Conservation Analysis of Food Waste Composting: Insight from the Nutrient Content and Compost Quality Index (CQI) Assessment

Nur Fatin Nabila Hissham[1], *Aeslina* Abdul Kadir[1,2,3*], *Noor Amira* Sarani[4] and *Mohd Ikhmal Haqeem* Hassan[5]

[1]Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Batu Pahat 86400, Johor, Malaysia
[2]Center of Excellence Micro Pollutant Research Centre (MPRC), Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Batu Pahat 86400, Johor, Malaysia
[3]Center of Excellence Geopolymer and Green Technology (CEGeoGTech), Universiti Malaysia Perlis (UniMAP), Arau 01000, Perlis, Malaysia
[4]Center for Environmental Sustainability and Water Security (IPASA), Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), Skudai 81310, Johor, Malaysia
[5]Faculty of Engineering and Life Science, Universiti Selangor (UNISEL), Bestari Jaya 45600, Selangor, Malaysia

Abstract. Compost has a critical role in preserving and conserving soil health and increasing soil fertility, both of which are essential for sustainable agricultural systems. The purpose of this research was to evaluate the efficacy of effective microorganisms (EM) in composting vegetable waste (VW), fruit waste (FW), and mixed food waste (MFW) using the Takakura Composting Method. During the 30-day composting period, nutrient content, including total nitrogen (TN), total phosphorus (TP), potassium (K), carbon to nitrogen (C/N) ratio, pH, and phytotoxicity as measured by germination index (GI), were evaluated. The compost quality index (CQI) was also used to evaluate the quality of the compost. The results showed that all VW, FW and MFW had pH values, TN, TP, K and C/N ratios that were within the acceptable range for mature and high-quality compost. The GI of VW and MFW were both above 80%, while FW's GI was slightly phytotoxic at 79.3%. Based on the CQI score, MFW was found to be a very good compost variant, trailed by VW and FW. The results show that EM can accelerate the production of high-quality compost, which benefits conservation efforts.

* Corresponding author: aeslina@uthm.edu.my

1 Introduction

The expansion of the global human population has resulted in a significant increase in the production of municipal solid waste (MSW), which encompasses many forms of waste, including food waste. The global quantity of MSW is projected to reach around 3.4 billion tons by the year 2050 [1] and currently the quantity of food waste daily is around 1.13 million tons, with fruits and vegetables accounting for approximately 38% of this total [2]. According to a prior study conducted in Malaysia, it was found that Malaysians generated around 38,000 tons of MSW daily. Out of this total, an estimated 16,688 tons of waste per day consisted of food [3].

Food waste is associated with substantial economic losses, exacerbates food insecurity, and increase pressures on climate, water, and land resources, contributing to natural resource depletion and environmental pollution. In general, a massive amount of food waste is burnt or dumped in landfill sites. Food waste in landfills releases toxic substances in the soil that cause negative consequences for groundwater and also contributes to the development of greenhouse gases (GhG) in landfills. For every 1kg of food thrown at landfill, it is equivalent to 2.5 kg of GhG being emitted [4]. Despite the biodegradability of food waste, their decomposition process can be lengthy, resulting in substantial timeframes for complete breakdown.

Therefore, the composting process has consistently been regarded as the optimal solution for disposing of food waste instead of depositing it in landfills. The Takakura composting method is considered a more favourable option due to its cost-effective and has a rapid decomposition rate compared to traditional composting methods through the usage of inoculants rich in effective microorganisms [3]. Nevertheless, to ensure the safety of compost as an amendment in degraded soils, it is imperative to meet specific quality standards. Selecting compost type is crucial to reduce environmental impact and ensure high-quality compost recycling. By categorizing compost quality as good, moderate, or bad, can provide us with valuable guidance for selecting the most suitable compost to be used. Therefore, this study aimed to determine the comparative assessment of different types of composted food waste in terms of their maturity and nutrient content, as well as to evaluate the quality of each compost produced by using the Compost Quality Index (CQI).

2 Methods

2.1 Materials

Vegetable waste (VW), fruit waste (FW) and mixed food waste (MFW) was collected from the food stalls at Arked UTHM and residential college cafeterias. Takakura Composting Method (TCM) was used in this study, which utilize black soil with rice husk in ratio 2:1 as the decomposing medium. The combination of fermented soybean and brown sugar was used as effective microorganisms (EM) in this composting process to stimulate microorganisms' activity and accelerating the decomposition process of organic materials. 3 L of water mixed with 250g of brown sugar and one piece of fermented soybean were fermented for a week before being used along with the decomposing medium.

The conservation analysis of the compost samples was performed in terms of pH level, nutrient content (Total Nitrogen, Total Phosphorus, and Potassium), C/N ratio and microbial counts for 30 days according to the standard method. In addition, the stability-maturity and the quality of compost produced were also be evaluated by using germination index and CQI.

2.2 Composting Process

The flow of the composting process involved 4 main steps; 1) the preparation of EM, 2) the preparation of decomposing medium, 3) the preparation of compost reactor, and finally, 4) the composting process itself. In this study, 2kg of black soil with 1 kg of rice husk were prepared properly before being added with the prepared EM and homogeneously mixed. Three composts reactors were set up in this study, according to the types of food wastes (Table 1). This experiment was carried out in 17.5 L reactors (40.0 cm x 28.5 cm x 23.0 cm) with aeration holes at the all sides, as shown in Fig. 1. The reactors were covered with mosquito net and closed to maintain their temperature and prevent insects or pests from entering. All samples were aerated by turning the pile every day in the first two weeks and once a week for the rest of the study (30 days).

Table 1. Reactors prepared in the experimental work

The decomposing medium and EM used	Reactor	Types of food waste	Amount of waste (g)
(Rice husk + Black soil) + (Brown sugar + Water + Fermented soybeans)	MFW	Mixed food waste	250
	VW	Vegetable waste	250
	FW	Fruit waste	250

2.3 Compost analysis

pH values were observed by using pH meter as done by the previous study [5]. For nutrient content, digested compost samples were initially prepared by following the digestion method as suggested by Kadir et al. [6]. Total Nitrogen (TN) and Total Phosphorus (TP) were measured and determined according to Method 10072 – Persulfate Digestion Method (2 – 150 mg/L N (HR)) and Method 8190 – USEPA PhosVer3 with Acid Persulfate Digestion Method (0.02 – 1.10 mg/L P) by using DR6000 UV-Vis Spectrophotometer, respectively. Atomic Absorption Spectroscopy (AAS) was used to determine potassium (K) concentration by following Method 311B, while CHONS analyzer was used to determined C/N ratio. Most Probable Number (MPN) analysis [7] was used to calculate the microbial counts of compost and compost extract test for germination index [8] has been used to measure phytotoxicity level.

3 Results and discussion

3.1 pH value

Fig. 1 illustrates the fluctuations in pH values observed in FW, VW, and MFW, exhibiting a comparable trend. The pH values of the VW compost treatment showed a rise, transitioning from an initial pH of 6.8 to a final pH of 7.9. The pH content for FW increased from 6.4 to maximum pH of 8. The initial pH of the MFW compost was measured to be 7.4, and it subsequently increased to a final pH of 8.2. The prior study [9] has shown that the recommended pH range for compost of good quality is between 6 and 8.5, which signifies the stability of organic matter. Upon completion of the composting process, it was seen that the pH values of all compost samples were within the acceptable range. This outcome suggests that the pH levels were conducive to ensuring the compost's good quality and maturity.

The increase in pH levels from acidic to neutral implies that the acids present in the compost were depleted. The initial rise in pH during the composting process can be attributed to the generation and release of ammonia resulting from microbial activities involved in ammonification and mineralization of organic nitrogen [10, 11]. An effective aeration process could increase the pH level and prevent the growth of anaerobic microbes, which can lead to a decrease in pH levels. The pH values exhibited a declining trend towards the end of the composting period, ultimately reaching a state of stability characterized by alkaline values. This may be attributed to several factors, including the release of carbon dioxide as a by-product of the decomposition process, the volatilization of ammonia, and the generation of organic and inorganic acids. The release of H^+ from microbial nitrification during the breakdown of organic waste is responsible for the subsequent reduction in pH observed during the later stages of the composting period [11, 12].

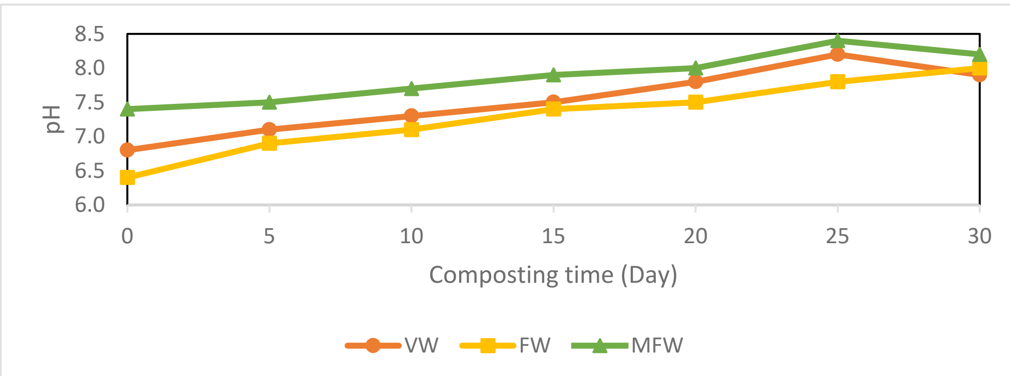

Fig. 1. pH variation versus composting time

3.2 Nutrient content

Availability of nutrient content which were include total nitrogen (TN), total phosphorus (TP) and potassium (K) in compost is important to produce good quality of compost. Fig. 2 displays the TN values at the end of the composting process for FW, VW, and MFW; 2.734%, 2.875%, and 3.43%, respectively. High-quality compost has a TN concentration between 0.45% to 3.50%, and all compost samples fell within this range. Nitrogen-fixing bacteria thrived in the composting environment, producing a high N content [13]. Another possible explanation for the high concentration of N at the completion of the composting process is that N is used by microbes to produce new cells, resulting in a decrease in N, but some of the dead organisms are eventually recycled as N, causing the rise in N concentration [6].

Meanwhile, Fig. 3 displays TP values of FW (0.734%), VW (0.874%), and MFW (1.09%) for the compost samples, all of which fall within the 0.2-1.55% range suggested for high-quality compost. High rates of carbon loss from the breakdown of organic materials led to an increase in the concentration of phosphorus. Compost with a high TN content may have an elevated TP content due to increased microbial activity to break down P elements [14].

The chemical parameters of high-quality compost include a K content between 0.4% to 1.5%. Fig. 4 showed K content varies from 1.442% in FW compost to 1.327% in VW compost to 0.981% in MFW compost. As a result, in this scenario, every compost sample possesses the qualities associated with mature compost. The use of rice husk as a decomposing medium may account for the observed elevation in K value [15]. Composting using rice husk was effective because it absorbed and held onto moisture. As moisture content is absorbed, the material's structural integrity and porosity are preserved, potentially increasing K's value [16].

https://doi.org/10.1051/e3sconf/202343703009

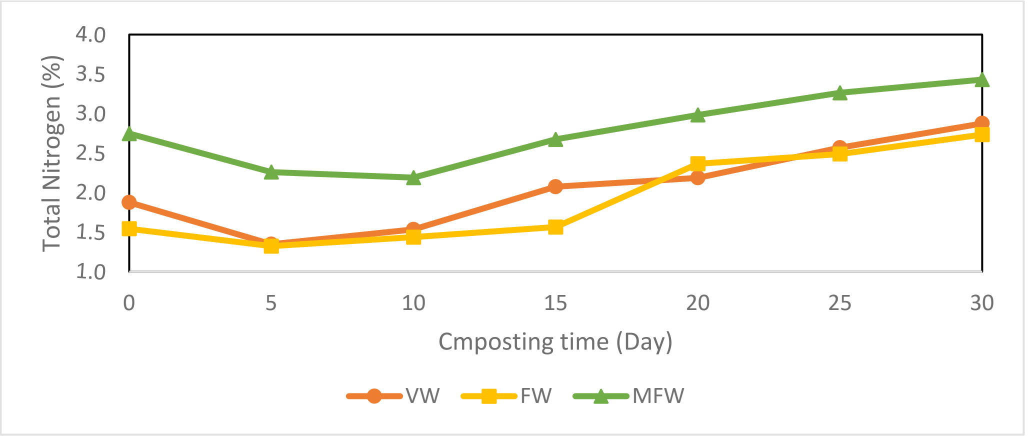

Fig. 2. Total Nitrogen versus composting time

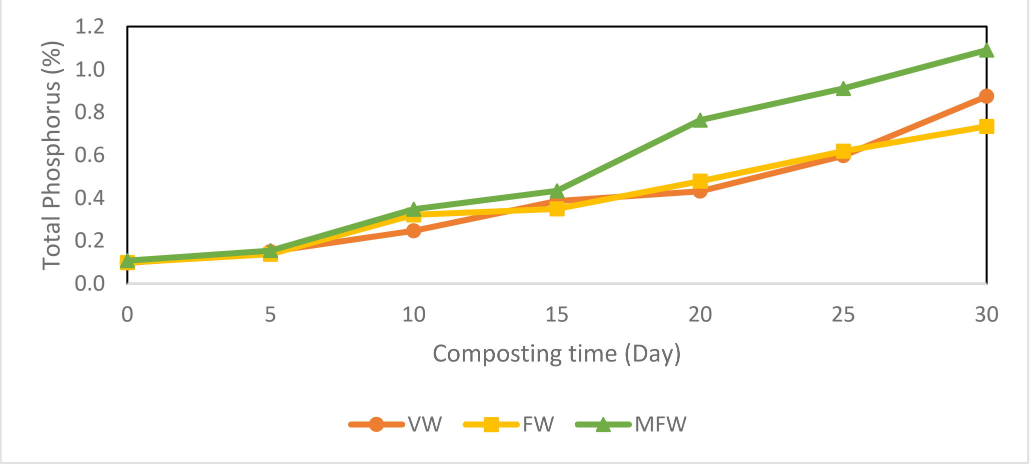

Fig. 3. Total Phosphorus versus composting time

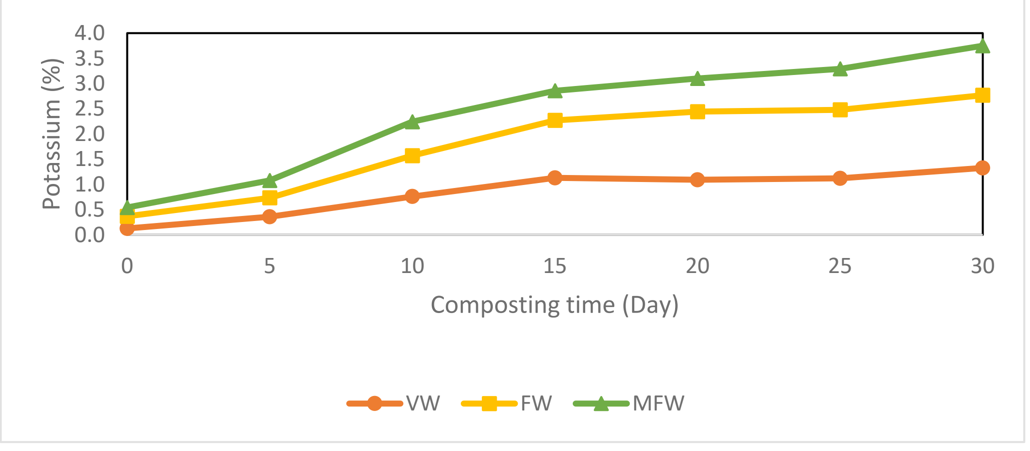

Fig. 4. Potassium versus composting time

3.3 C/N ratio

Table 2 represents the final C:N ratio for all the compost samples. Compost maturity might be determined throughout the process of decomposition by measuring the C/N ratio. All of the compost samples ended up with a lower C/N ratio than they had at the beginning of the process. On day 30 of the composting period, the C/N ratio for VW compost was 18.3, 19.7 for FW compost, and 15 for MFW compost. According to Jusoh et al. [9], the final C/N ratio of compost must be less than 20 for complete decomposition to occur. However, as stated by Bernal et al. [18], a C/N ratio of 15 or less indicates that the compost has reached the proper level of maturity. These statements suggest that all the compost samples were mature and ready to be used as intended.

Table 2. C/N ratio of compost samples

Types of compost	Initial C/N ratio	Final C/N ratio	Recommended range
VW	33.6	18.3	<20 [9] <15 [18]
FW	32.3	19.7	
MFW	30.4	15	

3.4 Microbial counts

Microbial counts in the VW, FW, and MFW were 1.53×1012 cfu/g, 1.47×1011 cfu/g, and 2.34×1012 cfu/g, respectively. The total microbial counts of MFW are the highest compared to VW and FW. Besides, total number of bacteria is far higher than that of fungi and actinomycetes, as seen in Table 3. Bacteria are essential in composting due to their nutritional value and capacity to initiate decomposition and produce heat and carbon dioxide, thus accelerating the process [19]. According to Pathak et al. [20], bacteria are most active and multiply during the thermophilic phase (40°C to 60°C) as organic materials are readily available as a food supply.

Table 3. Microbial counts of compost samples

Microbial parameters (cfu g-1)	VW	FW	MFW
Total bacterial count	15×10^{11}	13×10^{10}	23×10^{11}
Total fungal count	68×10^{5}	50×10^{5}	52×10^{6}
Total actinomycetes count	27×10^{9}	17×10^{9}	39×10^{9}
Total microbial counts	1.53×10^{12}	1.47×10^{11}	2.34×10^{12}

3.5 Germination index

Compost maturity and phytotoxicity may be measured with the germination index (GI). When compost has a GI greater than 80%, it will be labelled as phytotoxin-free [21-23]. The absence of phytotoxicity indicates that the compost is matured enough for use. As shown in Fig. 5, the compost's GI increased as the process progressed, indicating that the phytotoxicity component in the compost pile was gradually eradicated. VW and MFW completed composting with GI values of 89.1% and 82.1%, respectively, whereas 79.3% of GI value was recorded for FW. This shown that the phytotoxicity levels were slightly higher in the compost treatment for FW than in the other two.

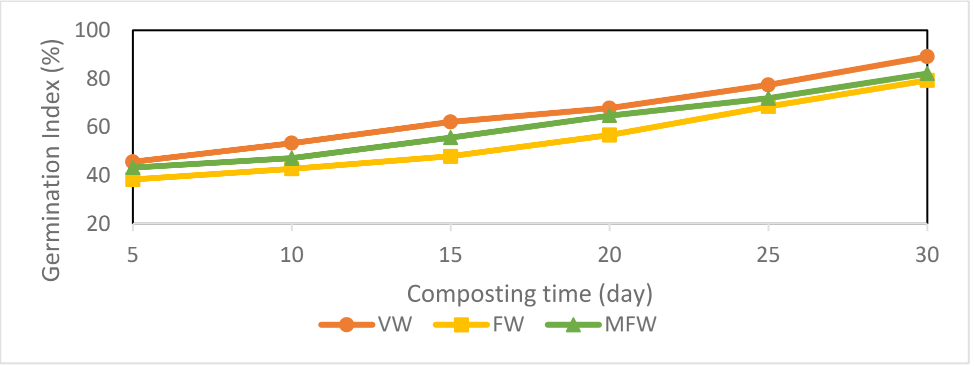

Fig. 5. Germination index versus composting time

3.6 Germination index

The following equation (1) represents the Compost Quality Index (CQI), which was developed using five analysis parameters (Table 4) to categorize the different categories of composts quality [24].

$$CQI = \frac{NVNPK \times MP \times GI}{C/N\ ratio} \qquad (1)$$

Where,
NVNPK = Total % of NPK;
MP = Total microbial population (total bacteria + total fungi + total actinomycetes);
GI = Germination Index

Table 4. Compost quality classification

Compost Quality Index (CQI)	Compost Quality Classification
> 2.00	Poor
2.00 – 4.00	Moderate
4.00 – 6.00	Good
6.00 – 8.00	Very Good
8.00 – 10.00	Extremely Good

Using equation (1), we can see from Table 5 that the VW compost sample has a CQI of 4.24, indicating good quality compost, while the FW compost sample has a CQI of 2.92, indicating moderate quality of compost. The CQI value of 7.05 for the MFW compost sample indicates very good quality of compost.

Table 5. CQI of compost samples

Types of compost	**CQI**	**Compost Quality Classification**
VW	4.24	Good
FW	2.92	Moderate
MFW	7.05	Very good

4 Conclusion

The conservation analysis from the study above showed that that the pH level, nutrient content (TN, TP, and K), and C/N ratio of VW, FW, and MFW compost were all within the acceptable range for high-quality compost. The total microbial counts showed that many more bacteria than fungi or actinomycetes were present, indicating that bacteria were actively growing during the thermophilic phase of composting to ensure a complete decomposition process of the organic materials. In terms of the GI, VW and MFW have exceeded 80% signifies their phytotoxin free and achieved maturity level, while FW was only slightly phytotoxic with 79.3% of GI. Based on the CQI values, MFW was in very good quality compost sample, following by VW which is in good quality classification and lastly compost sample FW was moderate quality compost. In conclusion, the study demonstrates that EM may help improve and produce high-quality food waste compost within 30 days of composting.

Acknowledgements

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Geran Penyelidikan Pascasiswazah (GPPS) (Vot H705). Authors wishing to acknowledge Micropollutant Research Centre (MPRC) and Environmental Analysis Laboratory, Faculty Civil Engineering and Built Environment (FKAAB), Universiti Tun Hussein Onn Malaysia for the laboratory facilities.

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