35	8.53	8.97	9.99
Electrical conductivity (mS/cm)	2.23	3.65	4.18	4.26	2.23	2.82	3.38	3.67
pH	8.99	8.95	8.81	8.99	9.01	8.95	8.83	9.01
C/N ratio	19.89	12.09	8.72	6.99	19.89	13.75	10.28	8.52
Cation Exchange Capacity (Cmol/kg)	8.2	12.1	16	19.2	8.2	13.1	17	21.2
Available Phosphorus (g/kg)	1.02	1.05	1.55	1.75	1.02	1.2	1.2	1.54

Table 03: Compost quality parameters

Total Organic Carbon

During the composting process, organic matter is oxidised and converted to carbon dioxide, water, ammonia and new microbial biomass. The rate of organic matter loss is an indicator of the overall composting rate. During the study, both volume and mass of composting material within the piles were decreased due to the degradation of organic matter during the decomposition. Table 03 shows the variation of organic carbon content in each treatment during the decomposition. According to the table, Total Organic Carbon (TOC) is gradually decreasing in all treatments during the composting process. Initial TOC was 284.7 g/kg and end with 143.33 g/kg in aerated piles and 152.1 g/kg in non-aerated piles. In the aerated piles organic carbon declined in increasing rate since decomposition is an aerobic process. The rate of organic C degradation was more in aerobic piles than anaerobic piles. But there is no significant reduction within the treatments.

Total Nitrogen

According to the results, total nitrogen content shows an increasing trend even in the first week of composting, possibly due to the decrease of substrate carbon resulting from the evolution of CO_2 gas. Total N concentration was increasing due to the rapid degradation of the organic matter, which reduced the weight of the composting mass. Because of the fast degradation of composting materials, the total N concentration was increased significantly (0.0136-Pr value) in aerated piles than non-aerated piles.

Ammonium-Nitrogen

Ammonium and nitrate-nitrogen concentrations provided an indication of compost maturity because the concentration of nitrate should be higher than that of ammonium at the end of the composting process [7]. The table shows the variation of $NH4^+$-N concentration with time. Here, the ammonium levels were recorded as high initially and then dropped rapidly during the decomposition process. According to table 03, initial NH^{4+}-N concentration was 0.34g/kg and rapidly dropped down within one week to 0.09 and 0.14 g/kg in aerated and non-aerated piles respectively. NH_4^+ –N concentration was significantly higher (Pr value-0.0077) in non-aerated piles compared to the aerated piles. It might be due to volatilisation losses due to air circulation [11] and the higher rate of nitrification under aerobic composting caused by comparatively more favourable conditions, particularly oxygen, to survive the nitrifying bacteria. Nitrification is a bio-oxidative process, requiring oxygen for the nitrifying bacteria [14].

Nitrate-Nitrogen

In this study, NO_3^- -N levels increase parallel to the declining of NH4+-N concentration due to nitrification in both treatments. However, the nitrification rate is getting slower during the thermophilic phase due to the inhibition of nitrifiers' activity and growth in temperatures greater than 40 ^{0}C [6]. Therefore, NO_3^--N concentration has increased significantly in aerated piles than non-aerated piles. In non-aerated piles (Pr value-0.0005), the temperature was 40 ^{0}C within 40 days from the beginning. Therefore, NO_3^- -N concentration was lower than aerated piles.

Exchangeable Potassium

Exchangeable K concentration in all treatments increased with composting time, with formulations under aerobic conditions showing significantly (PR value-0.0029) higher concentration than those under anaerobic conditions. The increase in Potassium (K) in both treatments during composting can be caused by concentration-effect from the higher rate of carbon loss when organic matter is decomposed or mineralised into CH_4 or CO_2 [4].

Electrical Conductivity

The Electrical Conductivity (EC) indicates the total salt content in compost, and it may explain the quality of compost to be used as a fertiliser. EC measures the total soluble salts in the compost; higher EC may indicate more nutrients [10]. According to the table, initial electrical conductivity was 2.23 mS/cm and after five weeks were 4.26 and 3.67 mS/cm in aerated and non-aerated piles respectively. Aeration improved significantly (Pr value-0.0006) the EC in aerated piles than non-aerated piles.

pH

According to the results, pH value gradually decreased but did not show considerable variation with the composting process. Initially, the pH showed an average of 9.0, and it is 8.81 and 8.83 in aerated and non-aerated piles after 5 weeks respectively.

C: N Ratio

The carbon to nitrogen (C:N) ratio is one of the critical factors affecting the composting process and the properties of the end product. According to the literature, optimum C:N value for compost raw materials should be 20-30 [8]. According to the results, the initial C:N ratio of the raw materials is 19.89, and it is 6.99 and 8.52 in aerated and non-aerated piles after 5 weeks, respectively. The C:N ratio decreased during the composting process because total N value goes up and C is removed as CO_2 by microbial activities. There is a significant difference of C:N ratio (Pr value-0.0271) between aerated and non-aerated compost piles.

Cation Exchange Capacity

Cation exchange processes maintain nutrients in available forms to plants, prevent leaching of nutrients, and detoxify harmful substances by binding them to the cation exchange sites. The increase in CEC of the compost can be used as an indication of the degree of maturity. The organic matter humidification process leads to an increase in Cation Exchange Capacity during the composting period. In both treatments, CEC was increasing with composting time. CEC variation did not show a significant difference between treatments.

Available Phosphorus

Available P concentration in all treatments increased with composting time. The initial concentration was 1.03 g/kg and showed with 1.77 g/kg and 1.54 g/kg in the aerated and non-aerated pile after five weeks of decomposition. According to the results, available P concentration increased during decomposition with a reduction of mass of piles in both treatments. However, there is no significant difference in the improvement of available P concentration between treatments.

Comparison of nutrient composition with different types of compost

In this study, a primary objective was to produce compost with high nutritional value. Therefore, nutritional values (N, P and K) of the compost manure produced during this study were compared with compost from municipal waste, grass and hardwood residues and commercial compost in the local market. Table 04 compares the nutritional value of different compost with the compost produced in this research.

According to the results, the concentration of all the significant nutrients was significantly higher (N-20.5g/kg, P-1.8g/kg, K-10.4g/kg) in compost produced by this study than other types of compost.

Various type of compost	Nutrient Composition (g/Kg)		
	N	P	K
Aerated enriched compost (This study)	20.5	1.8	10.4
Compost from Municipal wastes	12.3	0.9	5.3
Compost from Grass and hardwood residues	4.5	0.57	1.2
Commercial compost in the local market	0.9	0.1	3.5

Table 04: Comparison of nutrient composition with different types of compost

CONCLUSION

This study aimed to improve nutrition level of compost by using nutrient-rich farmyard manure (cow dung, poultry manure and goat manure), rice straw, paddy husk ash and Eppawala rock phosphate. An artificial airflow was supplied to accelerate the aerobic microbial reactions.

The results revealed a significant increment in total N, exchangeable K, C:N ratio, EC and CEC in compost manure produced in aerated piles compared to the control. The nutrient composition of compost produced by both methods was significantly higher than commercial compost. Decomposition time is reduced by aeration to 35 days.

Therefore, it can be concluded that decomposition time can be effectively reduced by artificial aeration, and nutrient level can be increased by nutrient enrichment.

According to this study, it can be recommended that Eppawala Rock Phosphate be added to the compost after the decomposition process to improve the phosphorous level. Chopping raw materials into small pieces would further decrease generation time/duration by increasing the decomposition rate while enhancing the surface area of individual particles. A solar panel can also be used as a power source for the blower to decrease the production/energy cost.

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