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Experimental Study and Performance Analysis of Composting System for Solid Organic Waste

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Abstract

The increased moisture content of organic waste leads to leachate generation. Municipal organic wastes, such as vegetable waste, include significant levels of moisture (88 to 94 percent), causing them to be detrimental to the environment. To treat such organic waste, the composting process is utilized. This research focuses mostly on the physics of composting when vegetable waste is combined with inoculants and bulking agents. This research demonstrated the discovery of thermophilic phases at various temperatures. The highest temperature increase reported during operation is 79 degrees Celsius. During the composting process, the ambient temperature and vegetable waste temperature were determined to be 40 °C and 79 °C, respectively. Composting food waste mixed with various bulking agents (wheat straw, hay, and wood shavings) yields a final heat output of 4,644 kcal per kilogramme of vegetable waste.

Key Word: Organic solid waste, Composting process, Inoculants and bulking agents.

1 Introduction

The degradation of organic wastes in the presence of oxygen is known as composting.This method is the best biological treatment used to convert waste into a useful compound known as compost. This waste management process is inexpensive, eco-friendly, and viable. It naturally enhances organic waste's handling properties by reducing its volume and weight. This process is affected by environmental factors such as moisture content, temperature, pH and aeration, and some organic waste properties.

The efficiency of the process and the level of organic waste disposal are enhanced by providing proper aeration of the compost pool. It is known that bulking agent's best achieve current composting conditions by distributing much-needed aeration throughout the process. It not only improves microbial activity but also controls the porosity of the raw material and thus improves overall aeration. Much research has been done on the effect of agglomerating agents in composting different types of slurries (wastewater and industrial sewage) using various composting methods. A study was also conducted to evaluate the impact of agglomerating agents on manure and animal manure. Previous researchers demonstrated correlation effects between large biological/chemical structures and gas emissions. However, it is not uncommon in the literature for reduction of organic matter or changes in body parameters such as bulk density (BD), porosity, and free air space (FAS) to introduce vegetable waste into the inoculum and to be added with agglomerating agents.

The high moisture content in organic waste leads to leachate production. Vegetable waste is a type of municipal solid organic waste that contains a lot of moisture (88–94%) and is thus harmful to the environment. Composting is a viable technology for the treatment of such organic waste[1]. The overall assessment of the current review work has kept the environment free from the hazards of CO and CO2 emissions. Bio-peels, another form of solid waste, have been established as a good detoxifier to be used in wastewater treatment. It has been shown that solid waste recycling and reuse are central to achieving eco-friendly, eco-efficient, and sustainable infrastructure development globally [2]. Vegetable, fruit, and garden (VFG) waste is collected selectively and composted. We studied the effects of combined application of three different doses of VEG manure and cattle slurry over 7 years on maize dry matter yield and three soil fauna groups: nematodes, micro-arthropods (springtails and mites), and earthworms. The combined use of VFG compost and slurry gave the highest yield [3].

Solid waste management is one of the major environmental problems facing Nigeria as a third-world country. This is between indiscriminate disposal and its management by the agencies concerned [4]. This study considers the production of compost from dehydrated, anaerobically stabilized primary sewage sludge (DASPSS) and sawdust (SWD). SWD is added to increase the humic substances in the final product. DASPSS is mixed with clinoptilolite (Cli), used as a bulking agent, at 20% w/w, and the mixture is amended with sawdust at 10%, 30%, and 40% w/w, respectively. The final results indicated that by increasing the concentration of sawdust in the starting mix, the humic substances in the final product also increased [5].

Although the on-site waste samples were relatively genuine, the representativeness of the samples is still questionable due to the uneven distribution of household waste and the randomness of sampling. In addition, it was often necessary to separate samples obtained in the field in order to determine the composition of the samples [6]. The organic fraction of municipal solid waste and its proper disposal are becoming a serious challenge worldwide. Environmental pollution, public health hazards, and the depletion of dumping lands are the results of its improper disposal. Embodied energy recovery associated with organic waste can be achieved with waste minimization using anaerobic digestion [7]. Due to the rapid urban population growth and technological development, the municipal solid waste rate is increasing continuously. The collection and disposal of municipal solid waste (MSW) causes serious environmental problems, making its management one of the important challenges facing the world [8].

The environmental, cultural, socio-economic, and political conditions of each community greatly influence municipal efforts and decision-making in managing household waste. Composting at home can be used as a concrete method of SWM; waste can be managed at the source itself, thereby increasing its recyclability. And vermicomposting is a viable option at the household level, as long as family members are willing to handle the worms and then remove the worm-casts [9]. It avoids the need for waste transport, and the bio-modified material can be recycled locally as a soil conditioner. Generally, decentralized composting systems require a long period (up to 3 months or more) for waste stabilization. Additionally, odor nuisance has been reported as a major issue as anaerobic conditions develop due to insufficient diversion and inadequate ventilation in the composting system.

Therefore, a research study was planned to develop a naturally ventilated household community drum that can generate good-quality compost from FW in a short period [10]. The rapid growth of solid waste is a global challenge, and organic waste accounts for the bulk of it. Composting is an efficient and effective way of converting solid organic waste into fertilizers that can be returned to agricultural land and reduce pollution. But so far, composting of solid organic waste has not been widely used [11]. Field-scale performance of three pile composting systems was studied and compared in the composting of the source-selected organic fraction of municipal solid waste (OMSW): pile (TP), static forced-aerated pile (SAP), and turned forced-aerated heap (TAP). Regular parameters like temperature, oxygen content, moisture, and porosity were monitored. The temperature was found to be higher in the forced-aerated system, while the oxygen content was higher in the forced-aerated system [12].

Improper waste management is harmful to human health. Apart from being unsightly, it causes air pollution, affects water bodies when dumped into them, and destroys the ozone layer when burned, adding to the effects of climate change. Waste is often improperly managed using traditional methods [13]. Composting has become a better option for treating organic waste to obtain a stable, clean final product that can be used as an organic amendment. Composting is one of the few technologies that can be implemented at practically any scale, from home composting to large municipal wastewater treatment plants[14].

2 Materials and methodology

2.1 Experimental setup

The fertilization research was carried out on a 200-litre rotary batch machine operated in batch mode. The rotary drum combustor is mounted on a rotating blade attached to a metal bracket and is rotated by a DC motor with a power supply on one side shown in Fig 1. The interior of the tank is designed using dimensions of 1450 x 350 x 300 mm^3 to ensure proper mixing with the environment. Cow dung was added for faster decomposition, and sawdust was added to the inoculum to prevent lump formation. Before composting, a large plant bed of 1-2 cm in size is obtained for better ventilation and moisture control.

Figure 1 Experimental setup with mixing unit

2.2 Experimental procedure

Samples (200 g per sample) were collected from the center and two ends (top, middle and bottom) of each respondent. Then each sample was divided into two parts. As part of the oven is dry, the soil passes through a 112-micron soil filter and is deposited on a removable table. Oven-dried samples are used to determine body composition, pH, conductivity (EC), particle size, solid content (VS), and organic carbon.

The compost mixture was prepared by mixing vegetables (20 kg), cow dung (10 kg) and salt (2 kg) in the ratio 6:3:1, making the total weight 32 kg. A total of 10% of dried citrus selected to be locally available with a total weight of 32 kg in the blend. After the feedstock's were fed to rotary drum composter, composting process was taken out for 20 days at indoor ambient temperature. Drum was rotated manually to aerate and agitate feedstock.

Thermal properties such as heat storage capacity, or a given temperature of many substances, often affect the amount of material needed to maintain the proper temperature. Some of the thermal energy is also a function of the moisture content. As expected, an increase in ash content was observed with a decrease in VS content. An increase in direct ash content affects a certain temperature increase during the composting process. Furthermore, in the present study, an increase of 24% was observed in a fixed temperature range during the thermophilic phase.

3 Final heat generations

The specific heat of a substance can be used to calculate the temperature change that a given substance will undergo when it is either heated or cooled. The equation that relates heat (q) to specific heat (cp), mass (m), and temperature change (ΔT), (ΔT) is shown below.

$q=cp\times m\times \Delta Tq$

$=cp\times m\times \Delta T$

The heat that is either absorbed or released is measured in joules. The mass is measured in grams. The change in temperature is given by

$\Delta T=Tf-Ti\Delta T$

$=Tf-Ti$,

where

Tf is the final temperature

Ti is the initial temperature.

Every substance has a characteristic specific heat, which is reported in units of cal/g•°C or cal/g•K, depending on the units used to express ΔT. The direction of heat flow is not shown in heat = mc ΔT. If energy goes into an object, the total energy of the object increases, and the values of heat ΔT are positive.

- Heat =q
- Mass =m=1Kg=m=1000g

Heat = mc ΔT to determine the amount of heat, but first we need to determine ΔT. Because the final temperature of the Vegetable Wastes is 76°C and the initial temperature is 33°C, ΔT is as follows:

$\Delta T = T_{final} - T_{initial} = 76°C - 33°C = 43°C$

The mass is given as 1000 g, and the specific heat of Vegetable Wastes as 0.108 cal/g°C. Substitute the known values into heat = mcΔT and solve for amount of heat:

Heat= (1000 g) (0.108calg°C) (43°C) = 4644cal/Kg

Heat=4.644 Kcal/Kg

4 Results and discussion

One of the important factors that indicates microbial activity during composting is temperature. It also affects the rate of reactions. Table 1 with Figure 2 shows the vegetable waste based heat generation. It displays the ambient temperature as well as the temperature of the vegetable waste, allowing for a comparison in which the temperature of the vegetable waste is found to be higher.

Table 1 Vegetable wastes based heat generation

Sl. No.	Days	Ambient Temperature (°C)	Vegetable Wastes Temperature (°C)
1	1	28	40
2	2	29	48
3	3	32	51
4	4	33	52
5	5	38	72
6	6	39	69
7	7	32	53
8	8	29	47
9	9	28	39
10	10	30	38

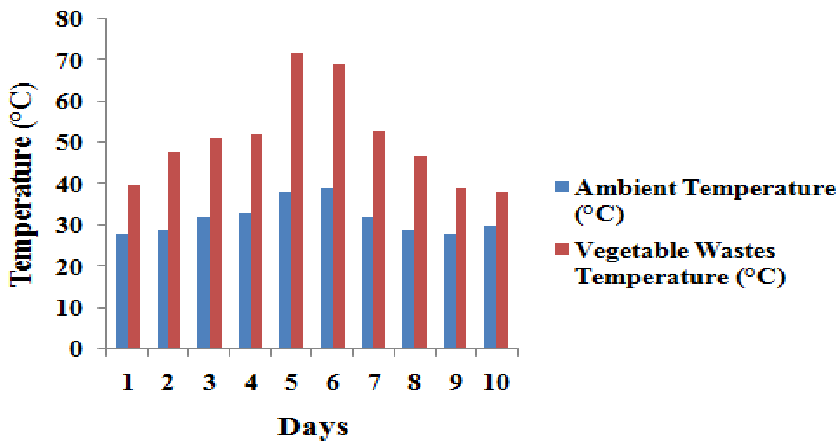

Figure 2 Vegetable wastes based heat generation

Table 2 and Figure 3 show the heat-based vegetable waste used for composting food waste mixed with different composting ingredients (wheat straw, hay, and wood shavings). Table 3 and Figure 4 show the vegetable waste based moisture content and volatile solids. Table 4 and Figure 5 show the composting of vegetable waste based on moisture content and volatile solids content using mixed food waste composting with different composting materials (wheat straw, hay, and wood shavings).

Table 2 Heat-based vegetable waste is used to compost food waste mixed with different compost materials (wheat straw, hay and wood shavings)

Sl. No.	Days	Ambient Temperature (°C)	Vegetable WastesTemperature (°C)
1	1	28	42
2	2	29	44
3	3	33	54
4	4	33	79
5	5	40	79
6	6	35	79
7	7	33	58
8	8	32	41
9	9	28	49
10	10	29	38

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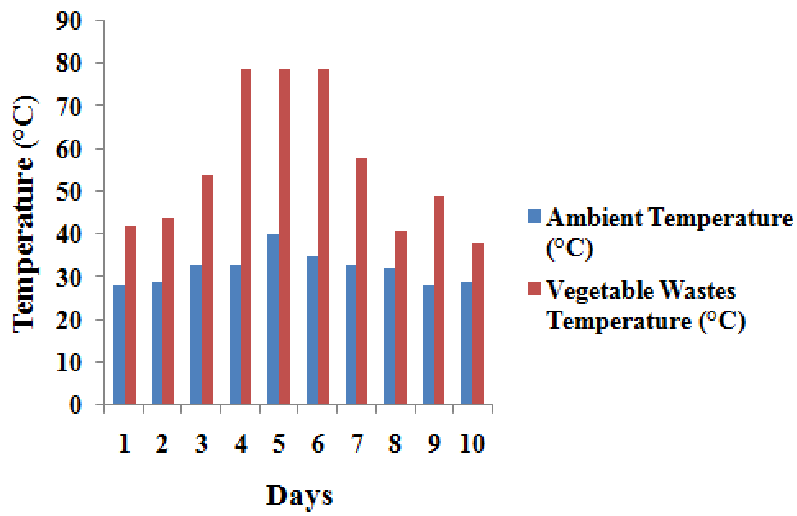

Figure 3 Heat-based vegetable waste is used to compost food waste mixed with different compost materials (wheat straw, hay and wood shavings).

Table 3 Vegetable wastes based moisture content and volatile solids

Sl. No.	Days	Moisture content (%)	Volatile solids (%)
1	1	61	70
2	2	63	72
3	3	61	74
4	4	65	76
5	5	57	77
6	6	58	71
7	7	56	72
8	8	52	64
9	9	53	63
10	10	42	61

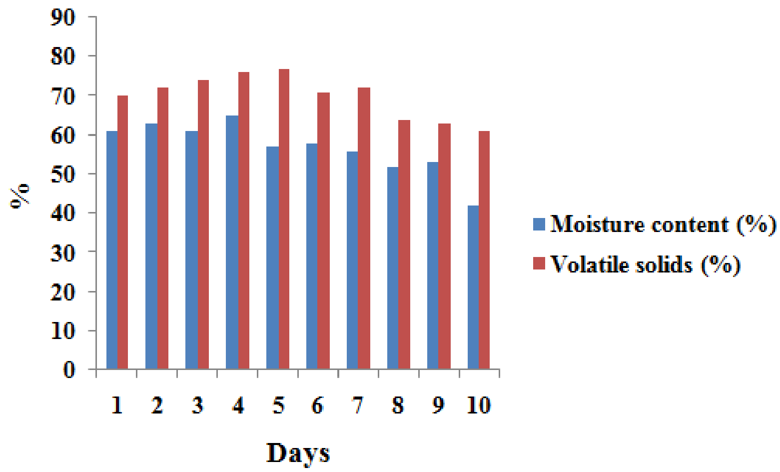

Figure 4 Vegetable wastes based moisture content and volatile solids

Table 4 Vegetable wastes based on moisture content and volatile solids using food waste composting mixed with different composting materials (wheat straw, hay and wood shavings)

Sl. No.	Days	Moisture content (%)	Volatile solids (%)
1	1	73	70
2	2	69	77
3	3	63	72
4	4	65	85
5	5	63	85
6	6	59	85
7	7	57	73
8	8	52	68
9	9	54	63
10	10	43	61

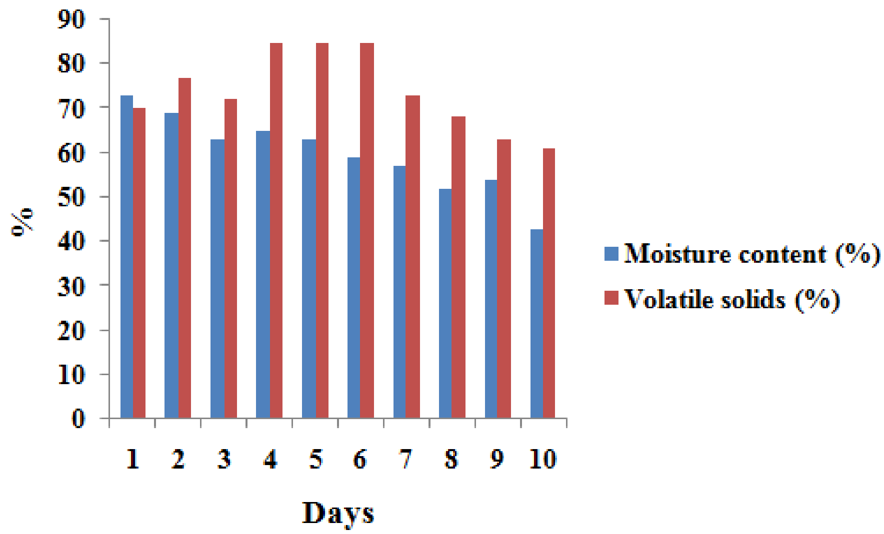

Figure 5 Vegetable wastes based on moisture content and volatile solids using food waste composting mixed with different composting materials (wheat straw, hay and wood shavings)

The ambient temperature and vegetable waste temperature during the composting process were found to be 40°C and 79°C, and were within the recommended limits shown in Table 2 and Figure 3. Moisture and volatile solids were found to be 61% and 81% during the composting process, and it was within the recommended limits, as shown in Table 4, Figure 5, moisture and volatile solids were found to be 65% and 85%, respectively. This percentage remained stable during 4 to 5 days of vegetable composting using moisture and volatile solids composting of food waste with different bulking agents (wheat straw, hay, and wood shavings). is combined. The final heat production using composting of food waste mixed with various bulking agents (wheat straw, hay, and wood shavings) is 4.644 kcal/kg of vegetable waste.

5 Conclusions

The results of the current study explain the significance of additives in the composting process. The maximum temperature rise observed during operation is 79°C. The ambient temperature and vegetable waste temperature were found to be 40 °C and 79 °C during the composting process, respectively, and were within the recommended limits shown in Table 2, Figure 3. The moisture and volatile solids were found to be 61% and 81%, respectively. During the composting process, which was within the recommended limits, as shown in Table 4, Figure 5, it was found that the moisture and volatile solids were 65% and 85%, respectively. The percentage was stable for 4 to 5 days during the composting of vegetables based on moisture and volatile solids using food waste compost mixed with various agglomerating agents (wheat straw, hay, and wood shavings). The final heat output using composting of food waste mixed with various bulking agents (wheat straw, hay, and wood shavings) is 4.644 kcal per kg of vegetable waste.

Data Availability Statement

All data generated during the study appear in the published article.

Declaration

Conflict of interest: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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