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The Utilization of Oil Palm Empty Fruit Bunch (OPEFB)Fibre in Home Compost Making

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DECLARATION

I hereby declare that the work embodied in this report is the result of my own research except individual citations and summaries that I have explained their sources.

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Penggunaan Serat Tandan Kosong Kelapa Sawit (OPEFB) dalam Pengkomposan Buatan Sendiri di Rumah.

ABSTRAK

Seperti yang kita sedia maklum, Malaysia merupakan pengeluar minyak sawit kedua terbesar di dunia selepas Indonesia. Setiap tahun, berjuta-juta tan sisa kelapa sawit dijana, di mana OPEFB yang dihasilkan oleh kilang kelapa sawit menyumbang sebahagian besar sisa. Pengurusan OPEFB yang tidak betul boleh membawa kepada banyak masalah alam sekitar. Oleh itu, pengkomposan dianggap sebagai kaedah pengurusan sisa yang berkesan. Namun, pengkomposan OPEFB mengambil masa yang lama disebabkan oleh kandungan lignin dan selulosa yang tinggi. Oleh itu, dalam kajian ini, gentian OPEFB telah dikompos di rumah dengan penambahan larutan EM yang dibuat secara sendiri. Penyelidikan ini mempunyai tiga matlamat. Matlamat pertama adalah untuk membuat kompos buatan sendiri menggunakan gentian OPEFB. Pengkomposan gentian OPEFB dijalankan dengan kaedah pengkomposan aerobik dengan sisa dari taman iaitu daun kering dan sisa dapur iaitu sisa sayuran. Objektif kedua adalah untuk menentukan kesan jumlah gentian OPEFB yang berbeza pada tempoh pengkomposan. Sebanyak 9 sampel kompos yang mengandungi jumlah gentian OPEFB yang berbeza telah dibuat yang mempunyai tempoh pengkomposan yang berbeza iaitu antara 4 hingga 8 minggu. Larutan EM telah ditambah pada replikasi sampel kompos untuk membantu dalam proses penguraian gentian OPEFB dan memberikan nutrien tambahan kepada campuran kompos. Berdasarkan hasil kajian yang diperolehi, ternyata kompos yang mengandungi lebih banyak gentian OPEFB mengambil masa yang lebih lama untuk matang. Sampel kompos yang diperbuat daripada 100 % gentian OPEFB memerlukan tempoh 8 minggu untuk selesai pengkomposan, manakala sampel replikasi yang dirawat dengan EM mengambil tempoh 7 minggu untuk selesai pengkomposan. Matlamat terakhir kajian ini adalah untuk menguji keberkesanan kompos pada proses tumbesaran pokok cili padi. Medium penanaman telah disediakan dengan nisbah 3: 1: 1 dengan campuran tanah, kompos, dan gambut kelapa. Gambut kelapa telah ditambah pada lapisan paling atas untuk mengawal kelembapan tanah. Mengikut hasil kajian, tanah yang dirawat dengan kompos yang mengandungi gentian OPEFB menunjukkan hasil pertumbuhan pokok yang lebih baik berbanding tanah yang tidak dirawat dengan kompos serta yang dirawat dengan sampel kompos terkawal (0 % gentian OPEFB). Ia juga menunjukkan bahawa kompos dirawat dengan larutan EM yang mengandungi 14 % serat OPEFB dan 86 % sisa sayuran, dengan nisbah C: N permulaan pengkomposan 29.9: 1, mempunyai kesan terbaik ke atas pertumbuhan pokok. Oleh itu, berdasarkan kajian ini, kompos yang diperbuat daripada gentian OPEFB boleh digunakan sebagai medium pertumbuhan untuk menyokong pertumbuhan pokok. Akhir sekali, pengkomposan berasaskan rumah adalah satu amalan yang boleh meningkatkan kesedaran di kalangan rakyat Malaysia bahawa pengurusan sisa sebenarnya boleh bermula di rumah sebelum ia boleh dilakukan dalam skala yang lebih besar.

Kata kunci: serat OPEFB, kompos berasaskan rumah, kompos aerobik, larutan EM, pokok cili padi.

The Utilization of Oil Palm Empty Fruit Bunch (OPEFB) Fibre in Home Compost Making

ABSTRACT

Malaysia is known to be the second largest global producer of palm oil after Indonesia. Every year, millions of tons of oil palm waste are produced where OPEFB which is produced at the palm oil mills covers the largest portion of waste. Improper management of OPEFB can lead to many environmental problems. Therefore, composting is considered as an effective method for waste management. However, composting of OPEFB takes a long time due to its high lignin and cellulose content. Therefore, in this research, home-based composting of OPEFB fibres was carried out with the incorporation of home-made EM solution. There were three objectives of this research. The first objective was to prepare home-made compost by using OPEFB fibre. Composting of OPEFB fibre was carried out by using aerobic composting method together with garden waste which is dried leaves and kitchen waste which is vegetable scraps. The second objective was to determine the effects of different amounts of OPEFB fibre on the duration of composting. A total of nine compost samples with different amounts of OPEFB fibre was made which had different duration of composting of 4 to 8 weeks. EM solution was added to the replicated compost samples to aid in the decomposition of OPEFB fibre and to provide nutrients to the compost mixture. Based on the results obtained, it was proven that compost containing higher amounts of OPEFB fibre took a longer time to mature. Compost sample made from 100 % OPEFB fibre took 8 weeks of composting period while its replicate sample which was treated with EM took 7 weeks for composting. Finally, the objective was to investigate the effectiveness of home-made compost to support plant growth of bird's-eye chili. The planting medium was prepared with a ratio of 3: 1: 1 of soil, compost and cocopeat. Cocopeat was added to the top layer to regulate moisture of the soil. Based on the results, soil treated with compost containing OPEFB fibres showed better results for plant growth compared to soil that was treated without compost and with controlled sample of compost (0 % OPEFB fibre). It was also proven 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 on plant growth. Therefore, based on this research, compost made from OPEFB fibre can be utilized as a growing medium to support plant growth. Finally, home-based composting is a practice which can be carried out to create awareness among Malaysians that waste management can actually begin from home before this effort can be developed at a higher scale.

Keywords: OPEFB fibre, home-based composting, aerobic composting, EM solution, bird's-eye chilies.

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α	: Alpha
≈	: Approximately
cm	: Centimetre
cm^3	: Cubic Centimetre
° C	: Degree Celsius
g	: Grams
L	: Litre
kg	: Kilograms
kPa	: Kilopascal
ml	: Millilitre
mm	: Millimetre
mt	: Metric Tons
%	: Percent

LIST OF ABBREVIATIONS

ALOF : Active Liquid Fertilizers

ANOVA : Analysis of Variance

BCed : Biochar Composted

BCing : Biochar Composting

C : Carbon

CEC : Cation Exchange Capacity

C: N : Carbon-to-nitrogen

CO_2 : Carbon Dioxide

COMBI : Co-composted Biochar

CRD : Complete Randomized Design

EM : Effective Microorganisms

H_2O : Water

H_3O^+ : Hydronium Ion

H_2S : Hydrogen Sulphide

HSD : Honest Significant Difference

K : Potassium

K_2O : Potassium Oxide

LAB : Lactic Acid Bacteria

LDPE : Low-density Polyethylene

MARDI : Malaysian Agricultural Research and Development Institute

MC : Moisture Content

Mg : Magnesium

N : Nitrogen

Na : Sodium

NH_3 : Ammonia

Ni : Nickel

O_2 : Oxygen

OM : Organic Matter

OPEFB : Oil Palm Empty Fruit Bunches

OPFFB : Oil Palm Fresh Fruit Bunches

P : Phosphorus

P_2O_5 : Phosphorus Pentoxide

POM : Palm Oil Mill

POME : Palm Oil Mill Effluent

SPSS : Statistical Package for the Social Sciences

TSC : Total Solid Content

CHAPTER 1

INTRODUCTION

1.0 Introduction

The oil palm industry is the largest agricultural sector in Malaysia (Hirschmann, 2020). Malaysia is the second largest global palm oil producer after Indonesia. The total global supply of palm oil by both countries are more than 80 %. The two main export countries of the Malaysian palm oil are China and India. Besides, the United States as well as the other Asian countries also import their countries' palm oil supply from Malaysia.

In Malaysia, millions of hectares of land are used for the plantation of oil palm trees. The oil palm is commonly known as *Elaeis guineensis*, an ornamental plant that was 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 are the kernel (MPOB, 2017). The mesocarps 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 process of extraction of palm oils generates huge amounts of solid oil palm biomass which includes about 23 % OPEFB, 5 % shells and 12 % mesocarp fibre (Trisakti et al., 2018).

The OPFFB is processed in the POM of the factory (Trisakti et al., 2018). During milling, the OPFFB undergo steam treatment under high pressure of 294 kPa for about 1 hour in order to detach the fruits from the bunches (Tan et al., 2017). The by-products of this process are the OPEFB which are 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 pest such as insects and rats.

Compost is a bio-organic fertilizer that is produced through the process of composting (Siddiquee et al., 2017). Compost is produced where biodegradable organic materials that are rich in N and C are piled alternatingly and undergo decomposition with the help of certain organisms and heat (Anyaoha et al., 2018). Therefore, composting of OPEFB can be considered as an environmental-friendly method for waste management. Since the OPEFB that are generated in POM have low bulk density and are very moist (≈ 60 % MC), the OPEFB have to undergo water retting process to convert them into fibres (Tan et al., 2017). During water retting process, microorganisms and moisture are used to dissolve the cellulose tissue and pectin which results in the formation of OPEFB fibres. The fibre is ready to be recycled and utilized during compost making process to add value to the compost. The OPEFB fibre can be used as a compost material due to its characteristic of high MC as well as high C: N ratio which makes them a C-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 fertilizer which can be used to replace chemical fertilizers during home-planting or at any agriculture sector (Siddiquee et al., 2017).

1.1 Research Background

The research on the utilization of OPEFB fibre in home compost making was conducted at my home garden which is located at Taman Amar Diraja, Kluang, Johor. The OPEFB fibre was obtained from my father's working place which is from Kluang Oil Palm Processing Sdn. Bhd.

Malaysia is known to be the second leading global exporter of palm oil after Indonesia. This result in production of biomass wastes which are high in lignin and cellulose which are known as lignocellulosic waste material. The estimated yield of OPEFB is about 16 million tons per year (Rosli et al., 2017). Over the years, people have become aware of the importance of recycling OPEFB in order to manage waste. However, in order to manage waste effectively, proper waste management methods need to be adopted to prevent any negative side effects especially to the environment. Traditionally, OPEFB are recycled in a different way when compared to the methods that are used recently (Rosli et al., 2017). The OPEFB are traditionally burnt in incinerators at POM to convert them into ash. The ash is then used as fertilizers at oil palm plantation. The drawback of this traditional method is that it contributes to environmental problems.

Recently, OPEFB undergo pre-treatment which converts them into high bulk density fibre materials known as OPEFB fibre before being utilized. The pre-treatment of water retting is environmental-friendly and economical. Therefore, such method does not produce any negative side-effects to the environment. During the pre-treatment of water retting, the OPEFB are either submerged in cold or hot water for fibre extraction process (Omoniyi, 2019). The extracted OPEFB fibres can be utilized in various ways. Besides in composting, they can also be used as a form of biofuel. In addition, OPEFB fibre can also be used in the reinforcement of biopolymer materials as well as bio-composites (Tan et al., 2017).

Therefore, in this research study OPEFB fibre was used as the main material in the home-made compost. The compost was then tested on its effectiveness to support plant growth.

1.2 Problem Statement

According to the statistical analysis by Rosli et al. (2017), the oil palm industries in Malaysia produced about 16 million tons of OPEFB annually. This indicates that there is abundance of agricultural biomass which are the by-products of this industry that are produced in Malaysia. The OPEFB fibre can be considered as an economical material if utilized efficiently. Therefore, this research on home-make compost by utilizing OPEFB fibre can clearly create awareness among Malaysians that waste management can actually begin from home before this effort can be developed at a higher scale. During the conduct of this research, composting of the home-made compost samples were conducted by using aerobic composting method. The independent variable was the amount of OPEFB fibre where the samples contained different weight (g) of OPEFB fibre. This research was carried out to study the effects of different amounts of OPEFB fibre on the duration of composting and its effectiveness towards the growth of bird's-eye chili plants. Therefore, this research comprises of two dependent variables which are duration of composting (weeks) and plant growth which are measured as the length of roots (cm) and the height of shoots (cm) of the bird's-eye chili plants.

1.3 Hypothesis

The research was conducted to study the effects of the different amount of OPEFB fibre in the compost mixture on the duration of composting as well as on plant growth. Therefore, the hypotheses of the research are:

a. H_0: There is no relationship between the amounts of OPEFB fibre and duration of composting.

   H_1: There is a relationship between the amounts of OPEFB bunch fibre and duration of composting.

b. H_0: There is no relationship between the amounts of OPEFB fibre and plant growth.

   H_1: There is a relationship between the amounts of OPEFB bunch fibre and plant growth.

1.4 Objectives

There are three objectives that were involved in this research study.

1. To prepare home-made compost by using OPEFB fibre.
2. To determine the effects of different amounts of OPEFB fibre on the duration of composting.
3. To investigate the effect of home-made compost towards plant growth.

1.5 Scope of Study

This research focuses on the utilization of biomass materials. In this research, agricultural waste materials from oil palm industries which is the OPEFB fibre was used as the main material in compost making. Composting was carried out using home composting method. The effectiveness of the compost was then tested by using it as a source of natural-based fertilizer to study its effect on the growth and development of plants.

1.6 Significance of Study

The main reason for this research was to create awareness on the importance of waste management practice among Malaysians. Malaysians need to be aware of the various waste materials that are around them and the value that the waste material can offer when utilized efficiently. For example, the oil palm industries produce OPEFB fibre, which is the major agricultural waste. OPEFB fibre can be utilized as a bio-organic compost material to provide nutrients to soil in order to support the growth of plants.

1.7 Limitation of Study

There were several limitations that was involved in this research study. Firstly, during composting, small-scale composting took place by using small plastic containers. This is due to the limitation of tools and proper space that are available at home. Next, since the compost is built in small quantities, temperature changes during composting was not able to be identified during the different times of the day. Therefore, the study of temperature on the rate of decomposition of materials was not conducted. Finally, due to the Covid-19 pandemic, there was a huge inconvenience to return back to the university. Therefore, any forms of laboratory research on the compost samples were not able to be carried out for further testing.

CHAPTER 2

LITERATURE REVIEW

2.1 Compost

Compost is produced through a method known as composting (Raza & Ahmad, 2016). Composting involves the natural biological breakdown process called decomposition of OM through aerobic, biochemical and microbiological processes. The composting process results in the formation of a dark humus-like material called compost which is a relatively stable organic end product from the decomposition of OM (Rosalina et al., 2019). Therefore, compost can also be defined as decayed OM which is 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, sanitized and simpler decomposed organic materials (Adugna, 2016; Rastogi et al., 2020).

During composting, the OM are converted into a dark humus-like material known as compost with the help of certain organisms such as mesophilic and thermophilic organisms. Overall, composting involves three phases as shown in Figure 2.1 (Barthod et al., 2018; Rastogi et al., 2020). The initial composting phase is called as the mesophilic phase. During this phase, simple compounds such as sugars and amino acids are broken down by mesophilic bacteria and fungi. This results in the rapid increase of temperature within the compost mixture. Next, the second phase is also known as the thermophilic phase. During this phase, the optimum temperature for composting takes place between 40 to 65 °C which is sufficient to kill pathogens which are able to survive at extreme temperatures up to 55 °C (Barthod et al., 2018). Based on Figure 2.1, the stars (*) indicate the phases where pathogens are destroyed. Besides during this phase, thermophilic microorganisms break down the more complex OM such as fats and the lignocellulosic materials. This results in the decrease of organic C content in the feedstock due to the metabolic activities of these heat tolerant microbes. Finally, the last composting phase is either called as the cooling or maturation phase. During this phase, the rate of microbial activities decreases which result in the decrease of the temperature within the compost pile. During this period, the compost mass is recolonized by the mesophilic microbes which continues to break down the residual sugars, cellulose and hemicellulose, thus, converting the OM into humus. During this stage, the rate of degradation of OM decreases while the rate of humification and polymerization of the organic compounds increases. Therefore, compost is considered a form of organic-based fertilizer which are sustainable to the environment since they are made from the recycling of plant and animal remains.

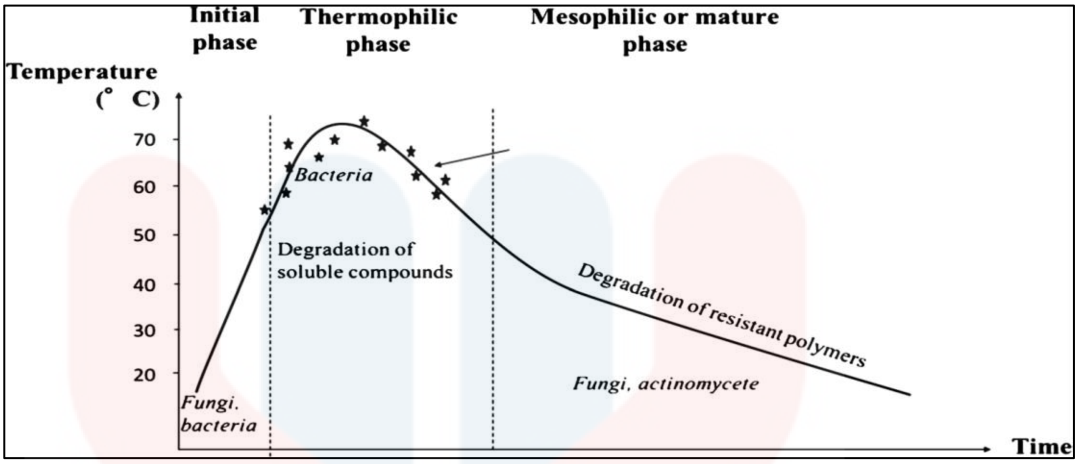

Figure 2.1: The changes of temperature and the corresponding microorganisms involved during the composting phases (Source: Barthod et al., 2018).

2.1.1 Effects of Compost on Soil Properties and Plant Growth.

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. For example, based on a study conducted by Do and Scherer (2013) on the effects of compost-based media on the growth of *Pelargonium* and *Salvia* showed that the growth of plant was the lowest in 100 % compost. According to the research, it was concluded that pure compost has too high nutrient contents. The large percentage of compost resulted in negative effects on plant growth due to excessive nutrient uptake of N, P, K and Na.

Next, compost is usually added to soil to improve the properties of soil (Kranz et al., 2020). Pure compost and COMBI can amend soil condition by increasing the fertility of soil (Busch & Glaser, 2015; Antonangelo et al., 2021). Both these compost types have the potential to overcome the low nutrient levels of soil through the slow release of their nutrients into soil. Next, based on a research conducted by Huang et al. (2016), it was found that compost also has the potential to function as a bio-sorbent for adsorbing heavy metals in soil. However, according to this research paper, pure compost may not be suitable to absorb all the types of heavy metals in soil. Pure compost can only immobilize the uptake of heavy metals by plants in which some heavy metals may still remained in the soil. Therefore, compost combined with other soil amendments such as biochar can further immobilize the heavy metals in the soil. For example, research conducted by Zeng et al. (2015) showed that BCed and BCing material had the greatest capacity to reduce the bioavailability and mobility of heavy metals in soil.

Therefore, compost functions as a growing medium where it serves as a soil amendment and a bio-organic fertilizer. Compost functions as a bio-organic fertilizer to provide nutrients to the soil which is important for the plant development (Raza & Ahmad, 2016). Compost can also improve soil properties by improving its fertility in order to improve its efficiency to support plant growth.

2.1.2 Home Composting

Home composting is usually carried out as a hobby or as a method to reduce waste materials at home (Environmental Protection Agency, March 31, 2021). The materials used during composting are usually collected from the home surrounding such as from the kitchen or garden. However, not all waste materials that are collected at home can be used during composting. For example, pet waste such as cat or dog faeces are not advisable to be added since these materials contains parasites and pathogens that are not healthy to support plant growth. Besides, the faeces also contribute to foul odor which may attract flies. In addition, food waste containing fats, grease as well as carcasses are not suitable to be used since they contribute to bad smell and may attract flies and pests such as rodents.

2.1.3 Aerobic Decomposition

Figure 2.2 illustrates the aerobic method of composting. Aerobic decomposition occurs in the presence of O_2. During this process, OM will be broken down by aerobic microorganisms. The main product of aerobic composting is compost, a dark brown humus-like material which has a moist texture and an earthy smell (Anne, 2012; Amery et al., 2020; Ayilara et al., 2020). Besides, the by-products of aerobic composting are CO_2, NH_3, H_2O and heat.

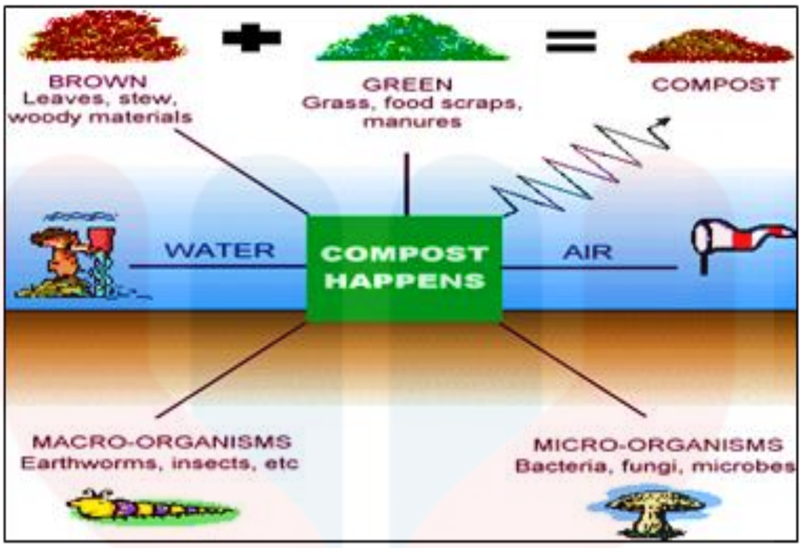

Figure 2.2: Aerobic method of composting (Source: Zafar, 2019)

2.2 Factors that Affect Aerobic Composting

During composting, there are several parameters that need to be considered to ensure optimum composting process is able to takes place (Raza & Ahmad, 2016). The factors include C: N ratio, MC and proper aeration.

2.2.1 The C: N ratio during Composting

The C: N ratio of a compost is defined as the mass ratio of C to N that is contained in each OM which is selected as the compost material (Priya et al., 2017). The initial C: N ratio of compost materials is important to determine the enzymatic breakdown process of OM by the microorganisms. This is because during decomposition, microorganisms require sufficient amounts of C as a source of energy and N to produce protein (*Carbon-*

to-Nitrogen Ratio | Planet Natural, n.d.). The microorganisms that are involved during composting changes the initial C: N ratio of the materials so that the compost produced will approach the C: N ratio of the soil.

Besides, C: N ratio can also affect the period of maturity of the compost (Tibu et al., 2019). Therefore, in order to achieve optimum composting, an optimum ratio of a total of 20 to 30 atoms of C is required for each atom of N (20 – 30:1). For conditions above and below the optimum C: N ratio will affect the rate of decomposition of the materials. For example, high C: N ratio is a result of excess C content in the compost mixture. When the level of C is too high in the compost, the MC of the compost will be reduce causing it to have a very dry texture. This may reduce the rate of decomposition of the compost material; thus, composting will take place for a longer period. At very low C: N ratio, this indicates the excess N content of the compost mixture. During this condition, the compost will have a very wet texture due to the excess moisture in the compost mixture, thus, resulting in the unpleasant smell of the compost pile.

2.2.2 MC

In order for effective composting to take place, the compost pile should not be too dry or too wet. According to Raza and Ahmad (2016), the MC of the waste materials that are used during composting should be between 50 to 55 %. When the condition is too dry, this may lead to the mortality of aerobic microorganisms. However, when the compost contains excess moisture, this may lead to anaerobic condition. As a result, greenhouse gas such as methane will be emitted and an unpleasant odour will be released (Slorach et al., 2019). Besides, MC above 75 % will reduce the temperature of the compost pile which results in slow decomposition of OM.

2.2.3 Proper Aeration

Based on Raza and Ahmad (2016), proper aeration can ensure the availability of oxygen in the compost pile. Proper aeration can be ensured through turning of the compost pile. Turning of the compost pile should take place once every three days to make sure that materials in the compost pile are evenly mixed and the moisture is distributed equally throughout the pile (Trisakti et al., 2018).

2.3 Advantages of EM in Composting

According to El-shafei et al. (2008), the concept of EM was first developed by a research professor called Professor Teruo Higa who was a horticulturist at the University of Ryukyus at Okinawa, Japan (Namasivayam & Kirithiga, 2010; Ab Muttalib et al., 2016). Based on his research in the 1970s, he reported that EM solution comprises of a variety of naturally occurring microorganisms. In his research EM solution containing a combination of ≈ 80 different types of beneficial microorganisms were proven to effectively degrade the OM in order to produce beneficial compounds such as vitamins, hormones, enzymes, organic acids, minerals and antioxidants (Wahid & Azman, 2016). EM comprises of a group of aerobic and anaerobic beneficial microorganisms such as bacteria (LAB, photosynthetic bacteria and actinomycetes), yeast and other fermenting fungi (*Aspergillus* and *Penicillium*) (Cóndor-Golec et al., 2007; Bhagavathi Pushpa et al., 2016; Wahid & Azman, 2016). EM solution can either be self-prepared or are available in the dormant form containing the mother culture which are usually cultured in the laboratories and could be purchased from stores as shown in Figure 2.3.

However, self-prepared EM solution may not contain a wide combination of beneficial microorganisms. For example, based on Zenyr Garden (2021), home-made EM solution containing LAB as the dominant beneficial bacteria was prepared by fermentation process of kitchen ingredients that are easily available. The recipe involved a 7-day fermentation process of a combination of 150 g of rice, 15 g sea salt, 45 g sugar and 1500 ml mineral water. The rice was the source of the beneficial microorganism since microbes are available on the external surface of grains. Sugar provided the microbes with energy and nutrients while sea salt provides the microbes with minerals. The sweet-sour smell of the solution indicate that the microbes are active in the solution and the solution are ready to be used. The home-made EM solution can be stored at room temperature up to 2 years by mixing a ratio of 1: 1 of molasses or sugar to the EM solution or have a shelf-life of 3 years when refrigerated. The stored EM solution must be reactivated by adding molasses and water to EM solution for active fermentation to take place.

Next, many research studies used the dormant form of EM solution. For example, in a research that was conducted by Bhagavathi Pushpa et al. (2016), the dormant EM solution was supplied by Environ Biotech, Coimbatore and was activated before it was used. During the activation process, 1 L of EM solution was activated through the addition of 20 L of water and 2 kg of pure cane sugar. The mixture was kept in an air tight container away from the exposure of light at ambient temperature for 7 days for fermentation to take place. The gas which are the by-product of fermentation was released every day until fermentation was completed. Besides, it was also observed that active fermentation resulted in the formation of a white layer of actinomycetes at the top layer of the solution which was accompanied with a sweet smell. An activated EM solution had a pH below 4.0. Next, a research that was conducted by Namasivayam & Kirithiga (2010), showed the application of EM solution which was supplied by Environ Biotech. The EM solution was activated through the addition of 100 ml of rice water to 1 ml of EM solution. The purpose of the addition of rice water was to increase the performance and the amount of nutrients of the EM solution.

The purpose of adding EM during composting is to speed up the breakdown of OM and thus reducing the duration of composting. Next, EM is also added to optimize the function of soil as a planting medium. EM provides nutrients to enhance development and growth of plants. A study which was conducted by Che Jusoh et al. (2013), to determine the effect of EM on the composting of rice straw and its influence on the quality of the compost samples. Based on the result, it was proven that samples treated with EM reached the highest peak of temperature increase on day 10 at 58.2 °C while samples without treatment of EM only managed to reach its highest peak for temperature increase on day 11 but at a lower temperature of 56.2 °C. Besides, the addition of EM shortens the thermophilic phase during composting where this phase took place for 23 days compared to samples without treatment of EM which took place for 30 days. Besides, a good quality compost has a pH within the range of 6.0 to 8.5. The addition of EM resulted in the pH of compost at 7.55 which is lower compared to samples without EM which recorded a pH value of 7.62. Besides, the t-test conducted showed that there was a significant difference ($p < 0.05$) between the nutrient content of compost samples that was treated with EM and the compost without treatment of EM. This showed that addition of EM increases the mineralization in the composting process where compost sample containing EM had more N, P and K content compared to compost without EM.

Besides, a study was also conducted by Ab Muttalib et al. (2016), on the application of EM in food waste composting. Based on the study it was reported that application of EM can potentially reduce pollution since the beneficial microorganisms promote faster decomposition of OM and does not emit gases of offensive smells such as H_2S and NH_3. The EM produces enzymes which breaks down the organic wastes and provide addition nutrients for the composting process to better take place. Therefore, EM can potentially be used to speed-up the composting process and increase the nutrient content in compost. EM function by controlling the temperature within the compost pile and reduces the pathogens in the compost in order to produce good quality compost.

A study was conducted by Fan et al. (2018) to determine the effect of EM on home scale organic waste composting of food waste, rice bran and dried leaves. Based on the results of this research study, samples containing EM and without EM were well-matured and were tested free from pathogens within 2 months of composting period. However, the addition of EM provided additional benefits by suppressing the foul odour of the sample while increasing the humification process of the OM. Besides, addition of EM resulted in higher fat reduction and N content of the samples. It was found that the EM compost sample has a sharper peak of aromatic double bonds of C atoms (C=C) which represents a better degree of humification. Compost with EM reached a slightly higher temperature at the early composting phase due to increase in microbial activity within the compost pile.

Therefore, addition of EM during composting can suppress the foul odour of the samples, resulting in an enhanced humification process which increases the nutrient content of the compost and resulted in a greater fat reduction outcome which was up to 73 %.

Figure 2.3: EM solution by Maple (Source: *Effective Microorganism – MMAQUA*, n.d.)

2.4 Plant Growth Measurements.

Compost functions a growing medium to support plant growth (Baessler, 2021). The performance and effect of compost on plant growth can be evaluated by carrying out pot trial and measuring the growth parameters of the plant. For example, in a research that was conducted by Rady et al. (2016), the effect of organo-mineral fertilizer compost was tested on the growth of common beans (*Phaseolus vulgaris* L.). The growth parameters that were measured after 7 weeks. The plants were removed carefully from the pot by dipping the roots in a bucket of water to remove the soil residues. The lengths of shoots and roots of the plants were measured by using a meter scale. The number of leaves were counted and the area of the leaves were measured by using a graph sheet, by counting the squares that are covered by the leaves. Besides, in a research study that was conducted by Syuhadah Aji et al. (2021), the compost that were made from food waste was tested by evaluating its effects of the growth of dwarf crape jasmine (*Tabernaemontana divaricate*). During the research conduct, the seedling was transplanted in potting mixture containing different amounts of compost. The growth parameters that were measured after 150 days were the dry matter weight, plant height and width, leaf surface area and total number of leaves.

2.4.1 Effect of Compost on the Growth of Bird's-Eye Chili Peppers.

Bird's-eye chili peppers which are also scientifically known as *Capsicum annum* are locally known as *cili padi* in Malaysia or *cabai rawat* in Indonesia (Natsir et al., 2018). They belong to the family Solanaceae 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 pH between 6 and 7 (Chatterjee et al., 2012). The plants can thrive in high temperature climates with growing season temperatures of 18 to 27 °C during the day which is important to help induce early flowering of the plants and 15 to 18 °C during the night which is crucial to promote greater branching and flowering effect.

A study was conducted by Moneruzzaman Khandaker et al. (2017) to determine the effects of different organic fertilizers on the growth, yield and quality of *Capsicum annuum* L. var. Kulai (red chilli Kulai). During the research, the plants were treated with different types of organic fertilizers with compost being one of them. The soil was mixed with sand and compost which were applied at the top layer at ratio of 1: 1. The compost were added at the top layer every 4 weeks. The results were analysed after 18 weeks. Based on the result, it was found that treatment of the plants with vermicompost showed the best results with highest plant height of 63.38 cm with average of 24 branches per plant, higher number of leaves, value of stomata conductance, chlorophyll content, and number of flower bud. Plants planted in the absence of any type of organic fertilizer was the shortest with a recorded height of 42.12 cm with the lowest number of branches with average of 5 branches per plant. Therefore, from the overall study, it was found that application of compost as organic fertilizer positively affects the growth, yield, and quality of chili plant.

Another study was conducted by Khaitov et al. (2019), to evaluate the impact of organic manure on growth, nutrient content and yield of chili pepper under various temperature environments. During the experiment, the chili seeds were dried and were sown directly into the soil in pots at a depth of 2 cm containing soil mixture of 55 % clay, 20 % silt, and 25 % sand. Manure which contains about 67.06 % OM, 2.42 % N, 1.51 % P_2O_5, and 0.41 % K_2O were added to replicated samples and the effects on the growth of the chili peppers were observed for about 130 days (≈ 19 weeks). Based on the results, the application organic manure result in increased in lengths of root, shoot, and the dry weights of fruits by 21.4 %, 52.4 %, and 79.7 % respectively in the greenhouse compared to controlled samples. Therefore, from the overall research, it was proven that organic amendments were able to provide best solution for chili pepper production under variable climate conditions.

2.5 Coco peat.

Coco peat as shown in Figure 2.4 are coconut coir piths which are the by-product from the coconut industry. Coco peat is a growing media which is used to support growth of plants and function as soil amendment to overcome issues related to nutrient and moisture loss from soil (Krishnapillai et al., 2020). Coco peat comes from the coconut husk. Coconut husk is made up of natural fibres called coir along with parenchymatous, a sponge-like material called coir pith which binds the fibres in the husk. As a growing media, the coconut husk fibres create aeration by providing porosity in the coir and creates a structure that prevents compaction. The coir pith function as a micro sponge which is able to store moisture. Therefore, the fibre and pith cause the cocopeat to become a great growing medium which is able to provide aeration and hold moisture in order to maintain the quality and fertility of the soil to support plant growth (Mariotti et al., 2020).

Based on a research study by Khan et al. (2019), pot experiment was conducted in order to determine the effect of different levels of coconut peat treatment on the growth and yield response of water spinach (*Ipomoea aquatica*). There was a total of five treatment samples which contained different weights of coco peat (0 kg, 1000 kg, 1500 kg, 2000 kg and 2500 kg) that were made. The results showed that treatment containing 2500 kg of coco peat recorded the highest result for plant growth due to high nutrient availability of the soil.

Figure 2.4: Coco peat

2.6 Biomass

Biomass is defined as biodegradable waste materials or residues which are either plant-based or animal-based which are obtained from agricultural and forestry sectors. Biomass also covers biodegradable materials such as industrial and municipal waste (Proskurina et al., 2017). Biomass can be considered as a unique source of energy that is easily available and are renewable. Biomass can be an alternative source of energy that can be used to replace non-renewable energy such as fossil fuels. Biomass materials that have undergone various pre-treatments can be used effectively to produce various valuable products. Pre-treatment through physical, chemical, biochemical as well as thermal processes can be used to treat various types of biomass raw materials.

2.6.1 Agricultural Biomass Waste or Residues

Agricultural sectors produce tones of biomass waste materials or residues daily. These waste materials include the plants' stalks, leaves, roots, fruit peels, seeds as well as nut shells. The waste materials were normally discarded after the crops have been harvested. For many years, these waste materials have been incinerated or disposed through open-burning which had caused many harmful environmental effects such as global warming and air pollution. Recently, many researches have been conducted and have found that agriculture residues can be recycled and are potentially valuable supply of feed-stock materials (Tripathi et al., 2009).

2.6.2 Oil Palm Biomass

Over the years, the oil palm industry has experienced exponential growth which has led to increasing amounts of waste materials are collected from this industry (Siddiquee et al., 2017). Oil palm biomass is an example of agriculture biomass waste or residue. Oil palm biomass can usually be obtained through harvesting and milling process. For example, during the harvesting of the OPFFB, the residues of this process include the fronds and the trunk. Next, at the oil palm industry, more oil palm biomass residues are obtained in both solid and liquid forms, especially during the milling process (Hoe et al., 2016). Among the solid residues are the OPEFB, fibres of oil palm fruit mesocarp and kernel shells. The liquid residue which is the POME can also be obtained in large quantities. Among the major waste that are obtained are the OPEFB and the

POME which contribute about 22 % and 67 % of the oil palm residues that are discharged at the POM.

2.6.3 OPEFB

The OPEFB is the major solid palm oil biomass residues that are discharged at the POM of the oil palm industry (Hoe et al., 2016). The OPEFB are usually collected after the fruits have been removed from the OPFFB through a steam treatment under high pressure at 294 kPa for about 1 hour (Tan et al., 2017). The breakdown in the OPFFB yield huge amounts of waste which includes 7 % palm kernel, 14 % mesocarp fibre, 7 % shells of palm kernel and 23 % of OPEFB (Suhaimi & Ong, n.d.). Disposal of these residual materials are difficult and may cause many negative side-effects to the environment if not disposed properly. For example, incineration of OPEFB may lead to air pollution while improper disposal at open fields may attract pests. Therefore, in order to overcome these issues, OPEFB can undergo pre-treatment so that they can be properly utilized. In order to convert OPEFB into fibres, the empty fruit bunches will undergo water retting process where microorganisms and moisture are used to dissolve the cellular tissues and pectin of the fruit bunches, thus converting them into OPEFB fibres. This process yields about 70 % of fibres from the OPEFB.

2.6.4 Utilization of OPEFB and OPEFB Fibre.

The OPEFB is recycled to be utilized in many ways. Firstly, the OPEFB are traditionally burnt to convert them into ash. These ashes are then utilized as fertilizer due to the high K content at $\pm$ 30 %. However, combustion of OPEFB will contribute to air pollution. Therefore, the Ministry of Environment under the Decree number 15 of 1996 on the blue-sky had banned this utilization method (Trisakti et al., 2018).

Therefore, in order to overcome any environmental issue, OPEFB undergo composting through a basket composting method (Trisakti et al., 2018). During this method, a laundry basket containing multiple holes are lined with a perforated carpet to control the flow of O_2 and other gases that are released during decomposition. During composting, additional ALOF was added at 55 to 60 % to enrich the compost with nutrients and microorganisms. The compost pile is turned once every three days to balance the MC of the compost mixture. As a result, the compost reached maturity within 40 days. The compost had characteristics of pH 9.0; with 52.59 % of MC; C: N ratio at 12.15; 1.96 % N; 0.58 % P; and 0.95 % K.

Next, Universiti Putra Malaysia (UPM) conducted research on composting of OPEFB fibre by using in-vessel composter (Wan Razali et al., 2012). During the study, a semi-commercial in-vessel composter was used. Next, POME, an anaerobic sludge was added to enhance decomposition of materials. As a result, composting only took place for 40 days and had a final C: N ratio of 13.85.

Furthermore, MARDI has also conducted composting of OPEFB (Suhaimi & Ong, n.d.). During the research conduct, two composting methods were used which were open and closed methods. Besides the OPEFB, fermentation liquid waste and chicken manure were used during the open method while POME and chicken manure were used in the closed method. The open composting system had natural aeration while the closed system had a controlled aeration. The closed system used large amounts of Windrow pile of 80 mt while a small pile of 1 mt were used for the open system. Besides, different types of OPEFB were used. During the closed system method, a hammer mill was used to reduce the size of the OPEFB, while during the opened system method, the OPEFB was cut into smaller pieces. As a result, opened system showed better result for composting compared to the closed system. The duration of composting for the open system was at 50 days while for the closed system was 85 days. The C: N ratio for the open system was 41: 1 and for the closed system was 56: 1.

Besides composting, OPEFB fibre can be utilized in making polymer composites (Mahjoub et al., 2013). These fibres are bio-renewable fibres which are biodegradable and requires low energy consumption when being processed. Besides, when compared to man-made fibres they are eco-friendly and cheaper since they are a form of waste material. As a result, composites of OPEFB are polymer composite with low mechanical properties where they have less tensile strength but high tensile modulus than pure resins. Therefore, these properties allow the OPEFB composites to have a reduced elongation at breaking compared to composites made from pure resins. An example of composites is OPEFB cement composites for building (Omoniyi, 2019).

CHAPTER 3

METHODOLOGY

3.1 Materials and Apparatus.

3.1.1 Materials used for Preparation and Collection of Compost.

The materials that were used during preparation of compost were 9 cylindrical plastic containers with weight approximately 43.27 g, diameter of 15.20 cm and height of 7.80 cm for each container. Besides, disposable LDPE plastic gloves (29.0 cm), electronic balance, recyclable plastic bags (30.0 cm x 45.0 cm), a pair of scissors, fine mesh filter, dried leaves, OPEFB fibre and vegetable scraps.

3.1.2 Materials used during Preparation of EM Solution.

The materials that were used during preparation of EM solution are plastic bottle (1.5 L), electronic balance, filter funnel, aluminium foil, rice, brown sugar, salt and mineral water.

3.1.3 Materials used during Planting.

The materials that were used during planting are polybags (10' x 12'), plastic container, shovel, disposable LDPE plastic gloves (29.0 cm), electronic balance, bird's-eye chili seeds, water, garden soil, coco peat and compost samples.

3.1.4 Other Materials.

The materials that were used for moisture content analysis is an oven (Khind toaster oven, model no: TO 1811), 9 pieces of aluminium foil baking cups and stopwatch. Besides, a three-way soil meter was used to measure the pH of soil and compost samples. Finally, a ruler (300 mm) was used to measure the length of roots.

3.2 Methods.

3.2.1 Sample Study Area.

Figure 3.1 shows the picture of the location of the research study which is at my home at Jalan Loh Fook Yen at Taman Dato Amar Diraja, Kluang Johor at which the study was conducted from the month of May to November 2021. The study was conducted outdoor which is at the garden.

Figure 3.1: The location of the research study

3.2.2 Identification of the C: N of the Compost Materials.

The materials that were used during composting are categorized into two types of materials which are the brown materials and green materials. The brown materials are those that are rich in C and has a higher value of C: N. The brown material includes the garden wastes which are dried leaves and the agricultural waste which is the OPEFB fibre. The green materials are those that are rich in N. The green material that will be used are kitchen wastes which are vegetable scraps. Table 3.1 shows the C: N of all the materials that will be used during composting.

Table 3.1: The C: N of the materials that was used during composting

Materials	C:N ratio
Dried leaves	60: 1
OPEFB fibre	60: 1
Vegetable scraps	25: 1

Source: Abu Bakar et al. (1998); Hamid et al. (2019)

3.2.3 Determination of MC of Compost Materials.

The MC of the dried leaves, OPEFB fibre and vegetable scraps were determined by using the conventional air oven-drying technique based on Figure 3.2. Firstly, all the materials undergo size reduction where both the dried leaves and vegetables scraps were cut into small pieces. Next, 10 g of each material were weighed into aluminium foil baking cup and were heated in an oven at 130 °C for 2 hours. The weight of each material was recorded at 30 minutes interval until a constant weight is obtained. The wet basis MC was calculated by using the equation below (Cochran & Carney, n.d.; Nirmaan et al., 2020). Besides, based on the MC values, TSC was also calculated as below.

$$\text{MC (\%)} = \frac{\text{Weight of moisture (g)}}{\text{Weight of material (g)}} \times 100$$

$$= \frac{[\text{Initial/wet weight (g)} - \text{Final/dry weight (g)}]}{\text{Initial/wet weight (g)}} \times 100$$

TSC (%) = 100 – Moisture content (%)

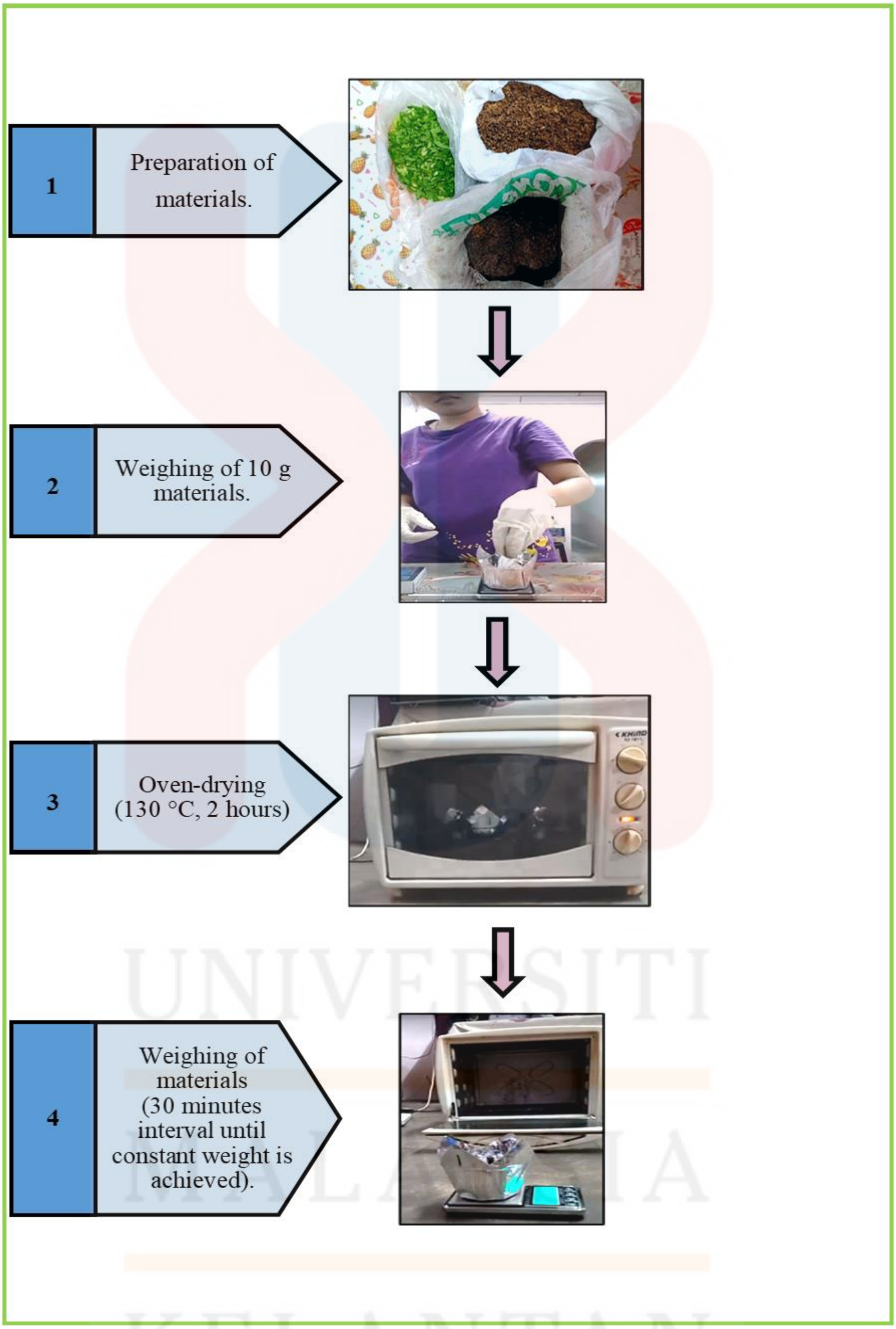

Figure 3.2: MC analysis through oven-drying technique

3.2.4 Preparation of Home-made EM Solution.

Table 3.2 shows the ingredients for making home-made EM. Master Cho, a farmer dedicated on natural farming had inspired the method of preparation of the home-made EM (Zenyr Garden, 2021). Firstly, mineral water was used to dissolve the brown sugar and the salt. The mixture was then poured into the bottle. Next, the rice 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. Next the bottle was kept in a warm dark place for with the lid on. The solution was kept away from sunlight to prevent the inactivation of heat-sensitive LAB. 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 allow CO_2, the product of lactic acid fermentation to be released. 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 to ensure that the microorganisms remain active. The procedure for the preparation of home-made EM solution is shown in Figure 3.3.

Table 3.2: The quantity of ingredients for home-made EM solution

Ingredients	Quantity
Rice	150.0 g
Mineral water	1.5 mL
Sea salt	15.0 g
Brown sugar	45.0 g

Source: Nanyuli et al. (2018); Zenyr Garden, (2021)

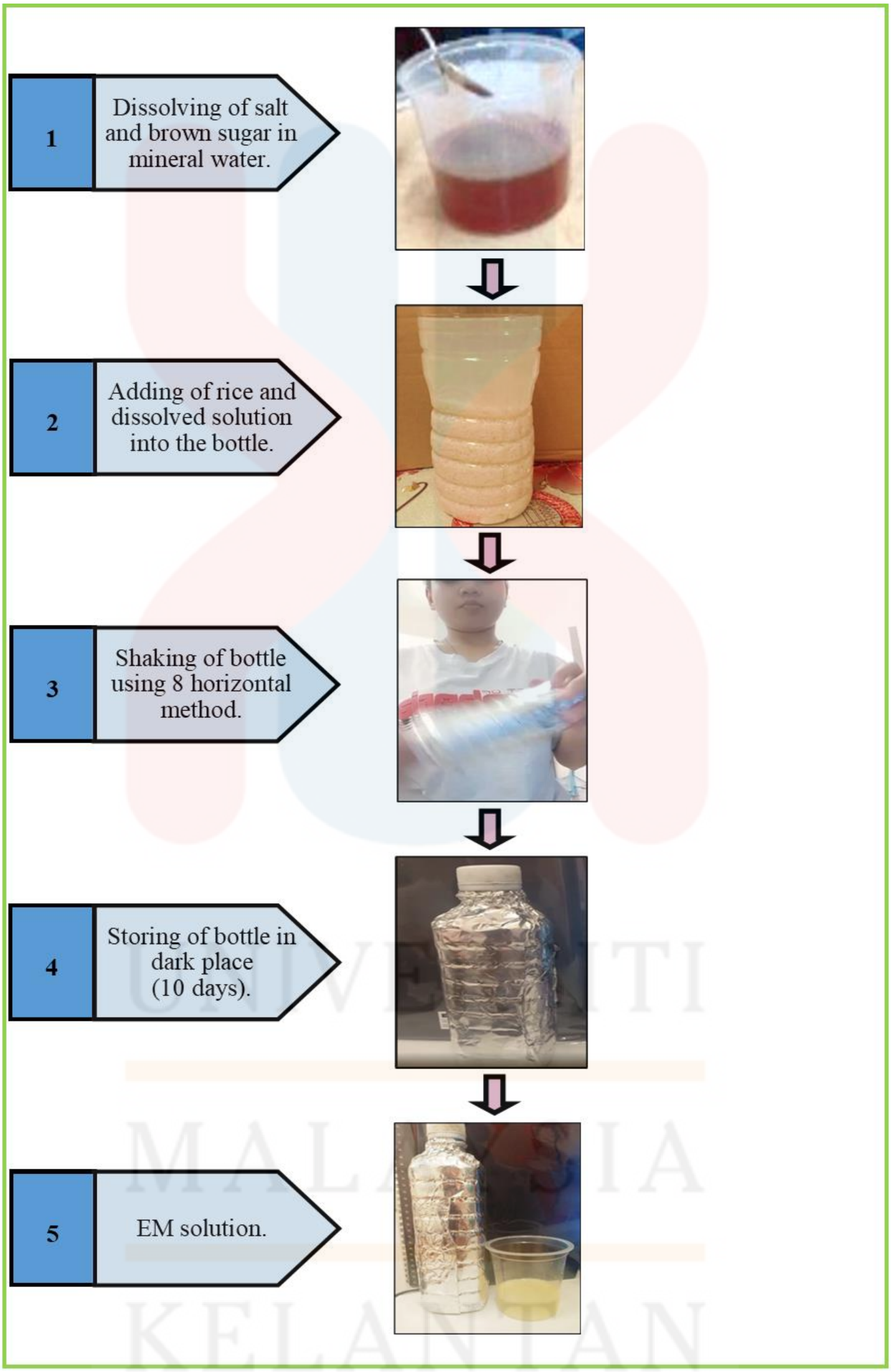

Figure 3.3: Preparation of home-made EM solution.

3.2.5 Experimental design for compost mix.

Table 3.3 shows the experimental design for the compost mix. The study was conducted on field scale basis and was arranged in a CRD. A total of 9 compost samples were made. The compost mix comprises of a mixture of brown and green materials. The brown materials have high C content while the green material have a high N content. The brown materials that were used are the dried leaves and/or OPEFB fibre while the green material is the vegetable scraps. The EM solution was also added to speed up the breakdown process of the materials. The presence of the material and EM solution is represented as (+) while their absence is represented as (-).

The compost mix of each sample was designed by method of determining the proportion of material necessary to develop a mix based on the initial C: N ratio of the material (Graves, 2000). The calculation method is performed by multiplying the proportion (%) of each material in the compost mix with their respective C: N ratio. The distribution of materials and C: N ratio of each compost sample is shown in Table 3.4. The initial C: N ratio of compost sample can be calculated as below (Graves, 2000):

C: N ratio = [Proportion of OPEFB fibre (%) x C:N ratio of OPEFB fibre] + [Proportion of dried leaves (%) x C:N ratio of dried leaves] + [Proportion of vegetable scraps (%) x C:N ratio of vegetable scraps]

For example, for sample A (control):

- Total weight of compost = 100 g
- Proportion of OPEFB fibre (60: 1) = (0 g / 100 g) x 100 = 0 %

- Proportion of dried leaves (60: 1) = (14 g / 100 g) x 100 = 14 %
- Proportion of vegetable scraps (25: 1) = (86 g / 100 g) x 100 = 86 %

Therefore, the initial C: N ratio of compost:

C: N ratio = [0 % x 60/1] + [14 % x 60/1] + [86 % x 25/1] = 29.9

Therefore, the initial C: N ratio of sample A is 29.9: 1 (≈ 30: 1). The calculation for the other samples were performed similarly and data are shown in Table 3.4.

Table 3.3: The experimental design for the compost mix

Sample	Material			EM
	Brown (High C)		Green (High N)	
	OPEFB fibre	Dried leaves	Vegetable scraps	
A (control)	-	+	+	-
B	+	+	+	-
C	+	+	+	-
D	+	-	+	-
E	+	-	-	-
B’	+	+	+	+
C’	+	+	+	+
D’	+	-	+	+
E’	+	-	-	+

The (’) indicate that the samples were treated with EM solution.

The (+) indicate the presence of the material while the (-) indicate the absence of the material.

Table 3.4: The distribution of materials and initial C:N ratio of each compost sample

Sample	Material Distribution						Initial C: N ratio
	Brown (High C)				Green (High N)		
	OPEFB fibre		Dried leaves		Vegetable scraps		
	(g)	%	(g)	%	(g)	%	
A (Control)	0	0	14	14	86	86	29.9: 1 (≈ 30: 1)
B B’	7	7	7	7	86	86	29.9: 1 (≈ 30: 1)
C C’	14	14	0	0	86	86	29.9: 1 (≈ 30: 1)
D D’	50	50	0	0	50	50	42.5: 1
E E’	100	100	0	0	0	0	60: 1

The (’) indicate that the samples were treated with EM solution.

3.2.6 Composting Process.

The method of composting that was used is aerobic composting. In this research, 9 compost samples were made by using different amounts of OPEFB fibre as shown in Table 3.3. The total compost mixture for each sample was 100 g. Firstly, the brown and green materials that are required were collected. The OPEFB fibre was collected from the palm oil mill at Kluang Oil Palm Sdn. Bhd. The dried leaves were collected from the garden while the vegetable scraps were collected from the kitchen which comprises of wilted vegetables and waste from chopping of the vegetables. Next, both the dried leaves and vegetables were cut into smaller pieces by using a pair of scissors. The materials were then measured and piled into the container according to the quantity stated in Table 3.3. Next, 50 mL of water was added into each container and 1 capful of EM solution (≈ 30 mL) was added into the replicated compost samples of B', C', D' and E'. Figure 3.4 shows the process for the preparation of compost mixture.

The duration of composting of all the 9 samples were different which took place within 4 to 8 weeks. The formation of a dark brown, earthy smelling material indicate that composting process is completed. During the beginning of the composting process, equal amounts of water of about 50 mL was added to the compost mixture to provide enough moisture. As composting took place, water was added, when necessary, when the compost mixture was observed to be dry. Besides, 1 capful of EM solution was added into the replicated samples once every week. The samples were placed outside under the shade for proper aeration and to obtain atmospheric heat to meet the appropriate conditions for decomposition to take place. The pile was turned twice every week by hand after 2 weeks of the initial composting.

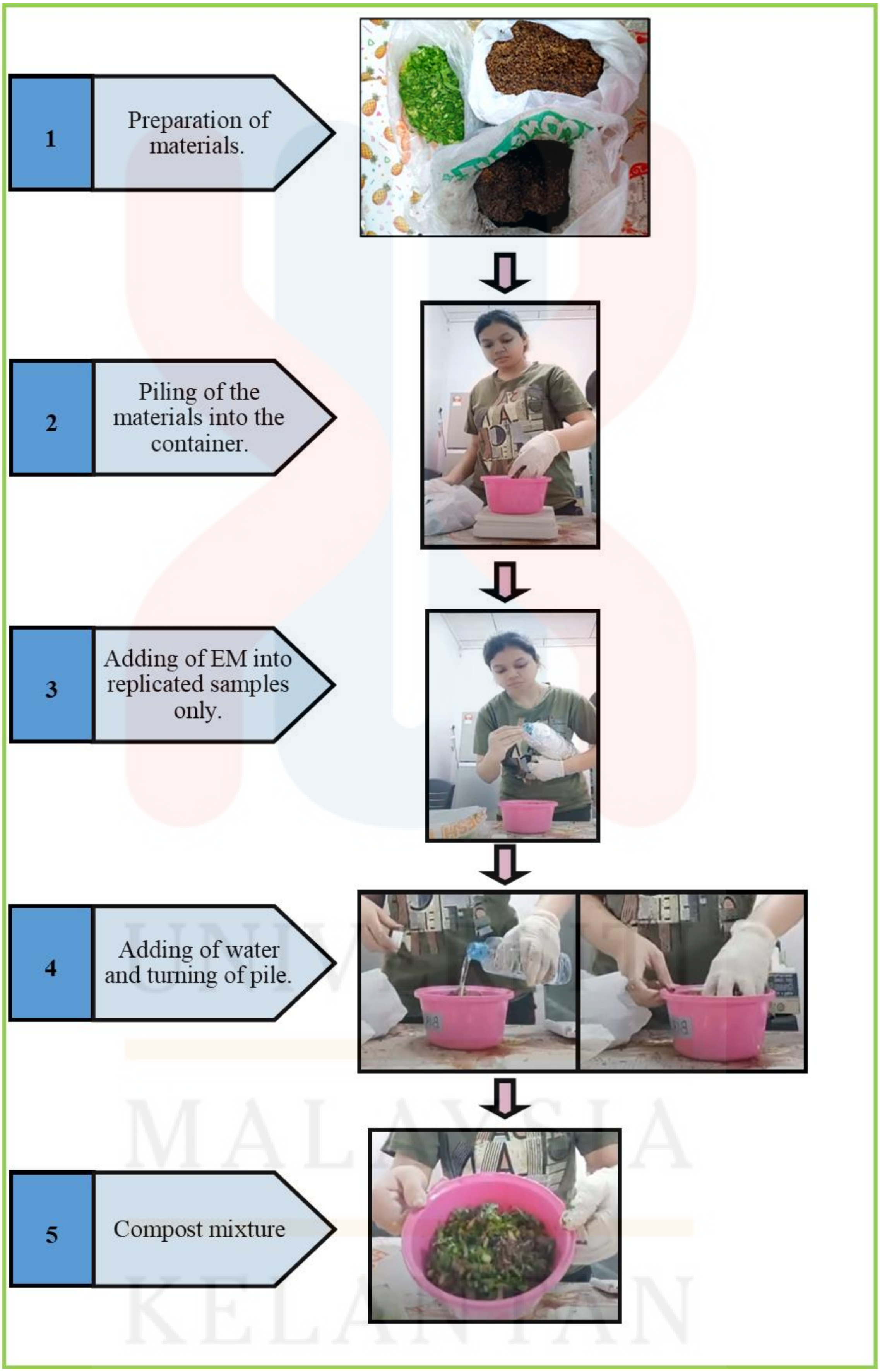

Figure 3.4: Preparation of compost mixture.

3.2.7 Determination of Duration of Composting.

The 9 compost samples were evaluated by determining the duration of composting. The duration of composting was determined by the number of weeks for all the materials to fully break down into finished compost. The characteristic of finished compost was determined through sensory assessment of the colour, odour and texture (Anne, 2012; Amery et al., 2020). The finished compost was dark brown where all the materials were not recognizable since they have already completely decomposed and have an earthy odour. The texture was moist instead of soggy or dry. During the determination of duration of composting, the finished compost was separated from the pile by using a mesh filter as shown in Figure 3.5 beginning the second week of composting. After removing the finished compost, the remaining materials in the pile was left to continue their decomposition process. The remaining pile was moistened with water and EM solution was added to the replicated samples. The finished compost that was collected were weighed and used for planting of the bird's-eye chilies. By the end of composting, the total weight loss was calculated by using the formula below (Verma et al., 2014).

$$\text{Total weight loss (\%)} = \frac{\text{Initial weight of organic material (g)} - \text{Final weight of decomposed material (g)}}{\text{Initial weight of organic material (g)}}$$

Figure 3.5: Separation of compost from pile by using a mesh filter.

3.2.8 Experimental Design of Soil Mix During Planting of Bird's-eye chilies.

The effectiveness of the compost samples was tested by evaluating its effect on plant growth. bird's-eye chilies was used as the plant selection (Vaishnavi et al., 2020). The purpose of using bird's-eye chilies is they are easily available and are fast-growing plants. Germination of seeds usually takes about 8 to 14 days (Chili-Plant.com, n.d.; Vaishnavi et al., 2020). Since compost is used as a growing medium and not a planting medium, the ratio of compost to soil that was used is 1: 3, with 1 part of compost to 3 parts of soil (*Guide to Planting with Compost - Mr Crapper's Potting Shed*, n.d.). Besides, 1 part of coco peat was also added at the top layer to regulate the moisture of the soil in order to prevent the soil from becoming dry.

Table 3.5 shows the experimental design of the soil mixture during planting of the bird's-eye chilies. During the research study, a total of 10 different types of samples were made. Sample X was the control sample where compost was absent and the soil mixture of 1 part coco peat to 3 parts of soil (1: 3) was used. The other 9 samples were made by addition of the 9 different compost samples (+ Compost A, B, C, D, E, B', C', D' or E') to determine their effectiveness to support plant growth. The soil mixture for all these 9 samples were 1 part of compost to 1 part coco peat to 3 parts of soil (1: 1: 3). For each type of sample, triplicate plant samples were made. The growth of the plant samples was observed for a total of 2 months.

Besides, the initial pH of soil and compost respectively and the final pH of mixture of soil and compost were recorded. The quantitative analysis of the mean of the length of the roots and height of shoots were also made. The data collected was analysed using the statistical analysis. Figure 3.6 shows process of planting and measuring of plant growth.

Table 3.5: The experimental design for the soil mix.

Plant sample	Materials										
	Soil	Compost									Coco peat
		A	B	C	D	E	B’	C’	D’	E’	
X (Control)	+	-	-	-	-	-	-	-	-	-	+
1	+	+	-	-	-	-	-	-	-	-	+
2	+	-	+	-	-	-	-	-	-	-	+
3	+	-	-	+	-	-	-	-	-	-	+
4	+	-	-	-	+	-	-	-	-	-	+
5	+	-	-	-	-	+	-	-	-	-	+
6	+	-	-	-	-	-	+	-	-	-	+
7	+	-	-	-	-	-	-	+	-	-	+
8	+	-	-	-	-	-	-	-	+	-	+
9	+	-	-	-	-	-	-	-	-	+	+

The (’) indicate that the samples were treated with EM solution.

The (+) indicate the presence of the material while the (-) indicate the absence of the material.

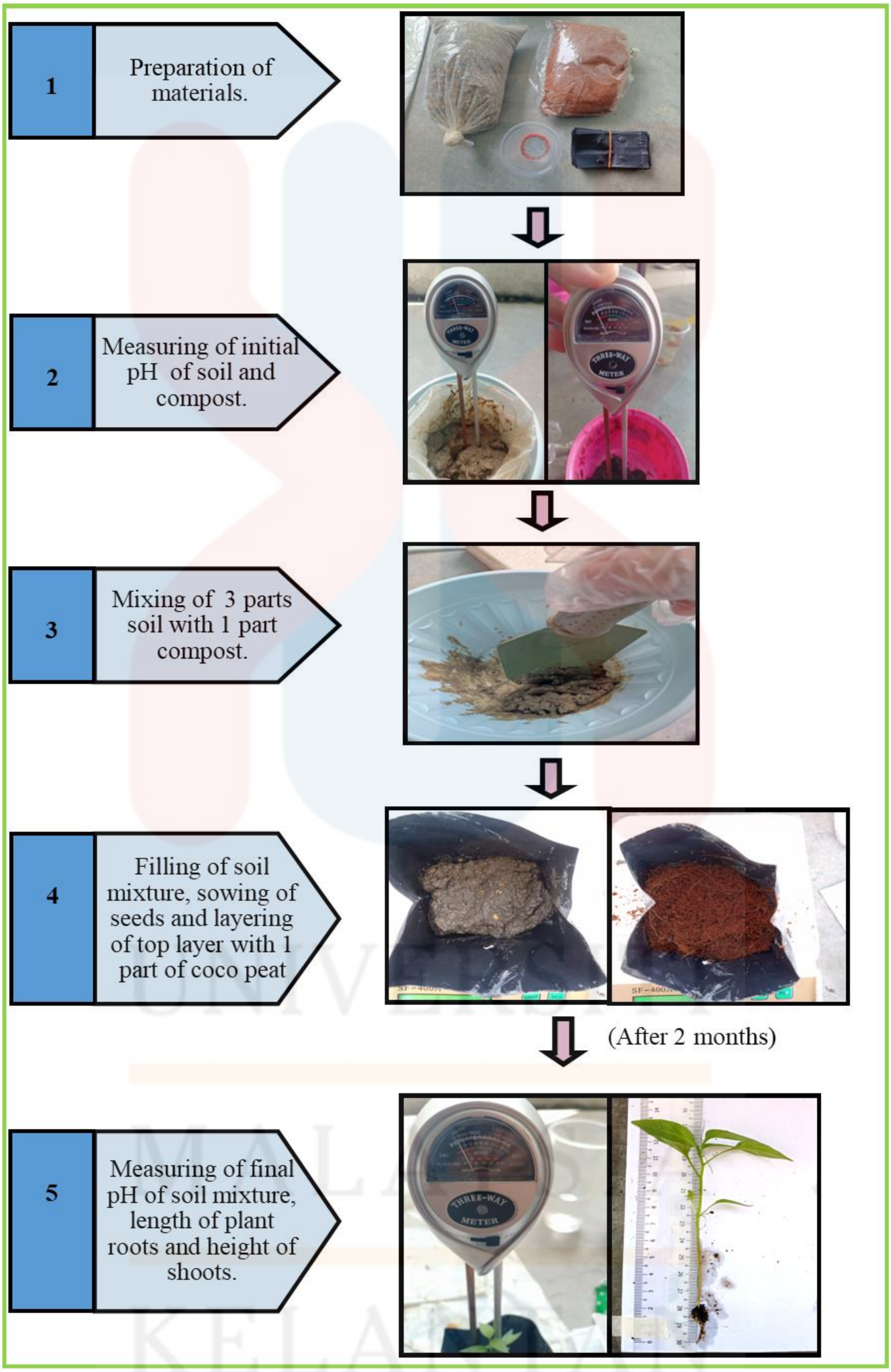

Figure 3.6: Process of planting and measuring of plant growth.

3.2.9 Data Processing and Statistical Analysis

During the research conduct, the data for the duration of composting (weeks), pH of compost and soil, length of roots (cm) and shoots were tabulated. The mean and standard deviation of the triplicate samples (n = 3) were calculated.

Next, the data obtained was analysed by using a statistical software known as SPSS 24.0. The advantages of using this software are because it can be used to perform a variety of statistical test and the results obtained are reliable (Kerr et al., 2002). The test of significance was performed by using ANOVA tests and paired t-test at 5 % significant level. For ANOVA test that were tested significant, an additional test of post-hoc analysis of Tukey's HSD was performed to determine the groups of samples that contain means that are significantly different. Next, linear correlation was also conducted. The correlation was used to determine the strength of the linear relationship between the dependent and independent variables (Bewick et al., 2003).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Compost Materials.

Overall, there were three materials that were used during composting. Firstly, vegetable scraps which is a form of green material containing high N content was used. Besides, OPEFB fibres and dried leaves which are brown materials containing high C content were also used. These materials were oven-dried at 130 °C for 2 hours in order to determine the percentage of MC and TSC. The results for each material were shown in Table 4.1 and were illustrated in Figure 4.1.

4.1.1 The MC (%) and TSC (%) of Compost Materials.

Table 4.1 and Figure 4.1 shows the differences between the MC and TSC of the materials that were used in the compost mix after performing the oven-drying procedure. Based on the result, it was observed that the higher the MC of the material, the lower its TSC. Overall, vegetable scraps had the highest MC (69.20 %) but the lowest TSC (30.80 %). Next, OPEFB fibre had a lower MC (46.10 %) but higher TSC (53.90 %) than vegetable scraps. Finally, dried leaves had the lowest MC (26.40 %) but the highest TSC (73.60 %).

Table 4.1: 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

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

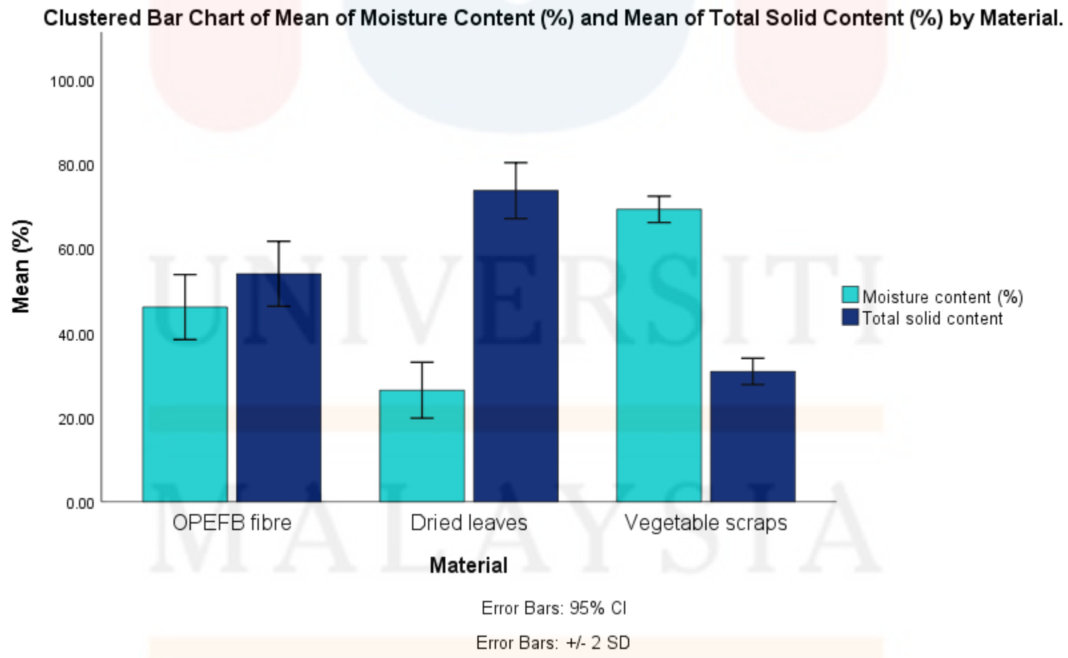

Figure 4.1: Cluster bar chart of mean of MC (%) and mean of TSC (%) of compost materials. Error bars represent standard deviation (n=3).

Vegetable scraps are food waste which have a low physical structure due to its characteristic of having high MC (Risse & Faucette, 2017). The high MC provides favourable conditions for the growth of bacteria. Besides, vegetable scraps are green materials which have high N content (Hamid et al., 2019). Therefore, when large amounts of food waste such as vegetable scraps are left to rot on their own, the high MC and N content will lead to uncontrol anaerobic decomposition due to microbial activity. This condition may result in the release of methane and carbon dioxide which are greenhouse gases and a foul smell due to the production of NH_3 which may lead to air pollution (Palaniveloo et al., 2020). Therefore, in order to overcome this issue, high bulking agents which have lower MC and higher TSC as well as C: N ratio such as OPEFB fibre and dried leaves are incorporated with vegetable scraps during composting to absorb the excess moisture thus, resulting in aerobic decomposition process. Finally, higher bulking agents also add structure to the compost pile. Bulking agents comprises of dry matter which have higher TSC that gives compost a porous structure (Hamid et al., 2019).

4.2 Compost Samples.

Table A.7 and A.8 in appendix A shows the compost samples throughout the composting period. Overall, a total of 9 compost samples were prepared. The independent variable of this research study was the amount of OPEFB fibre. Compost sample A was the control sample where OPEFB fibre was absent. Composts samples B to E were prepared by using different amounts of OPEFB fibre. Compost samples B' to E' are replicated samples containing EM solution. The different amounts of materials used in each sample can be observed from Table 3.3 and Table 3.4 in Chapter 3. Based on the result, even though all the 9 samples had the same initial weight of 100 g, all the samples recorded a different final weight of compost collected in Table 4.2 (a). Therefore, a statistical analysis of Pearson correlation was carried out to determine the relationship between the total percentage loss of sample and the weight of the materials used in the compost mixture. The results of this analysis are shown in Table 4.2 (b).

4.2.1 The Weight of Compost Collected (g) and The Total Weight Loss (%).

Table 4.2 (a) and Figure 4.2 shows the difference between the weight of compost collected (g) and total weight loss (%) of the compost samples. Overall, samples C and C' (14 % OPEFB fibre and 86 % vegetable scraps) recorded the lowest weight of compost collected which are 33.09 % (sample C) and 59.82 % (sample C') while recording the highest percentage of total weight loss of 66.91 % (sample C) and 40.18 % (sample C'). Besides, it was also observed that as the amount of OPEFB fibre increases (samples C to E and C' to E') with the absence of dried leaves, the total weight of compost collected also increases while the total percentage of weight loss decreases. It was also observed that samples A and B containing dried leaves result in higher weight of compost collected and lower total percentage of weight loss compared to sample C even though all these samples have similar initial C: N ratio (29.9: 1) which are within optimum range.

Table 4.2 (a): The weight of compost collected (g) and the total weight loss (%) of the samples.

Sample	Initial 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

The (’) indicate that the samples were treated with EM solution.

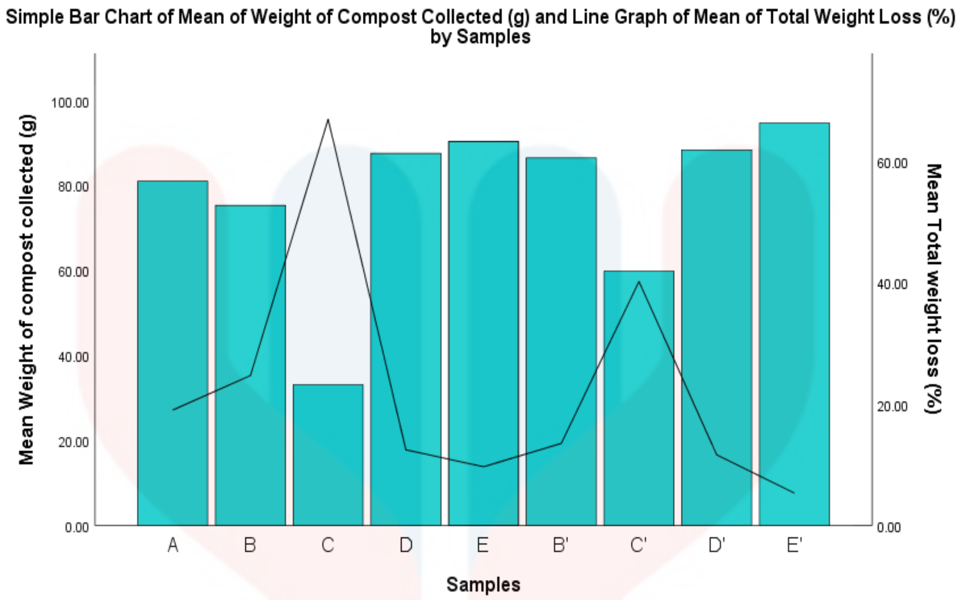

Figure 4.2: The bar chart of the mean weight of compost collected (g) and the line graph of the mean total weight loss of the samples (%).

Based on the overall results in Table 4.2 (a) and Figure 4.2, all samples experience a certain percentage of weight loss during composting. According to Verma et al. (2014), the compost sample will experience a high total percent loss in weight when the materials that were used in the compost mixture experience higher mineralization process of OM. During composting, weight of compost is reduced when OM are converted into stabilized forms of C rich product called compost by the action of microbial activity under controlled aerobic condition. 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 of samples may also be due to changes of chemical composition of the OM (Lerch et al., 2019). 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).

Therefore, based on Table 4.2 (b), total percentage of weight loss of samples 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 N content while OPEFB fibre and dried leaves are brown materials which have high C, hemicellulose and lignin contents (Verma et al., 2014; Hamid et al., 2019; Palaniveloo et al., 2020). Finally, bulking agents are lignocellulosic biomass which provides mass and structure to the compost (Akratos et al., 2017). Therefore, based on previous results in Table 4.1, it was recorded that dried leaves (73.60 $\pm$ 3.31 %) has higher TSC compared to OPEFB fibre (53.90 $\pm$ 3.84 %) which indicates that dried leaves have higher mass of solid compared to OPEFB fibre. Therefore, samples A, B and B' containing dried leaves recorded higher weight of compost collected but lower percentage of weight loss compared to samples C and C' where dried leaves are absent even though all these samples had the same C: N ratio of 29.9: 1.

Table 4.2 (b): The Pearson correlation coefficient value of total weight loss (%) of sample with the weight of materials used.

	Correlation coefficient value, r		
	Weight of OPEFB fibre	Weight of dried leaves	Weight of vegetable scraps
Total weight loss (%)	- 0.527	- 0.125	0.585

4.3 Composting.

Composting is a controlled biological breakdown process of OM into a humus-like substance called compost. In the presence of oxygen, microorganisms will feed on the OM (OPEFB fibre, dried leaves and vegetable scraps) which will result in the release of a considerable amount of heat, CO_2 and water vapour. The overall reaction during aerobic composting of the OM in this research is illustrated in Figure 4.3. The duration of composting is defined as the total time taken for completion of composting (Lalremruati & Devi, 2021). Overall, it was observed that the duration of composting of the samples were affected by the different amounts of materials used and presence of EM solution. Therefore, Pearson correlation analysis was performed to determine if the duration of composting is affected by the weight of materials that were used during composting. Besides, one-way ANOVA was also performed to determine if there was a significance difference between the weight of the materials used during composting with the duration of composting. Finally, the effects of the addition of EM solution to samples to aid in the composting process was also discussed. A paired t-test was also carried out to determine whether there was a statistically significant difference between the means of duration of composting when samples were treated with EM solution compared to those that were not treated with EM solution.

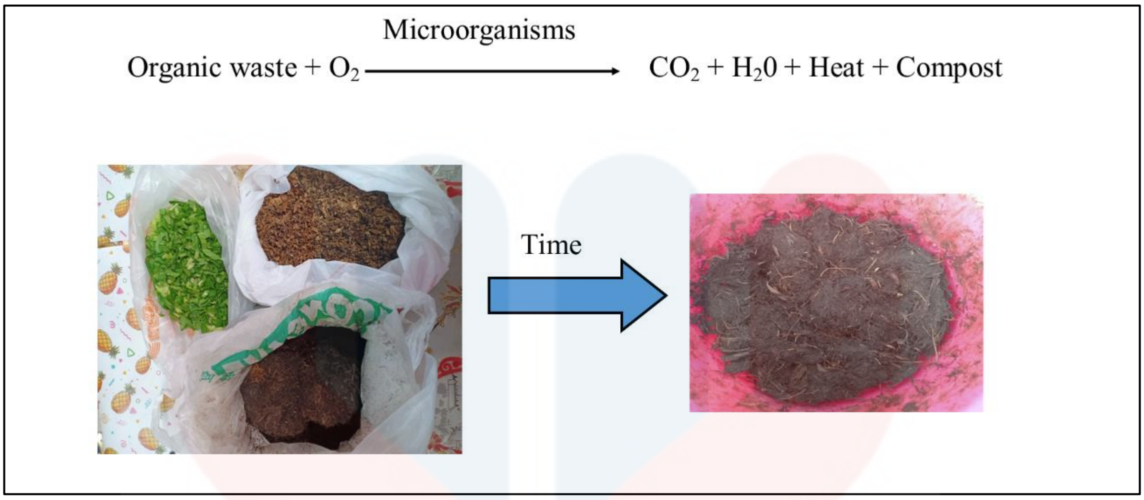

Figure 4.3: The reaction involved during aerobic composting (Source: Zafar, 2019)

4.3.1 Duration of Composting of the Samples.

Table 4.3 and Figure 4.4 shows the difference between the duration of composting between the compost samples. Firstly, based on the results, samples C and C’ recorded the shortest duration of composting which is within 4 weeks while sample E and E’ recorded the longest duration of composting which is within 8 and 7 weeks respectively. Next, control sample A (14 % dried leaves and 86 % vegetable scraps) took an extra week to complete composting process compared to samples C and C’ (14 % OPEFB fibre and 86 % vegetable scraps) even though all the samples were made up of same amount of green and brown materials at C: N ratio of 29.9: 1. This shows that dried leaves take a longer time to decompose compared to OPEFB fibre. This may be due to the characteristic of these materials where dried leaves have higher percentage of TSC compared to OPEFB fibre. In addition, it was also observed that as the weight of OPEFB fibre increases in the compost mixture, the longer the duration of composting. Finally, samples containing EM solution (B’, C’, D’, E’) recorded a shorter duration of composting compared to their replicated samples where EM solution was not incorporated (B, C, D, E).

Table 4.3: The duration of composting of the compost samples.

Samples	A	B	C	D	E	B’	C’	D’	E’
Weight of OPEFB fibre (g)	0.0	7.0	14.0	50.0	100.0	7.0	14.0	50.0	100.0
Duration of composting (weeks)	5	6	4	7	8	5	4	6	7

The (’) indicate that the samples were treated with EM solution.

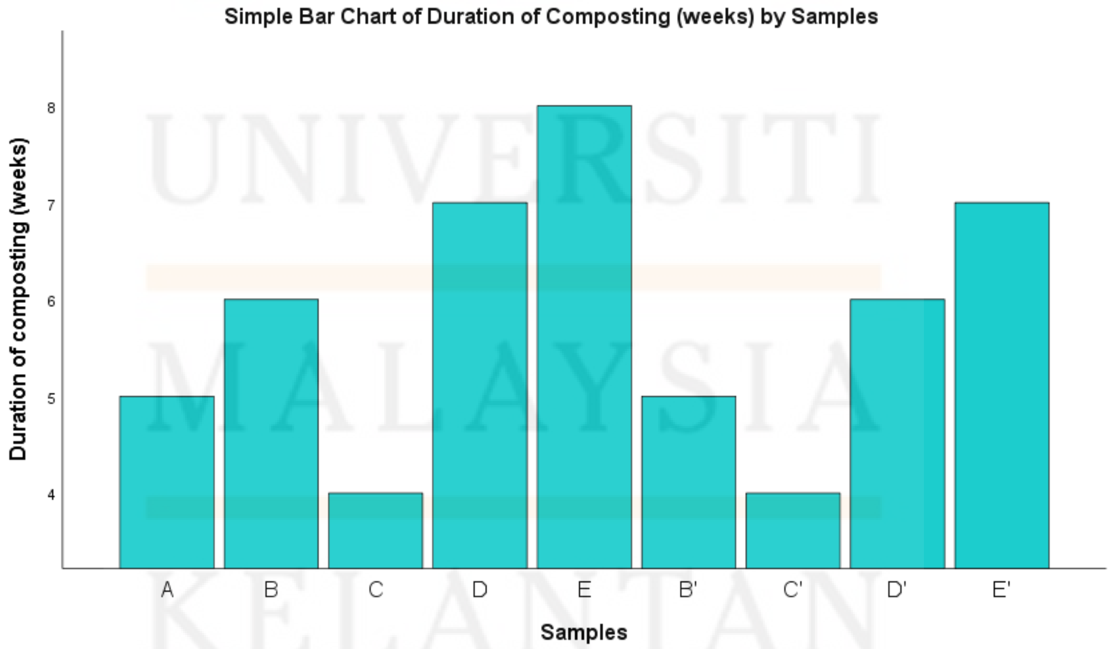

Figure 4.4: The duration of composting of the compost samples.

4.3.2 Statistical Analysis between the Weight of OPEFB fibre with the Duration of Composting.

A one-way ANOVA was run to determine whether there was a statistically significant difference between the means of duration of composting when samples were treated with different amounts of OPEFB fibres. Table B.2 in the appendix B illustrates the results of the one-way ANOVA which was performed at 5 % significant level (α = 0.05) to compare the effect of weight of the OPEFB fibre used in the compost mixture on the duration of composting. Based on the result, 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 was a statistically significant difference in duration of compost 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 means of the duration of composting that are significantly different.

Table B.3 in the appendix illustrates the results of the post-hoc analysis of Tukey's HSD test while Table 4.4 shows the homogenous subsets of means of duration of composting in terms of the different weight of OPEFB fibre. Tukey’s HSD test for multiple comparison found that the mean value of the duration of composting was significantly different between (1) samples containing 100.0 g and 14.0 g OPEFB fibre [$p = 0.07$ at 95 % confidence interval of (1.30, 5.70)], (2) samples containing 100.0 g and 0.0 g OPEFB fibre [$p = 0.03$ at 95 % confidence interval (0.30, 4.70)] and (3) samples containing 50.0 g and 14.0 g OPEFB fibre [p = 0.03 at 95 % confidence interval (0.30, 4.70)].

Table 4.4: 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 significantly (α = 0.05)

The objective of this research study was to determine the effects of different amounts of OPEFB fibre on the duration of composting. Based on the results of the duration of composting in Table 4.3, it was observed that as the higher the weight of the OPEFB fibre that was incorporated in the compost mixture, the longer the duration of composting takes place. This is only true for samples C to E and C’ to E’ even though compost samples A (0.0 g OPEFB fibre) and B, B’ (7.0 g OPEFB fibre) had lower amounts of OPEFB fibre in their compost mixture. This was due to the addition of dried 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). Therefore, the compost samples (A, B, B’) recorded duration of composting which was higher compared to samples containing only OPEFB fibre as the brown material. Therefore, based on the one-way ANOVA post-hoc test, there was no significance differences of mean duration of composting among samples B or B’ with other compost samples.

According to Wan Razali et al. (2012), OPEFB is historically known to experience difficulty to degrade. This is due to its characteristic of having rigid structures where their structure contains relatively large amounts of cellulose, hemicelluloses, and lignin. Besides, OPEFB fibre have relatively low MC between 40 to 50 % which creates an unfavourable condition for microorganisms to carry out their bioactive processes to degrade this material. Therefore, compost containing pure OPEFB fibre (E and E’) took longer time to decompose at 7 and 8 weeks respectively.

A study conducted by Adam et al. (2016) have provided a few treatment methods to enhance composting of OPEFB. Firstly, incorporation of materials containing high N content can create a higher initial C: N ratio and enhance the MC of the compost mixture. This helps to enhance the microbial activity within the compost pile for faster degradation process of the OPEFB fibre. Next, turning of the pile should be carried out for as frequent as thrice a week in order to maintain an even distribution of moisture within the pile and to prevent the build-up heat which may cause the beneficial microorganism to denature.

Therefore, 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 place within 4 to 6 weeks. The vegetable scraps are materials which have high N content which provides additional moisture to the compost mixture in order to aid in the degradation of the OPEFB fibre.

4.3.3 Statistical Analysis between the Treatment of EM Solution with the Duration of Composting.

A paired t-test was run to determine whether there was a statistically significant difference between the means of duration of composting when samples were treated with EM solution compared to those that were not treated with EM solution. Based on Table B.5 in appendix B, the duration of composting of samples that were treated without EM solution (6.25 $\pm$ 1.708 weeks) were higher compared to samples that were treated with EM solution (5.50 $\pm$ 1.291 weeks). Next, based on Table B.6 in appendix B, the duration of composting of samples that were treated with and without EM solution were strongly and positively correlated ($r = 0.983$, $p < 0.05$). Based on Table B.7 in appendix B, there was a significant average 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 higher duration of composting of 0.750 $\pm$ 0.500 weeks compared to samples that were treated with EM solution (95 % confidence interval [-0.046,1.546]).

EM solution consists of common food-grade aerobic and anaerobic microorganisms which are commonly available in the environment such as LAB bacteria, yeast and phototrophic bacteria. According to a study that was conducted by Nanyuli et al. (2018) on the effects of EM on the rate of decomposition and nutrient content of the composted manure, it was found that EM solution functions as a compost enhancer. 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. For example based on the research study that was conducted by Nanyuli et al. (2018), the application of EM resulted in the composting of manure samples to achieve its highest peak value of 58 °C on day 6 compared to the controlled sample that achieved its highest peak value 55 °C on day 8. A research study that was conducted by Che Jusoh et al. (2013) on the application of EM on the composting of rice straw also showed similar outcomes. Based on the results of this research, rice straw samples that were treated with EM reached the highest peak value of increase in temperature at 58.2 °C on day 10 compared to composting treatment without EM which recorded its highest peak value of 56.2 °C on day 11.

Therefore, based on the results of this research, EM solution result in a significant lower duration of composting compared to samples that were not treated with EM solution. This is because the beneficial microorganisms that were present in the EM solution increases the rate of decomposition of the materials, thus resulting in a reduced period of composting.

4.4 The Effects of Compost on Soil pH.

Table 4.5 shows the pH values of each compost samples and the changes in the pH of soil before and after addition of compost. Overall, based on the results it was observed that the incorporation of compost increases the pH of soil after 2 months. All compost samples are observed to be slightly alkaline (pH > 7.0) therefore, when compost was incorporated with soil, the pH of soil changes from neutral (pH 7.0) to slightly alkaline.

Table 4.5: 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 (plant 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 (Cochran & Carney, n.d.; Che Jusoh et al., 2013). Since all the 9 compost samples recorded pH values that were within this range, it can be concluded that all the compost samples are preferable to be used as a growing medium. Next, the pH of soil is an important factor that should be taken into consideration during planting. The pH of soil is the main factor that affects the soil fertility and its ability to provide sufficient amounts of nutrients for plant development (Shareef et al., 2019). The optimum pH of soil is within pH 5.5 to 7.0 (Ward, n.d.). Based on the results, the soil that was 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.

Based on the results, the incorporation of compost with the soil had increased the pH of the soil. According to a research study that was conducted by Valarini et al. (2009) to study the effects of application of compost on the properties of a volcanic soil from Central South Chile, 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 poly-cation levels of the soil. This causes the soil to become more stabilized due to the increase of its buffer capacity. Besides, another research study on the effects of compost made from municipal solid waste on physicochemical soil characteristics also explain that the reason for the increase of soil pH after incorporating with compost was due to the effect of compost which increases the 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 which will increase the soil pH.

4.5 Plant Growth.

The growth of the bird's-eye chili plants was analysed in terms of the length of roots and height of shoot. Plants obtain nutrients from soil through their roots which may later contribute to the growth and development of their shoots (Chen et al., 2020). Therefore, to study on the factors that affect the growth and development of the bird's-eye chilies, there are two statistical analysis that was carried out. Firstly, one-way ANOVA was carried out to determine if there is a statistical difference between the pH of compost with the plant growth. Next, one-way ANOVA was also conducted to determine if there is a statistical difference between the compost samples containing different amounts of OPEFB fibre with the plant growth. Finally, a paired t-test was run to determine whether there was a 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 treated with compost incorporated with EM solution compared to those that were not treated with EM solution.

4.5.1 The Length of Roots (cm) and Height of Shoots (cm) of the Bird's-eye Chili Plant Samples.

Table 4.6 and Figure 4.5 shows the mean length of roots and mean height of shoots of the bird's-eye chili plant samples. When the soil is treated with compost which have an optimum C: N ratio of 29.9: 1, the length of roots and height of shoots of the plants increases as the OPEFB fibre content increases in the compost samples (samples X to 3 and samples 6 to 7). Next, soil treated with compost sample E and E' (100 %) showed a lower result for length of roots and height of shoots compared to soil treated with samples D and D' (50 % OPEFB fibre and 50 % vegetable scraps). Besides, soil treated with EM incorporated compost showed better results for the length of roots and height of shoots.

Table 4.6: The length of roots (cm) and height of shoots (cm).

Plant samples	Length of roots (cm)	Height of shoots (cm)
X (plant 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).

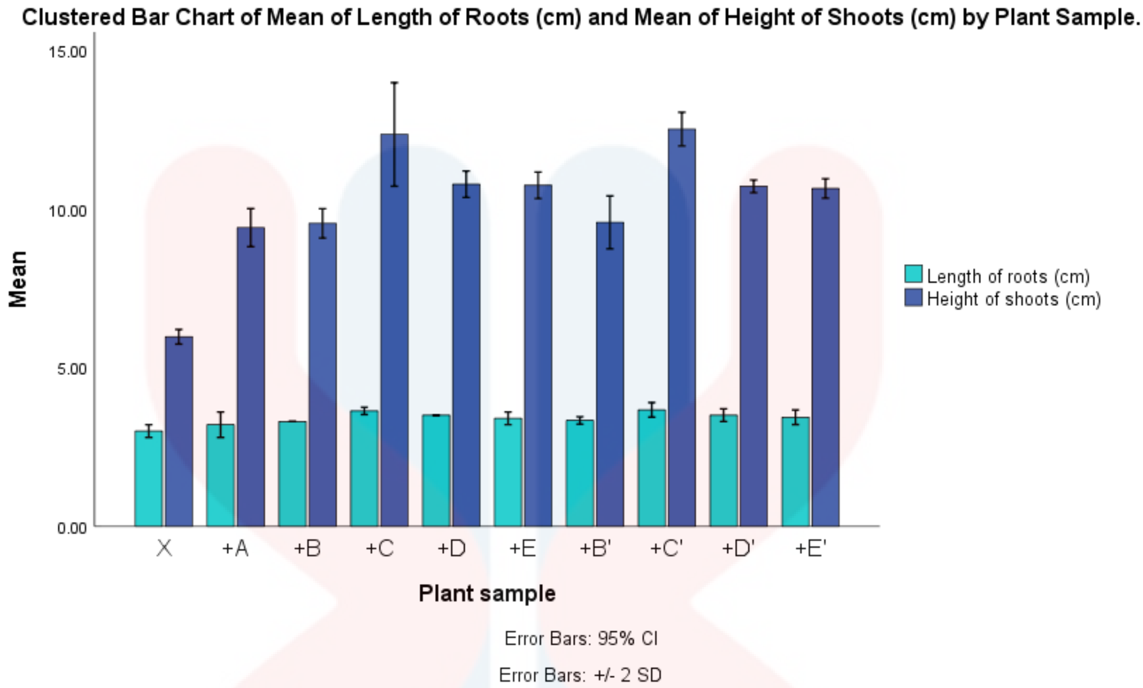

Figure 4.5: Cluster bar chart of mean of length of roots (cm) and mean of height of shoots (cm) by plant sample. Error bars represent standard deviation (n=3).

4.5.2 Statistical Analysis between the pH of Compost and Plant Growth.

A one-way ANOVA was run to determine whether there was a statistically significant difference between the means of (a) length of roots and (b) height of shoots at when the soil was treated with different pH of compost. Table B.8 in the appendix B illustrates the results of the one-way ANOVA which was performed at 5 % significant level ($\alpha = 0.05$) to compare the effect of pH of compost on the (a) length of roots and (b) height of shoots of the bird's-eye chili plants. Based on the result, 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 reveals that there was a statistically significant difference (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 different pH of compost. 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 B.9 in the appendix illustrates the results of the post-hoc analysis of Tukey's HSD test while Table 4.7 shows the homogenous subsets of (a) length of roots and (b) height of shoots of plant samples which was treated with soil containing different pH of compost. Tukey's HSD test for multiple comparison found that the 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 the growth of the plants differently.

Table 4.7: 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 soil amendment that will significantly affect the pH of soil which is an important factor that affects the plant growth. The addition of compost can affect the pH of the soil by enhancing 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 important 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 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 (*Cations and Cation Exchange Capacity | Fact Sheets | Soilquality.Org.Au*, 2022).

A research study was conducted by Abdul Halim et al. (2018) on the influence of soil amendments incorporated in acidic soil on the growth and yield of rice. According to the result of the research, soil that was treated with compost for 43 days showed an increase in the soil pH from 3.7 to 6.2. Besides, the soil treated with compost showed the highest reading of growth in 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. Therefore, based on the results in Table 4.6, soil treated with compost showed better plant growth compared to the control plant sample X.

4.5.3 Statistical Analysis between the Different Amounts of OPEFB Fibre and Plant Growth.

A one-way ANOVA was run to determine whether there was a statistically significant difference between the means of (a) length of roots and (b) height of shoots at when the soil was treated with compost samples containing different amounts of OPEFB fibre. Table B.12 in the appendix B illustrates the results of the one-way ANOVA which was performed at 5 % significant level ($\alpha = 0.05$) to compare the effect of pH of compost on the (a) length of roots and (b) height of shoots of the bird's-eye chili plants. Based on the result, 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 reveals that there was a statistically significant difference (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 B.13 in the appendix illustrates the results of the post-hoc analysis of Tukey's HSD test while Table 4.8 shows the homogenous subsets of (a) length of roots and (b) height of shoots of plant samples which was treated with soil containing different pH of compost. Tukey's HSD test for multiple comparison found that the almost 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 the growth of the plants differently.

Table 4.8: 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 ($\alpha = 0.05$).

Bio-compost from OPEFB fibres can be applied to soil as an organic fertilizer 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 % N, 0.1 % P, 2.5 % K and 0.2 % Mg 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 Ni post-mining soil. Based on the results of this research study, it was reported that OPEFB compost resulted in the highest average soil CEC. The increase in soil CEC was correlated with the increase in soil organic C. Besides, the effect of OPEFB compost on the plant growth of *Calopogonium mucunoides* resulted in the highest average volume of roots at 2.50 cm^3.

Therefore, based on the results in Table 4.6, 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 contain high level 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.

4.5.4 Statistical Analysis between the Treatment of EM Solution in Compost and Plant Growth.

A paired t-test was run to determine whether there was a 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 treated with compost incorporated with EM solution compared to those that were not treated with EM solution. Based on Table B.16 in appendix B, (a) length of roots and (b) height of shoots of plants that were planted in soil which were treated with compost incorporated 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. Next, based on Table B.17 in appendix B, (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. Based on Table B.18 in appendix B, 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 a higher (a) length of roots (1.017 ± 1.522 cm) and (b) height of shoots of plants (2.556 ± 3.885 cm) compared to samples that were treated without EM solution.

EM solution function as an additive to accelerate composting process and provide additional nutrients to the compost mixture. For example, based on a research study that was conducted by Fan et al. (2018) on the evaluation of EM on home scale organic waste composting showed that compost samples that were treated with EM has a higher nutrient content. Based on the results of the research, the compost with EM showed significantly ($p < 0.05$) higher N content (3.6 %) than the controlled sample (2.1 %). The study explained that compost treated with EM contains more N 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.

According to another research study by Che Jusoh et al. (2013) on composting of rice straw with EM, the result showed that EM solution increases the macro and micronutrient contents of compost. According to the result of this research study, compost containing EM recorded higher contents of N, P and K content compared to compost without EM.

Therefore, based on the results of this research, it can be explained that plant samples that were treated with compost containing EM had a significant higher growth compared to those treated with compost without EM. This is because EM solution increases the macro and micronutrients of compost and function as an additive which provided additional nutrition to the compost which later enriched the soil to provide this nutrient for growth and development of the plants.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion all the three objectives of the research were achieved. Firstly, composting of samples containing different amounts of OPEFB fibre with and without treatment of EM solution were achieved within 4 to 8 weeks. The second objective was also achieved where the effect of OPEFB fibre on the duration of composting were also determined. Compost with higher amount of OPEFB fibre resulted in a significantly higher ($p < 0.05$) duration of composting since the OPEFB fibre are lignocellulosic materials with high C (60: 1) content, a low MC (46.10 $\pm$ 3.84 %) and high TSC (53.90 $\pm$ 3.84 %). Besides, incorporation of EM solution resulted in a significantly lower ($p = 0.05$) duration of composting compared to samples that were not treated with EM solution. This is because the beneficial microorganisms that were present in the EM solution increases the rate of decomposition of the materials, thus resulting in a reduced period of composting.

Finally, the objective to determine the effect of home-made compost towards plant growth was also achieved. Based on the results it was found that soil that was incorporated with compost showed better plant growth compared to the control plant sample X. The compost samples had slightly increased the pH of soil. The addition of compost in soil significantly improved ($p < 0.05$) the growth of plants. The addition of compost in the soil balances the pH of the soil by boosting its CEC. Therefore, 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. Besides, it was also found that soil that were treated with compost containing OPEFB fibre showed better plant growth. This is because compost made from OPEFB fibre contain high level of nutrients which are essential for plant growth. Besides, compost made from OPEFB fibre functions as an effective soil amendment which can boost the soil CEC levels for efficient plant nutrient transfer. Finally, plant samples that were treated with compost containing EM had a significant higher growth compared to those treated with compost without EM. This is because EM solution increases the macro and micronutrients of compost and function as an additive which provided additional nutrition to the compost which later enriched the soil to provide this nutrient for growth and development of the plants.

Therefore, it can be concluded that OPEFB fibre can be utilized as compost which is able to improve soil properties and support plant development and growth.

5.2 Recommendation.

The research study is limited to home-based experiments. Therefore, further laboratory research could be conducted to determine the proximate analysis of the samples. Besides, laboratory research could be conducted to study the chemical properties of the compost samples which can better explain their effects on the duration of composting and plant growth.

Besides, since small scale composting was carried out, the effect of temperature was changes during composting was not able to be identified during the different times of the day. Therefore, large scale of composting could be carried out in the future to study about the temperature change during composting.

Finally, future studies could be conducted to investigate the composting properties of biochar compost of OPEFB fibre to compared their duration of composting and their effect on plant growth to compost made from fresh OPEFB fibre.

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APPENDIX A

DESCRIPTIVE DATA

Table A.1: Moisture analysis of OPEFB fibre.

Sample	Time (min)					Final weight (g)
	0	30	60	90	120	
T1	10.00 g	8.11 g	6.45 g	5.49 g	5.49 g	5.49
T2	10.00 g	8.01 g	5.40 g	4.97 g	4.97 g	4.97
T3	10.00 g	8.11 g	6.01 g	5.73 g	5.72 g	5.72

Table A.2: Descriptive statistics of moisture analysis of OPEFB fibre.

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
OPEFB fibre	3	1.00	3.00	2.0000	.57735	1.00000
Weight (g)	3	4.97	5.72	5.3933	.22184	.38423
Moisture content (%)	3	42.80	50.30	46.0667	2.21836	3.84231
Total solid content (%)	3	49.70	57.20	53.9333	2.21836	3.84231
Weight loss (g)	3	4.28	5.03	4.6067	.22184	.38423

Valid N (listwise)	3

Table A.3: Moisture analysis of dried leaves.

Sample	Time (min)					Final
	0	30	60	90	120	weight (g)
T1	10.00 g	8.89 g	8.01 g	7.65 g	7.65 g	7.65
T2	10.00 g	9.11 g	8.54 g	7.00 g	7.00 g	7.00
T3	10.00 g	8.99 g	7.43 g	7.43 g	7.43 g	7.43

Table A.4: Descriptive statistics of moisture analysis of dried leaves.

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Dried leaves	3	1.00	3.00	2.0000	.57735	1.00000
Weight (g)	3	7.00	7.65	7.3600	.19088	.33061
Moisture content (%)	3	23.50	30.00	26.4000	1.90875	3.30606
Total solid content (%)	3	70.00	76.50	73.6000	1.90875	3.30606
Weight loss (g)	3	2.35	3.00	2.6400	.19088	.33061
Valid N (listwise)	3					

Table A.5: Moisture analysis of vegetable scraps.

Sample	Time (min)					Final weight (g)
	0	30	60	90	120	
T1	10.00 g	5.11 g	4.80 g	3.13 g	3.13 g	3.13
T2	10.00 g	4.89 g	3.21 g	3.21 g	3.21 g	3.21
T3	10.00 g	4.01 g	2.91 g	2.91 g	2.91 g	2.91

Table A.6: Descriptive statistics of moisture analysis of vegetable scraps.

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Vegetable scraps	3	1.00	3.00	2.0000	.57735	1.00000
Weight (g)	3	2.91	3.21	3.0833	.08969	.15535
Moisture content (%)	3	67.90	70.90	69.1667	.89691	1.55349
Total solid content (%)	3	29.10	32.10	30.8333	.89691	1.55349
Weight loss (g)	3	6.79	7.09	6.9167	.08969	.15535
Valid N (listwise)	3					

Table A.7: Composting process of samples without EM solution.

Duration (week)	Samples				
	A (Control)	B	C	D	E
0					
1					
2					
3					

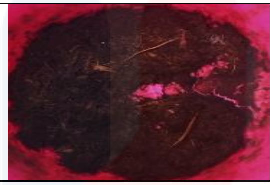
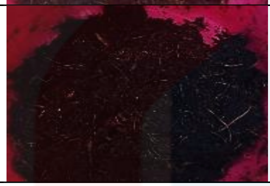
4					
5					
6					
7					
8					

Table A.8: Composting process of samples with EM solution.

Duration (week)	Samples			
	B’	C’	D’	E’
0				
1				
2				

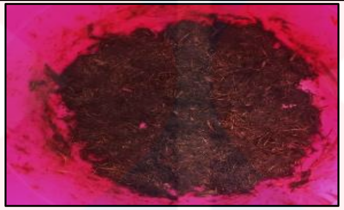
3				
4				
5				
6				
7				

Table A.9: Amount of compost collected per week

Sample	Week									Total (g)
	0	1	2	3	4	5	6	7	8	
A	0 g	0 g	13.38 g	15.53 g	22.96 g	29.12 g	-	-	-	80.99
B	0 g	0 g	6.17 g	11.45 g	16.26 g	16.45 g	24.98 g	-	-	75.31
C	0 g	0 g	10.01 g	8.19 g	14.89 g	-	-	-	-	33.09
D	0 g	0 g	14.50 g	15.80 g	23.41 g	23.01 g	4.12 g	6.70 g	-	87.54
E	0 g	0 g	4.12 g	12.11 g	13.19 g	15.98 g	10.11 g	16.11 g	18.71 g	90.33
B’	0 g	0 g	6.98 g	18.01 g	25.26 g	36.23 g	-	-	-	86.48
C’	0 g	0 g	25.45 g	22.43 g	11.94 g	-	-	-	-	59.82
D’	0 g	0 g	17.89 g	16.04 g	25.65 g	20.11 g	8.68 g	-	-	88.37
E’	0 g	0 g	3.98 g	16.59 g	39.19 g	20.02 g	8.01 g	6.88 g	-	94.67

Table A.10: pH of soil and compost.

Plant sample	pH of compost				Final pH of soil (Incorporated with compost)			
	C1	C2	C3	Average	T1	T2	T3	Average
+ A	7.8	7.8	7.8	7.80	7.8	7.7	7.7	7.73
+ B	7.8	7.8	7.8	7.80	7.6	7.6	7.6	7.60
+ C	7.7	7.7	7.7	7.70	7.5	7.6	7.4	7.50
+ D	7.6	7.6	7.6	7.60	7.6	7.6	7.6	7.60
+ E	7.6	7.6	7.6	7.60	7.6	7.8	7.7	7.70
+ B'	7.8	7.8	7.8	7.80	7.4	7.5	7.5	7.47
+ C'	7.7	7.7	7.7	7.70	7.5	7.5	7.4	7.47
+ D'	7.7	7.7	7.7	7.70	7.5	7.6	7.7	7.60
+ E'	7.6	7.6	7.6	7.60	7.7	7.7	7.7	7.70
X	-	-	-	-	7.0	7.1	7.0	7.03

Table A.11: Descriptive statistics of final pH of soil.

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Final pH A	3	7.70	7.80	7.7333	0.03333	0.05774
Final pH C	3	7.40	7.60	7.5000	0.05774	0.10000
Final pH E	3	7.60	7.80	7.7000	0.05774	0.10000
Final pH B'	3	7.40	7.50	7.4667	0.03333	0.05774
Final pH C'	3	7.40	7.50	7.4667	0.03333	0.05774
Final pH D'	3	7.50	7.70	7.6000	0.05774	0.10000
Final pH X	3	7.00	7.10	7.0333	0.03333	0.05774
Valid N (listwise)	3					

Table A.12: Length of roots (cm)

Sample	Length of roots (cm)		
	T1	T2	T3
+ A	3.40	3.00	3.20
+ B	3.30	3.30	3.30
+ C	3.70	3.60	3.60
+ D	3.50	3.50	3.50
+ E	3.40	3.50	3.30
+ B’	3.30	3.40	3.30
+ C’	3.60	3.80	3.60
+ D’	3.60	3.50	3.40
+ E’	3.50	3.30	3.50
X	3.00	3.10	2.90

Table A.13: Descriptive statistics of length of roots (cm)

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Length of roots A (cm)	3	3.00	3.40	3.2000	0.11547	0.20000
Length of roots B (cm)	3	3.30	3.30	3.3000	0.00000	0.00000
Length of roots C (cm)	3	3.60	3.70	3.6333	0.03333	0.05774
Length of roots D (cm)	3	3.50	3.50	3.5000	0.00000	0.00000
Length of roots E (cm)	3	3.30	3.50	3.4000	0.05774	0.10000
Length of roots B' (cm)	3	3.30	3.40	3.3333	0.03333	0.05774
Length of roots C' (cm)	3	3.60	3.80	3.6667	0.06667	0.11547
Length of roots D' (cm)	3	3.40	3.60	3.5000	0.05774	0.10000
Length of roots E' (cm)	3	3.30	3.50	3.4333	0.06667	0.11547
Length of roots X (cm)	3	2.90	3.10	3.0000	0.05774	0.10000

Valid N (listwise)	3

Table A.14: Height of shoots (cm).

Sample	Height of shoots (cm)		
	T1	T2	T3
+ A	9.1	9.7	9.4
+ B	9.4	9.4	9.8
+ C	12.7	11.4	12.9
+ D	10.6	11.0	10.7
+ E	10.5	10.8	10.9
+ B’	9.7	9.1	9.9
+ C’	12.8	12.4	12.3
+ D’	10.7	10.6	10.8
+ E’	10.8	10.5	10.6
X	5.9	5.9	6.1

Table A.15: Descriptive statistics of height of shoots (cm).

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Height of shoots A (cm)	3	9.10	9.70	9.4000	0.17321	0.30000
Height of shoots B (cm)	3	9.40	9.80	9.5333	0.13333	0.23094
Height of shoots C (cm)	3	11.40	12.90	12.3333	0.47022	0.81445
Height of shoots D (cm)	3	10.60	11.00	10.7667	0.12019	0.20817
Height of shoots E (cm)	3	10.50	10.90	10.7333	0.12019	0.20817
Height of shoots B' (cm)	3	9.10	9.90	9.5667	0.24037	0.41633
Height of shoots C' (cm)	3	12.30	12.80	12.5000	0.15275	0.26458
Height of shoots D' (cm)	3	10.60	10.80	10.7000	0.05774	0.10000
Height of shoots E' (cm)	3	10.50	10.80	10.6333	0.08819	0.15275
Height of shoots X (cm)	3	5.90	6.10	5.9667	0.06667	0.11547

Valid N (listwise)	3

APPENDIX B

SPSS RESULTS TABLES

Table B.1: Pearson correlation analysis between total weight loss of samples (%) with the weights of the different materials used in the compost mixture (g)

		Total weight loss (%)	Weight of OPEFB fibre (g)	Weight of dried leaves (g)	Weight of vegetable scraps (g)
Total weight loss (%)	Pearson Correlation	1	-0.527	-.125	0.585
	Sig. (2-tailed)		0.145	0.749	0.098
	N	9	9	9	9
Weight of OPEFB fibre (g)	Pearson Correlation	-0.527	1	-0.601	-0.994**
	Sig. (2-tailed)	0.145		0.087	0.000
	N	9	9	9	9
Weight of dried leaves (g)	Pearson Correlation	-0.125	-0.601	1	0.509
	Sig. (2-tailed)	0.749	0.087		0.162
	N	9	9	9	9
	Pearson Correlation	0.585	-0.994**	0.509	1

Weight of vegetable scraps (g)	Sig. (2-tailed)	0.098	.000	.162	
	N	9	9	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

Table B.2: The analysis of variance (ANOVA) of weight of OPEFB fiber (g) with the duration of composting (weeks).

Duration of composting (weeks)					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.600	4	3.650	12.167	.009
Within Groups	1.500	5	0.300		
Total	16.100	9			

Analysis was conducted at 5 % significant level (α = 0.05).

Table B.3: Tukey's HSD test for multiple comparison of the mean of the duration of composting (weeks) of the samples with different weight of OPEFB fibre (g).

Dependent Variable: Duration of composting (weeks)						
Tukey HSD						
					95% Confidence Interval	
(I) Weight of OPEFB fibre (g)	(J) Weight of OPEFB fibre (g)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
0.0	7.0	-0.500	0.548	0.881	-2.70	1.70
	14.0	1.000	0.548	0.450	-1.20	3.20
	50.0	-1.500	0.548	0.178	-3.70	0.70
	100.0	-2.500*	0.548	0.030	-4.70	-0.30
7.0	0.0	0.500	0.548	0.881	-1.70	2.70
	14.0	1.500	0.548	0.178	-0.70	3.70
	50.0	-1.000	0.548	0.450	-3.20	1.20
	100.0	-2.000	0.548	0.070	-4.20	0.20
14.0	0.0	-1.000	0.548	0.450	-3.20	1.20
	7.0	-1.500	0.548	0.178	-3.70	0.70
	50.0	-2.500*	0.548	0.030	-4.70	-0.30
	100.0	-3.500*	0.548	0.007	-5.70	-1.30
50.0	0.0	1.500	0.548	0.178	-0.70	3.70
	7.0	1.000	0.548	0.450	-1.20	3.20
	14.0	2.500*	0.548	0.030	0.30	4.70
	100.0	-1.000	0.548	0.450	-3.20	1.20

100.0	0.0	2.500*	0.548	0.030	0.30	4.70
	7.0	2.000	0.548	0.070	-0.20	4.20
	14.0	3.500*	0.548	0.007	1.30	5.70
	50.0	1.000	0.548	0.450	-1.20	3.20

*. The mean difference is significant at the 0.05 level.

Table B.4: Homogenous subsets of means of duration of composting.

Duration of composting (weeks)				
Tukey HSD[a]				
Weight of OPEFB fibre (g)	N	Subset for alpha = 0.05		
		1	2	3
14	2	4.00		
0	2	5.00	5.00	
7	2	5.50	5.50	5.50
50	2		6.50	6.50
100	2			7.50
Sig.		0.178	0.178	0.070

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table B.5: The paired sample statistics of the duration of composting of samples treated with or without EM solution.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Treatment without EM solution	6.25	4	1.708	0.854
	Treatment with EM solution	5.50	4	1.291	0.645

Table B.6: The paired samples correlation analysis of the duration of composting of samples treated with or without EM solution.

		N	Correlation	Sig.
Pair 1	Treatment without EM solution & Treatment with EM solution	4	0.983	0.017

Table B.7: The paired sample T-test of the duration of composting of samples treated with or without EM solution.

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Treatment without EM solution - Treatment with EM solution	0.750	0.500	0.250	-0.046	1.546	3.000	3	0.058

Analysis was conducted at 5 % significant level (α = 0.05).

Table B.8: The analysis of variance (ANOVA) of pH of compost with (a) length of roots (cm) and (b) height of shoots (cm) of bird's-eye chili plants.

		Sum of Squares	df	Mean Square	F	Sig.
Length of roots (cm)	Between Groups	0.992	3	0.331	28.868	0.000
	Within Groups	0.298	26	0.011		
	Total	1.290	29			
Height of shoots (cm)	Between Groups	84.857	3	28.286	87.783	0.000
	Within Groups	8.378	26	0.322		
	Total	93.235	29			

Analysis was conducted at 5 % significant level (α = 0.05).

Table B.9: Tukey's HSD test for multiple comparison of the pH of compost with (a) length of roots (cm) and (b) height of shoots (cm) of bird's-eye chili plants.

Multiple Comparisons							
Tukey HSD							
						95% Confidence Interval	
Dependent Variable	(I) pH of compost	(J) pH of compost	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Length of roots (cm)	Control	7.60	-0.44444*	0.07135	0.000	-0.6402	-0.2487
		7.70	-0.60000*	0.07135	0.000	-0.7957	-0.4043
		7.80	-0.27778*	0.07135	0.003	-0.4735	-0.0821
	7.60	0.00	0.44444*	0.07135	0.000	0.2487	0.6402
		7.70	-0.15556*	0.05045	0.023	-0.2940	-0.0172
		7.80	0.16667*	0.05045	0.014	0.0283	0.3051
	7.70	0.00	0.60000*	0.07135	0.000	0.4043	0.7957
		7.60	0.15556*	0.05045	0.023	0.0172	0.2940
		7.80	0.32222*	0.05045	0.000	0.1838	0.4606
	7.80	0.00	0.27778*	0.07135	0.003	0.0821	0.4735
		7.60	-0.16667*	0.05045	0.014	-0.3051	-0.0283
		7.70	-0.32222*	0.05045	0.000	-0.4606	-0.1838
Height of shoots (cm)	Control	7.60	-4.74444*	0.37843	0.000	-5.7826	-3.7063
		7.70	-5.87778*	.37843	0.000	-6.9159	-4.8396
		7.80	-3.53333*	.37843	.000	-4.5715	-2.4952
	7.60	0.00	4.74444*	.37843	.000	3.7063	5.7826

	7.70	-1.13333*	0.26759	0.001	-1.8674	-0.3992
	7.80	1.21111*	0.26759	0.001	0.4770	1.9452
7.70	0.00	5.87778*	0.37843	0.000	4.8396	6.9159
	7.60	1.13333*	0.26759	0.001	0.3992	1.8674
	7.80	2.34444*	0.26759	0.000	1.6104	3.0785
7.80	0.00	3.53333*	0.37843	0.000	2.4952	4.5715
	7.60	-1.21111*	0.26759	0.001	-1.9452	-0.4770
	7.70	-2.34444*	0.26759	0.000	-3.0785	-1.6104

*. The mean difference is significant at the 0.05 level.

Table B.10: Homogenous subsets of means of length of roots (cm).

Length of roots (cm)				
Tukey HSD[a,b]				
		Subset for alpha = 0.05		
pH of compost	N	1	2	3
Control	3	3.0000		
7.80	9		3.2778	
7.60	9		3.4444	3.4444
7.70	9			3.6000
Sig.		1.000	0.055	0.081

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 6.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table B.11: Homogenous subsets of means of height of shoots (cm).

Height of shoots (cm)					
Tukey HSD[a,b]					
		Subset for alpha = 0.05			
pH of compost	N	1	2	3	4
Control	3	5.9667			
7.80	9		9.5000		
7.60	9			10.7111	
7.70	9				11.8444
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 6.000.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table B.12: The analysis of variance (ANOVA) of compost samples containing different amounts of OPEFB fibre with (a) length of roots (cm) and (b) height of shoots (cm) of bird's-eye chili plants.

		Sum of Squares	df	Mean Square	F	Sig.
Length of roots (cm)	Between Groups	1.083	9	0.120	11.645	0.000
	Within Groups	0.207	20	0.010		
	Total	1.290	29			
Height of shoots (cm)	Between Groups	90.868	9	10.096	85.322	0.000
	Within Groups	2.367	20	0.118		
	Total	93.235	29			

Analysis was conducted at 5 % significant level ($\alpha = 0.05$).

Table B.13: Tukey's HSD test for multiple comparison of compost samples containing different amounts of OPEFB fibre with (a) length of roots (cm) and (b) height of shoots (cm) of bird's-eye chili plants.

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Plant sample	(J) Plant sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Length of roots (cm)	X	+A	-0.20000	0.08300	0.370	-0.4939	0.0939
		+B	-0.30000*	0.08300	0.043	-0.5939	-0.0061
		+C	-0.63333*	0.08300	0.000	-0.9272	-0.3394
		+D	-0.50000*	0.08300	0.000	-0.7939	-0.2061
		+E	-0.40000*	0.08300	0.003	-0.6939	-0.1061
		+B'	-0.33333*	0.08300	0.019	-0.6272	-0.0394
		+C'	-0.66667*	0.08300	0.000	-0.9606	-0.3728
		+D'	-0.50000*	0.08300	0.000	-0.7939	-0.2061
		+E'	-0.43333*	0.08300	0.001	-0.7272	-0.1394
	+A	X	0.20000	0.08300	0.370	-0.0939	0.4939
		+B	-0.10000	0.08300	0.963	-0.3939	0.1939
		+C	-0.43333*	0.08300	0.001	-0.7272	-0.1394
		+D	-0.30000*	0.08300	0.043	-0.5939	-0.0061
		+E	-0.20000	0.08300	0.370	-0.4939	0.0939
		+B'	-0.13333	0.08300	0.830	-0.4272	0.1606

	+C'	-0.46667*	0.08300	0.001	-0.7606	-0.1728
	+D'	-0.30000*	0.08300	0.043	-0.5939	-0.0061
	+E'	-0.23333	0.08300	0.198	-0.5272	0.0606
+B	X	0.30000*	0.08300	0.043	0.0061	0.5939
	+A	0.10000	0.08300	0.963	-0.1939	0.3939
	+C	-0.33333*	0.08300	0.019	-0.6272	-0.0394
	+D	-0.20000	0.08300	0.370	-0.4939	0.0939
	+E	-0.10000	0.08300	0.963	-0.3939	0.1939
	+B'	-0.03333	0.08300	1.000	-0.3272	0.2606
	+C'	-0.36667*	0.08300	0.008	-0.6606	-0.0728
	+D'	-0.20000	0.08300	0.370	-0.4939	0.0939
	+E'	-0.13333	0.08300	0.830	-0.4272	0.1606
+C	X	0.63333*	0.08300	0.000	0.3394	0.9272
	+A	0.43333*	0.08300	0.001	0.1394	0.7272
	+B	0.33333*	0.08300	0.019	0.0394	0.6272
	+D	0.13333	0.08300	0.830	-0.1606	0.4272
	+E	0.23333	0.08300	0.198	-0.0606	0.5272
	+B'	0.30000*	0.08300	0.043	0.0061	0.5939
	+C'	-0.03333	0.08300	1.000	-0.3272	0.2606
	+D'	0.13333	0.08300	0.830	-0.1606	0.4272
	+E'	0.20000	0.08300	0.370	-0.0939	0.4939
+D	X	0.50000*	0.08300	0.000	0.2061	0.7939
	+A	0.30000*	0.08300	0.043	0.0061	0.5939
	+B	0.20000	0.08300	0.370	-0.0939	0.4939

	+C	-0.13333	0.08300	0.830	-0.4272	0.1606
	+E	0.10000	0.08300	0.963	-0.1939	0.3939
	+B'	0.16667	0.08300	0.603	-0.1272	0.4606
	+C'	-0.16667	0.08300	0.603	-0.4606	0.1272
	+D'	0.00000	0.08300	1.000	-0.2939	0.2939
	+E'	0.06667	0.08300	0.998	-0.2272	0.3606
+E	X	0.40000*	0.08300	0.003	0.1061	0.6939
	+A	0.20000	0.08300	0.370	-0.0939	0.4939
	+B	0.10000	0.08300	0.963	-0.1939	0.3939
	+C	-0.23333	0.08300	0.198	-0.5272	0.0606
	+D	-0.10000	0.08300	0.963	-0.3939	0.1939
	+B'	0.06667	0.08300	0.998	-0.2272	0.3606
	+C'	-0.26667	0.08300	0.096	-0.5606	0.0272
	+D'	-0.10000	0.08300	0.963	-0.3939	0.1939
	+E'	-0.03333	0.08300	1.000	-0.3272	0.2606
+B'	X	0.33333*	0.08300	0.019	0.0394	0.6272
	+A	0.13333	0.08300	0.830	-0.1606	0.4272
	+B	0.03333	0.08300	1.000	-0.2606	0.3272
	+C	-0.30000*	0.08300	0.043	-0.5939	-0.0061
	+D	-0.16667	0.08300	0.603	-0.4606	0.1272
	+E	-0.06667	0.08300	0.998	-0.3606	0.2272
	+C'	-0.33333*	0.08300	0.019	-0.6272	-0.0394
	+D'	-0.16667	0.08300	0.603	-0.4606	0.1272
	+E'	-0.10000	0.08300	0.963	-0.3939	0.1939

+C'	X	0.66667*	0.08300	0.000	0.3728	0.9606
	+A	0.46667*	0.08300	0.001	0.1728	0.7606
	+B	0.36667*	0.08300	0.008	0.0728	0.6606
	+C	0.03333	0.08300	1.000	-0.2606	0.3272
	+D	0.16667	0.08300	0.603	-0.1272	0.4606
	+E	0.26667	0.08300	0.096	-0.0272	0.5606
	+B'	0.033333*	0.08300	0.019	0.0394	0.6272
	+D'	0.16667	0.08300	0.603	-0.1272	0.4606
	+E'	0.23333	0.08300	0.198	-0.0606	0.5272
+D'	X	0.50000*	0.08300	0.000	0.2061	0.7939
	+A	0.30000*	0.08300	0.043	0.0061	0.5939
	+B	0.20000	0.08300	0.370	-0.0939	0.4939
	+C	-0.13333	0.08300	0.830	-0.4272	0.1606
	+D	0.00000	0.08300	1.000	-0.2939	0.2939
	+E	0.10000	0.08300	0.963	-0.1939	0.3939
	+B'	0.16667	0.08300	0.603	-0.1272	0.4606
	+C'	-0.16667	0.08300	0.603	-0.4606	0.1272
	+E'	0.06667	0.08300	0.998	-0.2272	0.3606
+E'	X	0.43333*	0.08300	0.001	0.1394	0.7272
	+A	0.23333	0.08300	0.198	-0.0606	0.5272
	+B	0.13333	0.08300	0.830	-0.1606	0.4272
	+C	-0.20000	0.08300	0.370	-0.4939	0.0939
	+D	-0.06667	0.08300	0.998	-0.3606	0.2272
	+E	0.03333	0.08300	1.000	-0.2606	0.3272

		+B'	0.10000	0.08300	0.963	-0.1939	0.3939
		+C'	-0.23333	0.08300	0.198	-0.5272	0.0606
		+D'	-0.06667	0.08300	0.998	-0.3606	0.2272
Height of shoots (cm)	X	+A	-3.43333*	0.28087	0.000	-4.4279	-2.4387
		+B	-3.56667*	0.28087	0.000	-4.5613	-2.5721
		+C	-6.36667*	0.28087	0.000	-7.3613	-5.3721
		+D	-4.80000*	0.28087	0.000	-5.7946	-3.8054
		+E	-4.76667*	0.28087	0.000	-5.7613	-3.7721
		+B'	-3.60000*	0.28087	0.000	-4.5946	-2.6054
		+C'	-6.53333*	0.28087	0.000	-7.5279	-5.5387
		+D'	-4.73333*	0.28087	0.000	-5.7279	-3.7387
		+E'	-4.66667*	0.28087	0.000	-5.6613	-3.6721
	+A	X	3.43333*	0.28087	0.000	2.4387	4.4279
		+B	-0.13333	0.28087	1.000	-1.1279	0.8613
		+C	-2.93333*	0.28087	0.000	-3.9279	-1.9387
		+D	-1.36667*	0.28087	0.003	-2.3613	-0.3721
		+E	-1.33333*	0.28087	0.004	-2.3279	-0.3387
		+B'	-0.16667	0.28087	1.000	-1.1613	0.8279
		+C'	-3.10000*	0.28087	0.000	-4.0946	-2.1054
		+D'	-1.30000*	0.28087	0.005	-2.2946	-0.3054
		+E'	-1.23333*	0.28087	0.008	-2.2279	-0.2387
	+B	X	3.56667*	0.28087	0.000	2.5721	4.5613
		+A	0.13333	0.28087	1.000	-0.8613	1.1279
		+C	-2.80000*	0.28087	0.000	-3.7946	-1.8054

	+D	-1.23333*	0.28087	0.008	-2.2279	-0.2387
	+E	-1.20000*	0.28087	0.011	-2.1946	-0.2054
	+B'	-0.03333	0.28087	1.000	-1.0279	0.9613
	+C'	-2.96667*	0.28087	0.000	-3.9613	-1.9721
	+D'	-1.16667*	0.28087	0.014	-2.1613	-0.1721
	+E'	-1.10000*	0.28087	0.023	-2.0946	-0.1054
+C	X	6.36667*	0.28087	0.000	5.3721	7.3613
	+A	2.93333*	0.28087	0.000	1.9387	3.9279
	+B	2.80000*	0.28087	0.000	1.8054	3.7946
	+D	1.56667*	0.28087	0.001	0.5721	2.5613
	+E	1.60000*	0.28087	0.000	0.6054	2.5946
	+B'	2.76667*	0.28087	0.000	1.7721	3.7613
	+C'	-0.16667	0.28087	1.000	-1.1613	0.8279
	+D'	1.63333*	0.28087	0.000	0.6387	2.6279
	+E'	1.70000*	0.28087	0.000	0.7054	2.6946
+D	X	4.80000*	0.28087	0.000	3.8054	5.7946
	+A	1.36667*	0.28087	0.003	0.3721	2.3613
	+B	1.23333*	0.28087	0.008	0.2387	2.2279
	+C	-1.56667*	0.28087	0.001	-2.5613	-0.5721
	+E	0.03333	0.28087	1.000	-0.9613	1.0279
	+B'	1.20000*	0.28087	0.011	0.2054	2.1946
	+C'	-1.73333*	0.28087	0.000	-2.7279	-0.7387
	+D'	0.06667	0.28087	1.000	-0.9279	1.0613
	+E'	0.13333	0.28087	1.000	-0.8613	1.1279

+E	X	4.76667*	0.28087	0.000	3.7721	5.7613
	+A	1.33333*	0.28087	0.004	0.3387	2.3279
	+B	1.20000*	0.28087	0.011	0.2054	2.1946
	+C	-1.60000*	0.28087	0.000	-2.5946	-0.6054
	+D	-0.03333	0.28087	1.000	-1.0279	0.9613
	+B'	1.16667*	0.28087	0.014	0.1721	2.1613
	+C'	-1.76667*	0.28087	0.000	-2.7613	-0.7721
	+D'	0.03333	0.28087	1.000	-0.9613	1.0279
	+E'	0.10000	0.28087	1.000	-0.8946	1.0946
+B'	X	3.60000*	0.28087	0.000	2.6054	4.5946
	+A	0.16667	0.28087	1.000	-0.8279	1.1613
	+B	0.03333	0.28087	1.000	-0.9613	1.0279
	+C	-2.76667*	0.28087	0.000	-3.7613	-1.7721
	+D	-1.20000*	0.28087	0.011	-2.1946	-0.2054
	+E	-1.16667*	0.28087	0.014	-2.1613	-0.1721
	+C'	-2.93333*	0.28087	0.000	-3.9279	-1.9387
	+D'	-1.13333*	0.28087	0.018	-2.1279	-0.1387
	+E'	-1.06667*	0.28087	0.029	-2.0613	-0.0721
+C'	X	6.53333*	0.28087	0.000	5.5387	7.5279
	+A	3.10000*	0.28087	0.000	2.1054	4.0946
	+B	2.96667*	0.28087	0.000	1.9721	3.9613
	+C	0.16667	0.28087	1.000	-0.8279	1.1613
	+D	1.73333*	0.28087	0.000	0.7387	2.7279
	+E	1.76667*	0.28087	0.000	0.7721	2.7613

	+B'	2.93333*	0.28087	0.000	1.9387	3.9279
	+D'	1.80000*	0.28087	0.000	0.8054	2.7946
	+E'	1.86667*	0.28087	0.000	0.8721	2.8613
+D'	X	4.73333*	0.28087	0.000	3.7387	5.7279
	+A	1.30000*	0.28087	0.005	0.3054	2.2946
	+B	1.16667*	0.28087	0.014	0.1721	2.1613
	+C	-1.63333*	0.28087	0.000	-2.6279	-0.6387
	+D	-0.06667	0.28087	1.000	-1.0613	0.9279
	+E	-0.03333	0.28087	1.000	-1.0279	0.9613
	+B'	1.13333*	0.28087	0.018	0.1387	2.1279
	+C'	-1.80000*	0.28087	0.000	-2.7946	-0.8054
	+E'	0.06667	0.28087	1.000	-0.9279	1.0613
+E'	X	4.66667*	0.28087	0.000	3.6721	5.6613
	+A	1.23333*	0.28087	0.008	0.2387	2.2279
	+B	1.10000*	0.28087	0.023	0.1054	2.0946
	+C	-1.70000*	0.28087	0.000	-2.6946	-0.7054
	+D	-0.13333	0.28087	1.000	-1.1279	0.8613
	+E	-0.10000	0.28087	1.000	-1.0946	0.8946
	+B'	1.06667*	0.28087	0.029	0.0721	2.0613
	+C'	-1.86667*	0.28087	0.000	-2.8613	-0.8721
	+D'	-0.06667	0.28087	1.000	-1.0613	0.9279

*. The mean difference is significant at the 0.05 level.

Table B.14 Homogenous subsets of means of length of roots (cm).

Length of roots (cm)						
Tukey HSD[a]						
		Subset for alpha = 0.05				
Plant sample	N	1	2	3	4
X	3	3.0000			
+A	3	3.2000	3.2000		
+B	3		3.3000	3.3000	
+B'	3		3.3333	3.3333	
+E	3		3.4000	3.4000	3.4000
+E'	3		3.4333	3.4333	3.4333
+D	3			3.5000	3.5000
+D'	3			3.5000	3.5000
+C	3				3.6333
+C'	3				3.6667
Sig.		0.370	0.198	0.370	0.096

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Table B.15: Homogenous subsets of means of height of shoots (cm).

Height of shoots (cm)					
Tukey HSD[a]					
		Subset for alpha = 0.05			
Plant sample	N	1	2	3	4
X	3	5.9667			
+A	3		9.4000		
+B	3		9.5333		
+B'	3		9.5667		
+E'	3			10.6333	
+D'	3			10.7000	
+E	3			10.7333	
+D	3			10.7667	
+C	3				12.3333
+C'	3				12.5000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Table B.16: The paired sample statistics of the (a) length of roots (cm) and (b) height of shoots (cm) of bird's-eye chili plants treated compost incorporated with or without EM solution.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Length of roots with EM (cm)	3.3389	18	0.22788	0.05371
	Length of roots without EM (cm)	2.3222	18	1.69413	0.39931
Pair 2	Height of shoots with EM (cm)	9.7889	18	2.04735	0.48256
	Height of shoots without EM (cm)	7.2333	18	5.33997	1.25864

Table B.17: The paired samples correlation analysis of the (a) length of roots (cm) and (b) height of shoots (cm) of bird's-eye chili plants treated compost incorporated with or without EM solution.

		N	Correlation	Sig.
Pair 1	Length of roots with EM (cm) & Length of roots without EM (cm)	18	0.784	0.000
Pair 2	Height of shoots with EM (cm) & Height of shoots without EM (cm)	18	0.806	0.000

Table B.18: The paired sample T-test of the (a) length of roots (cm) and (b) height of shoots (cm) of bird's-eye chili plants treated compost incorporated with or without EM solution.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Length of roots with EM (cm) - Length of roots without EM (cm)	1.01667	1.52209	0.35876	0.25975	1.77359	2.834	17	0.011
Pair 2	Height of shoots with EM (cm) - Height of shoots without EM (cm)	2.55556	3.88469	0.91563	.62374	4.48737	2.791	17	0.013

Analysis was conducted at 5 % significant level (α = 0.05).

The Utilization of Oil Palm Empty Fruit Bunch (OPEFB) Fibre in Home Compost Making

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