J. Trop. Resour. Sustain. Sci. 12 (2024): 112-122
https://doi.org/10.47253/jtrss.v13i2.1485

Journal of Tropical Resources and Sustainable Science

journal homepage: jtrss.org

Preliminary testing for utilising oil palm empty fruit bunch fibre in home compost making and its usability in planting medium towards growth of bird's-eye chili (*Capsicum annum*)

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Received 17 December 2023
Accepted 12 March 2024
Online 23 December 2024

Keywords:
aerobic composting, cocopeat, composting, effective microorganisms, OPEFB fibre

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Abstract

In this preliminary study, a home-based composting routine utilising waste oil palm empty fruit bunch (OPEFB) fibre, garden and kitchen waste, and home-made effective microorganism (EM) solution was carried out. The purpose of this research was to explore potential waste utilisation practice which can start from home. The 9 compost premix samples prepared with different amounts (7%, 14%, 50%, 100%) of OPEFB fiber displayed varying durations of composting time from 4 to 8 weeks. It was observed that compost containing higher amounts of OPEFB fibre took a longer time to mature. The addition of the EM solution to the compost premix samples aided the decomposition of the OPEFB fibre. The compost sample made of 100% OPEFB fibre took 8 weeks of composting period while its replicate sample which was treated with EM took 7 weeks to compost. The usefulness of the home-made compost in a planting medium consisting of soil, compost and cocopeat with a ratio of 3:1:1 was tested to grow bird's-eye chili seeds. Based on the results, soil treated with compost containing OPEFB fibres showed better results for plant growth compared to soil having no compost and with control compost samples (0% OPEFB fibre). It was also observed that compost treated with EM containing 14% OPEFB fibre and 86% vegetable scraps with an initial C: N ratio of 29.9:1 showed the best result towards the plants growth. Based on this finding, home-made compost utilising OPEFB fibre can be included as part of planting medium to support plant growth.

1. INTRODUCTION

Compost is produced through a natural biological breakdown process known as composting that involves decomposition of organic matter (OM) through aerobic, biochemical and microbiological processes (Raza & Ahmad, 2016). The composting process forms a dark humus-like material called compost, a relatively stable organic end product (Rosalina et al., 2019). Therefore, compost can also be defined as decayed OM produced through the recycling process of matured and stable plant debris and biosolids (Kranz et al., 2020). The degradation of complex OM into compost results in the production of relatively stable, sanitised and simpler decomposed organic materials (Adugna, 2016; Rastogi et al., 2020). The compost produced can have many uses and needs. Compost is not a planting medium but functions as a growing medium (Baessler, 2021). Compost is usually incorporated with soil before being used for planting. This means that plants cannot be grown directly in pure compost. This is because compost is rich in nutrients and minerals. Pure compost may provide excess nutrients and minerals to the plant which may cause the plant to experience a negative growth and eventually wilt. A study conducted by Do and Scherer (2013) on the effects of compost-based media on the growth of *Pelargonium* and *Salvia* showed that plant growth was the lowest in 100% compost. According to the research, it was concluded that pure compost had too high nutrient contents. The large percentage of compost negatively affected plant growth due to excessive nutrient uptake of nitrogen, phosphorus, potassium and sodium. Thus, compost is usually added to soil to improve soil properties (Kranz et al., 2020).

In Malaysia, millions of hectares of land are used for the plantation of oil palm trees. The oil palm industry is the largest agricultural sector in Malaysia (Hirschmann, 2020). Malaysia is the second largest global palm oil producer after Indonesia accounting for a total global

eISSN Number: 2462-2389

supply of palm oil by more than 80%. Oil palm is known as *Elaeis guineensis*, an ornamental plant first introduced in Malaysia in 1870. The oil palm fruits are widely used in the oil palm industry. The mesocarp of the fruits consists of about 49% of oil and the rest of the portion is the kernel (MPOB, 2017). The mesocarp are usually extracted to yield edible vegetable oil which is known as palm oil, an important raw material which is used in the development of various types of products such as cooking oils and soaps. However, the overall extraction process of palm oils generates huge amounts of solid oil palm biomass which includes about 23% oil palm empty fruit bunches (OPEFB), 5% shells and 12% mesocarp fibre (Trisakti et al., 2018). The oil palm fresh fruit bunches (OPFFB) are processed in the palm oil mill (POM). During milling, the OPFFB undergoes steam treatment under high pressure of 294 kPa for about 1 h in order to detach the fruits from the bunches (Tan et al., 2017). The by-products of this process are the OPEFB, a form of fibrous waste. The OPEFB are waste materials that need to be treated efficiently to prevent any environmental problems such as fouling. Besides, since the OPEFB are fibrous, they can also attract pests such as insects and rats. Traditionally, OPEFB fibre undergoes a combustion process to convert it into ash. These ashes are then utilised as fertiliser due to the high K content at ± 30 %. However, the combustion of OPEFB will contribute to air pollution. Therefore, under the Decree number 15 of 1996 on the blue-sky, the Ministry of Environment banned this utilisation method (Trisakti et al., 2018). Consequently, an environmentally-friendly method that can be adopted in order to manage the disposal of OPEFB fibre is converting it into compost.

Since the OPEFB that are generated in POM have low bulk density and are very moist, approximately 60% moisture content (MC), the OPEFB have to undergo a water retting process to convert them into fibres (Tan et al., 2017). During the water retting process, microorganisms and moisture are used to dissolve the cellulose tissue and pectin, forming OPEFB fibres. The fibre is ready to be recycled and utilised during the compost making process to add value to the compost. The OPEFB fibre can be used as a compost material due to its characteristic high MC and carbon-to-nitrogen (C:N) ratio, making them a carbon-rich material. Besides, in the form of fibre, this material can degrade easily and is eco-friendly which makes it suitable to be used as a compost material. Finally, compost containing OPEFB fibre is a good nutrient-enriched bio-organic fertiliser which can be used to replace chemical fertilisers during home-planting or in any agriculture sector (Siddiquee et al., 2017).

Bird's-eye chili peppers, also scientifically known as *Capsicum annum, are* locally called as *cili padi* in Malaysia or *cabai rawat* in Indonesia (Natsir et al., 2018). They belong to the Solanaceae family and are widely cultivated in many Asian countries especially in Malaysia. The plant is a small bush with multiple branches which produces whitish-green flowers. They also produce small and pungent fruits which can be separated very easily from the calyx causing them to be easily dispersed by birds (Vaishnavi et al., 2020). The plant grows best on well drained and moderately fertile soil with a pH between 6 and 7 (Chatterjee et al., 2012). The plants can thrive in high temperature climates with growing season temperatures of 18 °C to 27 °C during the day which is important to help induce early flowering of the plants and 15 °C to 18 °C during the night which is crucial to promote greater branching and flowering effect.

The objectives of this research were to (i) prepare home-made compost by using leftover OPEFB fibre, garden waste (i.e. dry leaves) and kitchen waste (i.e. vegetable scraps); (ii) to determine the effects of different amounts of OPEFB fibre on the duration of composting, and (iii) to investigate the usability of home-made compost as planting medium towards the growth of bird's-eye chili plants.

2. MATERIALS AND METHODS

2.1 EM solution preparation

The EM solution was prepared (Figure 1) as follows (modified from Zenyr Garden, 2021; Nanyuli et al., 2018). First, 1.5 L mineral water was used to dissolve the brown sugar (45 g) and the sea salt (15 g).

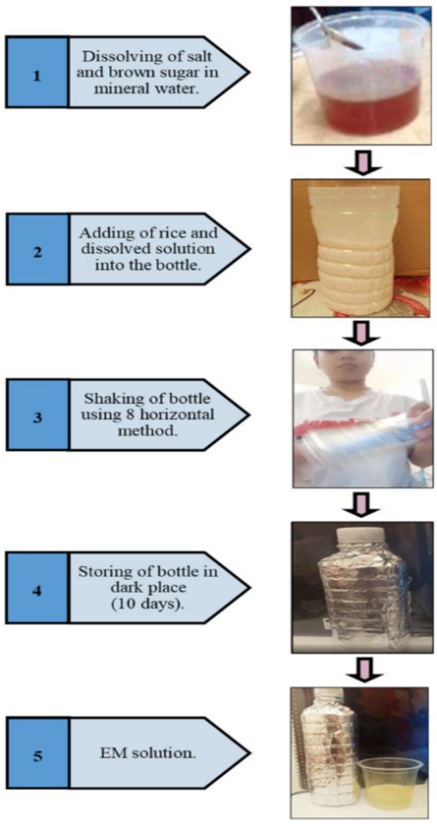


Figure 1: Preparation of home-made EM solution.

The mixture was then poured into the bottle. Next, rice (approximately 150 g) was poured into the bottle and the bottle was wrapped with aluminium foil. The bottle was shaken in a number 8 horizontal method for even mixing (2-3 min). Next the bottle was kept in a warm dark place with the lid on. The solution was kept away from sunlight to prevent the inactivation of heat-sensitive lactic acid bacteria. Next, within 7 to 10 days, the mixture in the bottle was checked for any observation of air bubbles and the lid was slightly opened to release carbon dioxide, the product of lactic acid fermentation. Finally, after 10 days the liquid containing EM was strained and the remaining rice was used as growing media in the garden. The EM solution was stored in a warm area with an aluminium foil wrapped around it or transferred to a dark bottle to keep the microorganisms active.

2.2 Compost premix preparation

The compost premix consisted of a mixture of brown materials (i.e., dried leaves and OPEFB fibre; high in carbon content) and green material (vegetable scraps; high in nitrogen content). The OPEFB fibre was sourced from a palm oil mill (Kluang Oil Palm Sdn. Bhd.). Figure 2 shows the preparation of compost mixture.

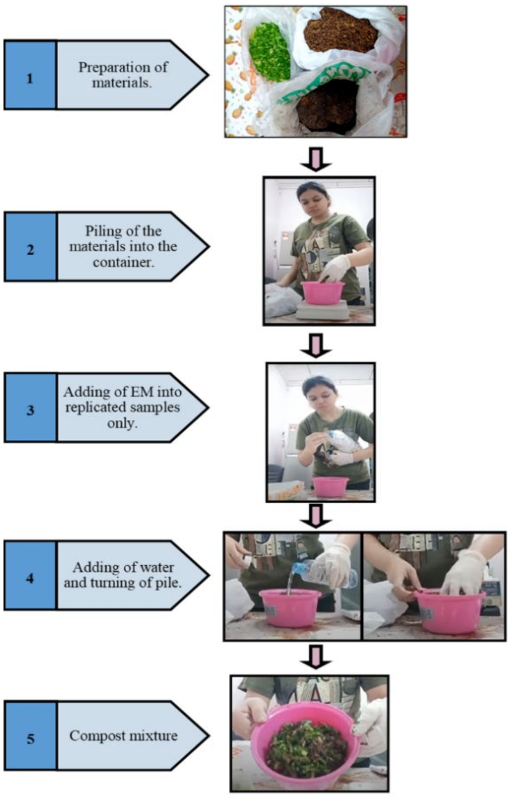


Figure 2: Preparation of compost mixture.

The dried leaves were gathered from the garden while the vegetable scraps were leftovers from the kitchen. Next, both the dried leaves and vegetables were cut into smaller pieces. The materials were then measured and piled into cylindrical plastic containers (measuring 15.2 cm in diameter and 7.8 cm in height). Next, 50 mL of water was added into each container and 1 cupful of EM solution (~ 30 mL) was added into the compost mixes. The samples were placed outside under the shade for proper aeration and to obtain atmospheric heat to meet the appropriate conditions for decomposition. The pile was turned twice every week.

2.3 Characterizing the process of composting

Aerobic composting was the method chosen in this study. The compost was separated from the pile by using a mesh filter beginning the second week of composting for testing. After removing the finished compost, the remaining materials in the pile were left for the decomposition process to continue. The pile was moistened with water and EM solution was added to the samples. The duration of composting was determined by the number of weeks taken for all the materials to fully break down forming a compost. The characteristic of matured compost was determined through sensory assessment of the colour, odour and texture (Amery et al., 2020). The mature compost will be moist, dark brown in colour with no recognizable materials, as they would have fully decomposed and emit an earthy smell.

Weight loss was recorded over the period of composting. The matured compost that was collected was weighed at the end to determine the changes in weight throughout the composting period. The matured compost was then used for planting the bird's-eye chilies. By the end of composting, the total weight loss (%) was calculated (Verma et al., 2014): Initial wet weight of organic material (g) – final weight of matured compost (g) / initial wet weight of organic material (g) x 100%.

2.4 Experimental design for composting and planting

A total of 9 compost premixes were made and the initial weight of each sample was 100 g. The distribution of materials and initial C:N ratio determined by calculation (Graves, 2000) of each compost premix sample is shown in Table 1. The main parameters observed were effects of EM inclusion, pH, and plant growth. A three-way soil meter (BLS 3 in 1 soil meter) was used to measure pH of compost samples and soil.

Table 1: Experimental design.

Media	Material						
	Brown				Green		
	OPEFB fibre		Dry leaves		Vegetable scraps		Initial C:N ratio
	g	%	g	%	g	%	
A (Control)	0	0	14	14	86	86	29.9:1
B	7	7	7	7	86	86	29.9:1
B’	7	7	7	7	86	86	29.9:1
C	14	14	-	-	86	86	29.9:1
C’	14	14	-	-	86	86	29.9:1
D	50	50	-	-	50	50	42.5:1
D’	50	50	-	-	50	50	42.5:1
E	100	100	-	-	0	0	60:1
E’	100	100	-	-	0	0	60:1

(’) indicate samples treated with EM solution.

2.5 Determination of moisture content (MC) and total solid content (TSC) of compost materials

The MC of the dry leaves, OPEFB fibre and vegetable scraps were determined by using a conventional oven (Khind Oven TO1811) through an air-drying technique. All the materials underwent size reduction where both the dry leaves and vegetables scraps were cut into small pieces. Next, 10 g of each material was heated in the oven at 130 °C for 2 h. The weight of each material was recorded at 30 min intervals until it was at a constant weight. The MC (%) was calculated on a wet basis (Nirmaan et al., 2020): Initial wet weight (g) – final dry weight (g) / initial wet weight (g) x 100%; and TSC (%) = 100 – MC (%).

2.6 Planting medium preparation and growth observation

Polybags (10’ x 12’) were used for the plant growth test. The study was conducted on field scale basis and was arranged in a complete randomized design. Figure 3 shows the process of planting and measuring plant growth. A total of 9 different types of compost mixed soil media were prepared as planting media for the bird’s-eye chilies’ growth test. Seeds were used. The media for the 9 samples (A, B, C, D, E, B’, C’, D’ or E’) stated earlier (Table 1) consisted of 1 part compost to 1 part coco peat to 3 parts of soil (1: 1: 3). Garden soil was used, and was not characterized further. Cocopeat was added to the top layer to regulate the moisture of the soil. Media X was the control (1 part coco peat to 3 parts of soil, 1:3), where no compost or EM were included. For each type of mixture, triplicate plant samples were prepared. The growth of the plant samples was observed for a period of 2 months. The initial pH of soil and compost, and the final pH of the mixture of soil and compost were recorded. The mean length (cm) of the roots and height of shoots were noted.

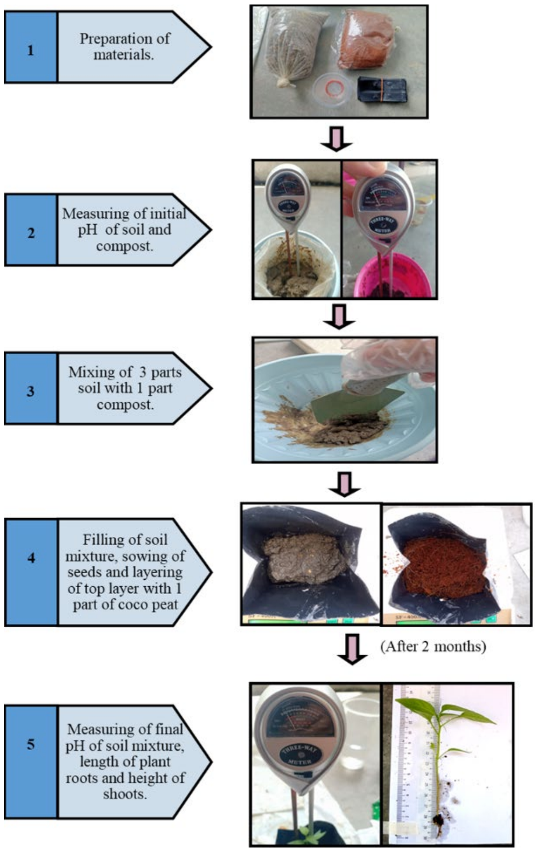


Figure 3: Process of planting and measuring of plant growth.

2.7 Data analysis

The data of triplicates (n=3) were tabulated, and analysed by SPSS 24.0, and their mean and standard deviations were determined. The significance test was performed by using analysis of variance (ANOVA) and paired t-test at 95% significance level. For significant ANOVA test readings, an additional post-hoc analysis of Tukey's Honest Significant Difference (HSD) was performed to determine the groups of samples that contain means that are significantly different. Linear correlation was conducted to determine the strength of the linear relationship between the dependent and independent variables (Bewick et al., 2003).

3. RESULTS AND DISCUSSION

3.1 Moisture content (MC) and total solid content (TSC) of compost materials

Table 2 shows the MC (%) and TSC (%) values of the materials used in the compost premix. It was observed that the higher the %MC of the material, the lower was its %TSC. Overall, vegetable scraps had the highest MC (69.20%), and the lowest TSC (30.80%), followed by OPEFB fiber with a lower MC (46.10%), but higher TSC (53.90%) than vegetable scraps. Dry leaves had the lowest MC (26.40%), but with the highest TSC (73.60%).

eISSN Number: 2462-2389

Table 2: The MC (%) and TSC (%) of compost materials.

Material	Final weight (g)	Weight of moisture (g)	MC (%)	TSC (%)
OPEFB fibre	5.39 ± 0.38	4.61 ± 0.38	46.10 ± 3.84	53.90 ± 3.84
Dried leaves	7.36 ± 0.33	2.64 ± 0.33	26.40 ± 3.31	73.60 ± 3.31
Vegetable scraps	3.08 ± 0.16	6.92 ± 0.16	69.20 ± 1.55	30.80 ± 1.55

All materials initial weight was 10.00 g. Columns represent the mean values ± standard deviation (n=3).

Vegetable scraps are food waste which have tender physical texture due to its high percentage MC (Risse & Faucette, 2017). The high percentage MC provides favourable conditions for the growth of bacteria. Besides, vegetable scraps are green materials having high N content (Hamid et al., 2019). So, when large amounts of food waste such as vegetable scraps are left to rot on their own, these characteristics will lead to uncontrolled anaerobic decomposition. This condition may result in the release of methane and carbon dioxide which are greenhouse gases with foul smell due to the production of ammonia which may lead to unhealthy air conditions (Palaniveloo et al., 2020). In order to overcome these issues, bulking agents with higher %TSC and high C:N ratio such as OPEFB fibre, and dry leaves are incorporated with vegetable scraps during composting to absorb the excess moisture thus, favouring the aerobic decomposition process. The bulking agents also add structural integrity to the compost pile. Bulking agents composed of dry matter give compost a porous structure (Hamid et al., 2019).

3.2 Weight loss in compost samples

Table 3 lists the weight of final compost collected (g) and total weight loss (%) of the premix compost samples. Overall, samples C and C' recorded the lowest weight of compost collected which are 33.09% and 59.82%, equating to the highest percentage of total weight loss of 66.91% and 40.18%, respectively. It was noted that as the amount of OPEFB fiber increased (from samples C to E, and C' to E', respectively), and with the absence of dry leaves, the total weight of compost collected also increased while the total percentage of weight loss decreased. It was also observed that samples A and B that contained dry leaves resulted in higher weight of compost collected and lower total percentage of weight loss compared to sample C even though all these samples had similar initial C:N ratio (29.9:1) which are within the optimal range.

As seen in Table 3, all samples experienced a certain percentage of weight loss (in the range of 5%-67%) during composting. According to Verma et al. (2014), a premix compost material will experience a higher percentage of weight loss when the materials used in the compost mixture undergo higher OM mineralization. During composting, weight is reduced when OM in the premixes is converted into stabilized forms of carbon-rich product called compost through action of microbial activity under aerobic conditions. Composting will result in the formation of compost which has a lower C:N ratio compared to its initial C:N ratio. Besides, the weight loss may also be due to changes in the chemical composition of the OM (Lerch et al., 2019).

Table 3: Weight of final compost collected (g) and the total weight loss (%) of the samples.

Sample	Initial premix weight (g)	Weight of compost collected (g)	Total weight loss (%)
A (control)	100	80.99	19.01
B	100	75.31	24.69
C	100	33.09	66.91
D	100	87.54	12.46
E	100	90.33	9.67
B'	100	86.48	13.52
C'	100	59.82	40.18
D'	100	88.37	11.63
E'	100	94.67	5.33

(') indicate samples treated with EM solution.

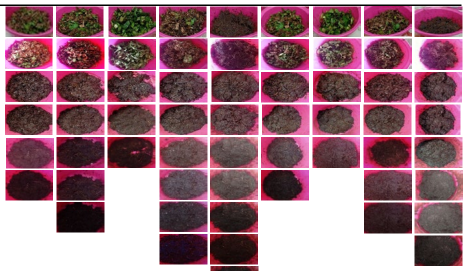
During composting, material such as vegetable scraps which contains simple carbohydrates, fats and amino acids are degraded easily and quickly while lignocellulosic biomass such as OPEFB fibres and dried leaves are partially degraded (Akratos et al., 2017; Bohacz, 2019). Total percentage of weight loss of sample material is positively correlated (r = 0.585) with weight of vegetable scraps but negatively correlated with weight of OPEFB fibre (r = - 0.527) and dried leaves (r = - 0.125). This is because vegetable scraps are green materials with high nitrogen content while OPEFB fibre and dried leaves are brown materials which have high carbon, hemicellulose and lignin contents (Verma et al., 2014; Hamid et al., 2019; Palaniveloo et al., 2020). Bulking agents as lignocellulosic biomass provides mass and structure to the compost (Akratos et al., 2017). As shown in Table 2, dry leaves have higher TSC (73.60 ± 3.31%) compared to OPEFB fibre (53.90 ± 3.84%) which indicates that dry leaves have higher mass of solid compared to OPEFB fibre. Hence, samples A, B and B' containing dry leaves recorded higher weight of final compost collected but lower percentage of weight loss compared to samples C and C' where dry leaves were absent even though all these samples had the same C:N ratio of 29.9:1.

3.3 Composting duration and treatment with EM solution

The composting duration difference among the samples is shown in Table 4.

Table 4: The duration of composting of the compost samples.

Samples	A	B	C	D	E	B'	C'	D'	E'
OPEFB fibre (g)	0.0	7.0	14.0	50.0	100.0	7.0	14.0	50.0	100.0
Week 0									
Week 1									
Week 2									
Week 3									
Week 4									
Week 5									
Week 6									
Week 7									
Week 8									
Duration (weeks)	5	6	4	7	8	5	4	6	7



(') indicate samples treated with EM solution.

Samples C and C' recorded the shortest duration of composting which is within 4 weeks while sample E' and E needed the longest duration of composting which is up to week 7 and 8, respectively. Sample A (control) required an extra week to complete the composting process compared to samples C and C' even though all the three samples were made up of the same amount of green and brown materials at C:N ratio of 29.9:1. This was because the presence of dry leaves in sample A resulted in a longer duration of composting. This may be due to the characteristic of dry leaves having a higher percentage of TSC. It was also observed that as the weight of OPEFB fibre was increased in the compost premix, the longer the duration of composting. Samples containing EM solution recorded a shorter duration of composting compared to samples not treated with EM solution.

3.3.1 Duration of composting of the samples

One-way ANOVA was performed to determine whether there was any statistically significant difference between the means of composting duration when different amounts of OPEFB fibres were used. Based on the results of the one-way ANOVA performed at 95% significance level ($\alpha = 0.05$), the p-value for the weight of OPEFB fibre was smaller than the significance level at $p = 0.009$. Therefore, the one-way ANOVA rejects the null hypothesis and reveals that there is a statistically significant difference in duration of composting between at least two groups of compost samples containing different weights of OPEFB fibre ($F (4,5) = 12.167$, $p = 0.009$). Since the result of the p-value was statistically significant, the post-hoc analysis of Tukey's HSD test was performed to determine the groups of samples that contain mean values that are significantly different. Table 5 shows the homogenous subsets of means of composting duration in terms of different weights of OPEFB fibre used. Tukey's HSD test for multiple comparison found that the mean value of composting duration was significantly different between (i) samples containing 100.0 g and 14.0 g OPEFB fibre [$p = 0.07$ at 95% confidence interval of (1.30, 5.70)], (ii) samples containing 100.0 g and 0.0 g OPEFB fibre [$p = 0.03$ at 95% confidence interval (0.30, 4.70)] and, (iii) samples containing 50.0 g and 14.0 g OPEFB fibre [$p = 0.03$ at 95 % confidence interval (0.30, 4.70)].

Table 5: The homogenous subsets of means of duration of composting of compost containing different weight of OPEFB fibre.

Weight of OPEFB fibre (g)	Duration of composting (weeks)
0.0	5.00^{bc}
7.0	5.50^{abc}
14.0	4.00^{c}
50.0	6.50^{ab}
100.0	7.5^{a}

*Small letters (a, b, c) represent designate homogenous groups; means marked with the same letter do not differ significantly while means marked with different letters differ significantly ($\alpha = 0.05$)

Therefore, it can be concluded that the higher the amount of OPEFB fibre incorporated in the compost premix, the longer will be the duration of composting. This is true for samples C to E and C' to E' even though control samples A and samples B, B' had lower amounts of OPEFB fibre in their compost mixture. This was due to the addition of dry leaves in samples A, B and B' which have higher TSC thus, having higher mass of solid compared to OPEFB fibre (Akratos et al., 2017). So, samples A, B and B' recorded composting duration which was higher compared to samples containing only OPEFB fibre as the brown material. Based on a One-Way ANOVA post-hoc test, there were no significant differences of mean duration of composting among samples B or B' with other compost samples. According to Wan Razali et al. (2012), OPEFB is known to be difficult to degrade. This is due to its characteristic of having rigid structures containing relatively large amounts of lignin, hemicellulose, and cellulose. Besides, OPEFB fibre presents less favourable conditions for microorganisms to carry out their bioactive processes to degrade the material. Thus, compost containing pure OPEFB fibre (samples E' and E) took longer time to decompose at 7 and 8 weeks respectively. Adam et al. (2016) have suggested methods to enhance composting of OPEFB by incorporating materials containing high nitrogen content to create a higher initial C:N ratio. This helps to enhance the microbial activity within the compost pile for faster degradation process of the OPEFB fibre. Also, turning off the compost pile more frequently as thrice a week to maintain an even distribution of moisture within the pile can prevent heat build-up which may cause the beneficial microorganism to denature. This explains the reason for the shorter composting period of samples containing higher weight of vegetable scraps (samples A, B, B', C and C') which took 4 to 6 weeks. The vegetable scraps are high nitrogen materials which have additional moisture that aids in the degradation of the OPEFB fibre.

3.3.2 Comparison between composting duration and EM solution treatment

A paired t-test was performed to determine whether there was any statistically significant difference between the means of composting duration when samples were treated with EM solution. Analysis showed that the composting duration of samples that were composted without EM solution were longer (6.25 ± 1.708 weeks) compared to samples that were treated with EM solution (5.50 ± 1.291 weeks). The duration of composting of samples that were treated with and without EM solution were strongly and positively correlated ($r = 0.983$, $p < 0.05$). There is a significant difference between the duration of composting between samples that were treated with and without EM solution ($t_3 = 3.000$, $p = 0.05$). Therefore, on average samples that were not treated with EM solution recorded a longer composting duration of 0.750 ± 0.500 weeks compared to samples that were treated with EM solution (95% confidence interval [-0.046, 1.546]). The prepared EM solution can consist of common food-grade aerobic and anaerobic microorganisms which are commonly available in the environment such as lactic acid bacteria, yeast and phototrophic bacteria. According Nanyuli et al. (2018), EM solution functions as a compost enhancer in their study relating to the effects of EM on the rate of decomposition and nutrient content of the composted manure. The application of EM solution in the compost mixture was able to reduce the period of composting from three months to only one month. The beneficial microorganisms that are present in the EM solution are responsible for the rapid thermophilic phase during composting (Che Jusoh et al., 2013; Nanyuli et al., 2018). The high microbial activity will enable the compost mixture to reach a higher peak temperature within a shorter period of time. As reported by Nanyuli et al. (2018), that the application of EM resulted in the composting of manure to achieve its highest peak value of 58 °C on day 6 compared to the control sample that achieved its highest peak value of 55 °C on day 8. Che Jusoh et al. (2013) also showed similar outcomes as the composting rice straw treated with EM reached the highest peak value of 58.2 °C on day 10 compared to composting without EM that only peaked at 56.2 °C on day 11. Thus, EM solution treatment resulted in a significant shorter duration of composting compared to samples that were not treated with EM solution. This was because the beneficial microorganisms that were present in the EM solution increased the rate of decomposition of the materials, and reduced the period of composting.

3.4 Compost effects

3.4.1 The effect of compost on soil pH

Table 6 shows the pH values of each compost sample and changes in the pH of soil before and after the addition of compost. Overall, it was observed that the incorporation of compost increased the pH of soil after 2 months. All compost samples were slightly alkaline (pH > 7.0) therefore, when compost was mixed with soil, the pH of soil changed from neutral (pH 7.0) to alkaline.

Table 6: The pH values of compost and soil before and after addition of compost.

Plant samples	Average pH of compost	Average pH of soil	
		Initial pH (Without compost)	Final pH (After 2 months)
X (control)	-	7.00 ± 0.00	7.03 ± 0.06
1 (+Compost A)	7.80 ± 0.00	7.00 ± 0.00	7.73 ± 0.06
2 (+Compost B)	7.80 ± 0.00	7.00 ± 0.00	7.60 ± 0.00
3 (+Compost C)	7.70 ± 0.00	7.00 ± 0.00	7.50 ± 0.10
4 (+Compost D)	7.60 ± 0.00	7.00 ± 0.00	7.60 ± 0.00
5 (+Compost E)	7.60 ± 0.00	7.00 ± 0.00	7.70 ± 0.10
6 (+Compost B')	7.80 ± 0.00	7.00 ± 0.00	7.47 ± 0.06
7 (+Compost C')	7.70 ± 0.00	7.00 ± 0.00	7.47 ± 0.06
8 (+Compost D')	7.70 ± 0.00	7.00 ± 0.00	7.60 ± 0.10
9 (+Compost E')	7.60 ± 0.00	7.00 ± 0.00	7.70 ± 0.00

*Columns represent the mean values ± standard deviation (n=3).

The preferred pH of compost is between pH 6.0 to 8.5 (Che Jusoh et al., 2013). Since all the 9 compost samples recorded pH values that were within this range, it can be deduced that all the compost samples are desirable to be used as a plant growing medium. The pH of soil is an important factor that should be taken into consideration during planting as it affects soil fertility and its ability to provide sufficient amounts of nutrients for plant development. The optimum pH of soil is within pH 5.5 to 7.0. Based on the results, the soil used had an optimum pH since the recorded pH was 7.0. Nutrients are most available to plants in the optimum pH range between 5.5 to 7.0 since within this range plant nutrients do not leach easily from soil (Shareef et al., 2019).

The incorporation of compost with the soil had increased the pH of the soil. According to Valarini et al. (2009) in studying the effects of application of compost on the properties of a volcanic soil, it was found that adding compost to soil increased pH levels of the soil. This is due to the presence of humic acids in the compost samples which led to increase of exchangeable bases with a decrease in polycation levels of the soil. This causes the soil to become more stabilized due to the increase in its buffering capacity. Another research on the effects of compost made from municipal solid waste on physicochemical soil characteristics also explained that the reason for the increase of soil pH after incorporating with compost was due to the effect of compost which increases the hydronium ion (H_3O^+) in soil (Machado et al., 2021). When compost is incorporated with soil, adsorption of organic anions occurs which result in the release of hydroxyl ions that will increase the soil pH.

3.4.2 The effect of compost on plant growth

Table 7 shows the mean length of roots and mean height of shoots of the bird's-eye chili plant samples depicting the effects of compost on plant growth. When the soil was mixed with compost, the length of roots and height of shoots of the plants increased as the OPEFB fibre amount increased in the compost samples (samples X to 3, and samples 6 to 7). Soils mixed with compost samples E and E' showed lower length of roots and height of shoots compared to soil mixed with compost samples D and D'. Interestingly, soils mixed with EM treated compost showed better results for the length of roots and height of shoots.

Table 7: The length of roots (cm) and height of shoots (cm).

Plant samples	Length of roots (cm)	Height of shoots (cm)
X (control)	3.00 ± 0.10	5.97 ± 0.12
1 (+ Compost A)	3.20 ± 0.20	9.40 ± 0.30
2 (+ Compost B)	3.30 ± 0.00	9.53 ± 0.23
3 (+ Compost C)	3.63 ± 0.06	12.33 ± 0.81
4 (+ Compost D)	3.50 ± 0.00	10.77 ± 0.21
5 (+ Compost E)	3.40 ± 0.10	10.73 ± 0.21
6 (+ Compost B')	3.33 ± 0.06	9.57 ± 0.42
7 (+ Compost C')	3.67 ± 0.12	12.50 ± 0.26
8 (+ Compost D')	3.50 ± 0.10	10.70 ± 0.10
9 (+ Compost E')	3.43 ± 0.12	10.63 ± 0.15

Columns represent the mean values ± standard deviation (n=3).

3.4.3 Relationship of compost pH and plant growth

One-way ANOVA was performed to determine whether there was any statistically significant difference between the means of (a) length of roots and (b) height of shoots when the soil was treated with compost samples having different pHs. Based on the results of the one-way ANOVA performed at 95% significance level ($\alpha = 0.05$) both the p-value for (a) length of roots and (b) height of shoots of the bird's-eye chili plants was smaller than the significance level at $p = 0.000$. Therefore, the one-way ANOVA rejects the null hypothesis and revealed that there was a statistically significant difference in (a) length of roots ($F (3,26) = 28.868$, $p = 0.000$) and (b) height of shoots ($F (3,26) = 87.783$, $p = 0.000$) between at least two groups of plant samples which was treated with soil containing compost of different pH.

Since the result of the p-value was statistically significant, the post-hoc analysis of Tukey's HSD test was performed to determine the groups of samples that contain means of the (a) length of roots and (b) height of shoots that were significantly different. Post-hoc analysis of Tukey's HSD test is represented in Table 8. It shows the homogenous subsets of (a) length of roots and (b) height of shoots of plant samples which was treated with soil containing compost of different pH. Tukey's HSD test for multiple comparison showed that all the mean values of the (a) length of roots and (b) height of shoots of plant samples were significantly different with all the pH value of compost ($p < 0.05$ at 95% confidence level). This shows that the application of compost with different pH values affects bird's-eye chili plants plant growth.

Table 8: The homogenous subsets of means of (a) length of roots and (b) height of shoots with pH of compost.

pH of compost	Length of roots (cm)	Height of shoots (cm)
Control	3.0000^{c}	5.9667^{d}
7.60	3.4444^{ab}	10.7111^{b}
7.70	3.6000^{a}	11.8444^{a}
7.80	3.2778^{b}	9.5000^{c}

*Small letters (a, b, c, d) represent designate homogenous groups; means marked with the same letter do not differ significantly while means marked with different letters differ significantly ($\alpha = 0.05$).

Compost function as a soil amendment can significantly affect or alter the pH of soil which is an important factor that affects plant growth. The addition of compost can affect soil pH by elevating the pH or buffering the pH of the soil (Ashraf et al., 2020). The pH of soil can later affect plant nutrient transfer from the soil which is imperative in supporting plant development. Compost has a slightly alkaline pH with a value which is very close to neutral. The addition of compost in soil can balance the pH of the soil by boosting its cation exchange capacity (CEC). The CEC of soil is the total capacity of a soil to hold exchangeable cations (USDA, 2018). Since compost are composed of degraded OM and the CEC levels in OM are usually high, therefore, addition of compost in soil will increase the CEC levels of soil. The nutrients in soil exists as cations such as magnesium, potassium and calcium ions. The addition of compost will increase the soil pH to be higher than pH 5 so that soil can maintain exchangeable plant nutrient cations (Soilquality, 2022). A study conducted by Abdul Halim et al. (2018) on the influence of soil amendments incorporated in acidic soil on the growth and yield of rice showed the pH of soil that was treated with compost for 43 days increased from pH 3.7 to 6.2. The soil treated with compost also presented the highest growth reading in terms of plant height, length of roots, number and size of panicles. Therefore, it can be concluded that with the addition of compost in soil, the soil can better support effective transfer of plant nutrients which are essential in supporting plant growth and development. Thus, soil treated with compost showed better plant growth compared to the control media (sample X).

3.4.4 Relationship of OPEFB fibre amount and plant growth

Further on, one-way ANOVA was performed to determine whether there was any statistically significant difference between the means of (a) length of roots and (b) height of shoots of the bird's-eye chili plants when the soil was treated with compost samples containing different amounts of OPEFB fibre. It was observed that both the p-value for (a) length of roots and (b) height of shoots of the

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bird's-eye chili plants was smaller than the significance level at $p = 0.000$.

Therefore, the one-way ANOVA rejects the null hypothesis and reveals that there is a statistically significant difference in (a) length of roots ($F_{(9,20)} = 11.645$, $p = 0.000$) and (b) height of shoots ($F_{(9,20)} = 85.322$, $p = 0.000$) between at least two groups of plant samples which was treated with compost samples containing different amounts of OPEFB fibre. Since the result of the p-value was statistically significant, the post-hoc analysis of Tukey's HSD test was performed to determine the groups of samples that contain means of the (a) length of roots and (b) height of shoots that are significantly different (Table 9). Tukey's HSD test for multiple comparison found that all the mean values of the (a) length of roots and (b) height of shoots of plant samples were significantly different with all the pH value of compost ($p < 0.05$ at 95 % confidence level). This shows that the application of compost samples containing different amounts of OPEFB fibre affects bird's-eye chili plants growth.

Bio-compost from OPEFB fibres can be applied to soil as an organic fertiliser to meet nutrient needs of crops (Gandahi & Hanafi, 2014). This form of bio-compost can supply soil with growth promoting substances and vitamins which can improve soil fertility to support plant growth. The average macronutrients that are available in OPEFB compost are 0.8% nitrogen, 0.1% phosphorus, 2.5% potassium and 0.2% magnesium on a dry weight basis. According to a research study that was conducted by (Neswati et al., 2022) it was found that the usage of OPEFB compost was able to improve the fertility of nickel post-mining soil. It was shown that plant samples treated with OPEFB fibre resulted in better growth compared to samples that were treated with the controlled compost sample (plant sample 1). This is because compost made from OPEFB fibre contains high levels of nutrients which are absorbed by the roots of the plants which are essential for the growth of the shoots. Besides, compost made from OPEFB fibre functions as an effective soil amendment which can boost the soil CEC levels for efficient plant nutrient transfer (Zakri & Adam, 2021).

3.4.5 Relationship of EM treatment and plant growth

A paired t-test was performed to determine whether there was any statistically significant difference between the means of (a) length of roots and (b) height of shoots of plants that were planted in soil which were incorporated with compost treated with EM solution. Observation showed that (a) length of roots and (b) height of shoots of plants that were planted in soil which were incorporated with compost treated with EM solution were higher at 3.34 ± 0.23 cm and 9.79 ± 2.05 cm respectively, compared to samples that were treated without EM solution which were at 2.32 ± 1.69 cm and 7.23 ± 5.34 cm respectively.

Table 9: The homogenous subsets of means of (a) length of roots and (b) height of shoots with plant samples treated with compost containing different amounts of OPEFB fibre.

Plant sample	Length of roots (cm)	Height of shoots (cm)
X	3.0000^{d}	5.9667^{d}
+A	3.2000^{cd}	9.4000^{c}
+B	3.3000^{bc}	9.5333^{c}
+C	3.6333^{a}	12.3333^{a}
+D	3.5000^{ab}	10.7667^{b}
+E	3.4000^{abc}	10.7333^{b}
+B'	3.3333^{bc}	9.5667^{c}
+C'	3.6667^{a}	12.5000^{a}
+D'	3.5000^{ab}	10.7000^{b}
+E'	3.4333^{abc}	10.6333^{b}

Small letters (a, b, c, d) represent designate homogenous groups; means marked with the same letter do not differ significantly while means marked with different letters differ significantly (α = 0.05).

The (a) length of roots ($r = 0.78$, $p < 0.05$) and (b) height of shoots of plants ($r = 0.806$, $p < 0.05$) that were treated with and without EM solution were strongly and positively correlated. There was a significant average difference between (a) length of roots ($t_3 = 2.834$, $p = 0. 011$) and (b) height of shoots of plants ($t_3 = 2.834$, $p = 0. 011$) that were treated with and without EM solution ($t_3 = 2.791$, $p = 0. 013$). Therefore, on average samples that were treated with EM solution recorded longer (a) length of roots (1.017 ± 1.522 cm) and taller (b) height of shoots of plants (2.556 ± 3.885 cm) compared to samples that were not treated with EM solution. EM solution functions as an additive to accelerate composting process and provide additional nutrients to the compost mixture. Fan et al. (2018) reported that EM usage in home scale organic waste composting is beneficial as compost samples that were treated with EM had higher nutrient content. Compost treated with EM showed significantly ($p < 0.05$) higher N content (3.6%) than the control sample (2.1%). The study explained that compost treated with EM contains more nitrogen because EM resulted in greater loss of C as production of carbon dioxide was higher due to the rapid microbial activity within the compost pile or due to the rapid nitrogen fixation process during composting.

4. CONCLUSION

In conclusion, the objectives of the research were met. Composting of samples consisting of dry leaves, vegetable scraps and OPEFB fibre with and without EM solution treatment were achieved within 4 to 8 weeks. It was found that compost with higher amount of OPEFB fibre resulted in a significantly ($p < 0.05$) longer duration of composting from 4 weeks (14% OPEFB), 6.5 weeks (50% OPEFB), and up to 7.5 weeks (100% OPEFB). While, the inclusion of EM solution resulted in a significantly ($p < 0.05$) shorter duration of composting (by 1 week) in all samples compared to samples that were not

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treated with EM solution. In terms of bird's-eye chili plants growth, it was observed that soil incorporated with compost showed better plant growth compared to the control plant sample X (without compost). The compost samples slightly increased the pH of soil. Plant samples that were planted with compost treated with EM solution had significantly better growth in terms of roots length and shoots height compared to those grown with compost not treated with EM solution. Further research that can be carried out include soil proximate and C:N analysis, microbiology analysis, temperature profiling, growth tests with different types of soils and plant seeds. Therefore, it can be concluded that OPEFB fibre can be utilised in composting with the inclusion of EM solution. The resulting compost can be included as a component of planting media to improve soil properties and support plant development and growth.

ACKNOWLEDGEMENTS

This project is covered under UMK-MoF research grant (R/MOF/A07.00/01397A/007/2020/00721).

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eISSN Number: 2462-2389