IMPROVEMENT OF EFB LIGNOCELLULOSIC DEGRADATION, ORGANIC MATTER AND COMPOST QUALITY WITH NATURAL ZEOLITE

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ABSTRAK

Pengkomposan adalah kaedah terbaik untuk mengolah sisa organik seperti tandan buah kosong, yang merupakan salah satu sisa yang dihasilkan oleh industri sawit akhir-akhir ini. kira-kira 20% tandan buah kosong dihasilkan untuk setiap tan buah segar dalam pengeluaran minyak sawit mentah. pengkomposan tandan buah kosong menghasilkan kompos tandan buah kosong yang akan bermanfaat bagi pertanian. walau bagaimanapun, kehilangan nitrogen yang besar semasa proses tersebut telah mengurangkan nilai kompos sebagai baja organik. zeolite ditambahkan untuk mengimbangi kehilangan nitrogen yang dapat menurunkan pengurangan nitrogen dan juga mengurangkan pencemaran udara. kajian ini difokuskan untuk menyelidiki peningkatan kualiti kompos tandan buah kosong yang dihasilkan dari pengkomposan tandan buah kosong dengan efluen kilang kelapa sawit dan agen penumpukan zeolit semula jadi. proses pengkomposan dilakukan dalam skala makmal dengan labu 250 ml pada dua suhu berbeza 30℃ dan 50℃. suhu tetap berterusan sepanjang eksperimen untuk mengkaji kesan suhu tetap pada ciri kompos tandan buah kosong. prestasi yang lebih baik didapati dalam kompos tandan buah kosong yang dihasilkan dari pengkomposan tandan buah kosong dengan air sisa kelapa sawit dan zeolit pada suhu 50℃. kompos tandan buah kosong mempunyai ph optimum dalam lingkungan 5.5 hingga 8, nisbah karbon ke nitrogen 5.2, kandungan fosfat 5.3% dan kandungan lembapan optimum 70%.

ABSTRACT

Composting is an excellent way of treating organic waste such as empty fruit bunches (EFB), which are one of the waste that highly produce by palm industry lately. It about 20% of EFB is generated for every tonne of fresh fruit bunch in production of crude palm oil. Composting of EFB produces EFB compost that will be beneficial to agriculture. However, large nitrogen loss during the process has reduced the value of compost as an organic fertilizer. Zeolite is added to offset the loss of nitrogen that can lowered the nitrogen reduction and also reduce air pollution. This study was focused on investigating the improvement quality of EFB compost produced from composting of EFB with palm oil mill effluent and natural zeolites bulking agent. The composting process was performed in laboratory scale with 250 ml flasks at two different temperatures of 30℃ and 50℃. The temperatures were kept constant throughout the experiments to investigate effect of constant temperatures on features of EFB compost. Better performance was found in the EFB compost produced from composting of EFB with palm oil mill effluent and zeolite at 50℃. The EFB compost had the optimum pH in range 5.5 to 8, carbon to nitrogen ratio 5.2, phosphorus content of 5.3% and optimum moisture content 70%.

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LIST OF ABBREVIATIONS

EFB	Empty Fruit Bunch
POME	Palm Oil Mill Effluent
FFB	Fresh Fruit Bunch
PFF	Pressed Fruity Fibre
OPS	Oil Palm Shells
OPT	Oil Palm Trunks
OPF	Oil Palm Shrubs
MC	Moisture Content
C/N	Carbon to Nitrogen Ratio
VS	Volatile Solid
WHC	Water Holding Capacity
TOC	Total Organic Carbon
GI	Germination Index
NI	Nitrogen Index
N	Nitrogen
P	Phosphorus
K	Potassium
EC	Electric Conductivity
C	Carbon
Mg	Magnesium
C	Calcium
S	Sulphur
Zn	Zinc
Mn	Manganese
Cu	Copper
Fe	Iron
B	Boron
NDF	Neutral Detergent Fibre
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin

NDFS	Natural Detergent Fibre Solution
ADS	Acid Detergent Solution
µS/cm	Micro Siemens per centimetre
S/cm	Siemens per centimetre
MW	Megawatt
mg/L	Milligram per Litre
CO_2	Carbon Dioxide
OMs	Organic Matters
HM	Heavy Matter
GHGs	Green House Gases
OSW	Organic Solid Waste
COD	Chemical Oxygen Demand
ALOF	Activated Liquid Organic Fertiliser
AlO_4	Alumina
SiO_4	Silica Tetrahedra
O	Oxygen
Si	Silicon
NH_3	Ammonia
NH_{4+}	Ammonium
CH_4	Methane
CEC	Cation Exchange Capacity
AOB	Ammonia-Oxidizing Bacteria
AOA	Ammonia-Oxidizing Archea
ARGs	antibiotic resistance genes
NGOs	Non-Government Organizations
FiT	Feed-in Tariff
w/v	Weight per Volume
EDTA	Disodium Ethylene Diamine Tetra Acetic Acid

CHAPTER 1

INTRODUCTION

This chapter provides an overview of the research background studies on oil palm composting, empty fruit bunches (EFB), palm oil mill effluent (POME), and natural zeolite. This chapter's layout is then followed by the scope of study, the significance of this research, and the goals to be achieved at the end of the composting process. The overview of all chapters is defined at the end of this chapter.

1.1 BACKGROUND OF STUDY

Oil palm is the most popular and widely grown plant families in Indonesia and Malaysia, in particular. Many common products and foodstuffs derive from oil palm and make them one of the most important economically (Panel & In, 2021b). In 2008, there were 4,487,957 hectares of oil palm plantations (Ibrahim, 2021). In 2009, there were some 80 million tonnes of palm oil and 57,4 tonnes of effluent from palm oil mills (POME). A total of around 90 million tonnes of renewable biomass are produced each year, such as shells, fibres, palms and empty fruit bunches (EFB) (Alkarimiah and Rahman, 2014).

The presence of this Palm oil waste has developed a major waste disposal issue (Abdullah and Sulaim, 2013). Oil palm empty bunches are recoverable lignocellulose biomass used as feedstock for the production of biofuels. (Mohammad et al., 2020). Empty fruit bunkers (EFB) are abundant waste available in our country, palm oil mill effluents (POME) are also a concern. EFB and POME are not good for the environment. It is clearly known that when incongruously discarded (Alkarimiah and Rahman, 2014).

Composting is an excellent way of treating organic waste and producing a good soil conditioner (Quazi, 2020). Compost is an extremely cost-effective technique of managing and disposing of bio-waste because it aids in materials storage and reuse (Panel and In, 2021b). Composting is a biochemical process that occurs in a controlled aerobic. A high - temperature microorganism-dominated ecosystem in which organic waste substrates are converted into a valuable humus-like material (Nur and Naher, 2017). Compost should be used as a soil-conditioning agricultural fertiliser in a safe and beneficial manner. Compost as a fertiliser improves the soil composition, ability to retain water, and aeration. Additionally, compost can include humus or organic matter, vitamins, hormones, and plant enzymes not found in synthetic fertilisers (Gandahi and Hanafi, 2014).

As chemical additives, a collection of organic materials such as leaves and non-biodegradable raw material such as zeolites, lime, and nutrients have been applied to the composting phase in order to improve and supply the composting matrix with the required biological, chemical, and physical properties (Waqas et al., 2019). The natural zeolite acts as a bulking agent which can increase the porosity of the compost material, increase air diffusion efficiency and reduce the risk of greenhouse gas emissions (Wu et al., 2020). The essential purpose of additives is to dry and modify the structure to provide air vacuum to improve ventilation (Waqas et al., 2019). Natural zeolite is beneficial for composting by its ability to absorb water and adsorb available nitrogen in plants via cation exchange, preventing compaction of soils and improving infiltration, both of which encourage aeration of the soil (Green and With, 2020).

1.2 PROBLEM STATEMENT

While the palm oil industry greatly contributes to Malaysia's economic growth by raising economic production welfare of the population, additionally, it adds to environmental problems by its activities on both the input and output lines. The mills generate significant waste products such as POME and EFB, which results in high annual disposal costs. Annually, approximately 44 million tonnes of solid oil palm residues are generated, with EFB accounting for 23.8 million tonnes (54%) (Nur and Naher, 2017) Regrettably, these wastes may cause environmental problems in the future, as their high organic content accumulates on the ground (Kabbashi et al., 2007).

Due to the low commercial value of EFB and its large quantity, it poses a disposal problem. Therefore, it is critical to maximise the use of EFB in order to address these issues while also generating valuable products. However, EFB may take longer period to degrade into small fibres, whereas POME, if not adequately handled, will contaminate the land and water sources with an unnecessary organic load (Alkarimiah and Rahman, 2014). The effluent from POME was established as a significant source of aquatic pollution in Malaysia (Singh, 2010).

It is necessary to manage the palm oil source products sustainably due to their benefits. They can lead to environmental pollution if not properly addressed (Singh, 2010). A biologically based process was adopted into useful end markets as a suitable alternative to stabilising organic matter to overcome all shortcomings in conventional EFB handling procedures (Nur and Naher, 2017). Composting palm oil mill waste can be good practise, since it is useful in recycling of useful plant nutrients (Singh, 2010). As many researchers have reported, composting is a cost-effective method of reducing organic waste. waste residues (Kabbashi et al., 2007). Composting EFB and POME is typically a lengthy process (Alkarimiah and Rahman, 2014). Composting is an extremely effective method of treating organic wastes and generating a beneficial soil conditioner (Quazi, 2020).

1.3 OBJECTIVE

i. To evaluate the effect of Zeolite in physical-chemical changes in EFB composting.
ii. To determine the degradation of Lignin, Cellulose and Hemicellulose of EFB fibre during composting process.

1.4 SCOPE OF STUDY

The purpose of this study is to compost biomass of Palm oil mill effluent (POME) with empty fruit bunches (EFB) with the addition of natural zeolite as a bulking agent in order to reduce composting time and improve compost quality. EFB and POME were sourced from United Oil Palm, which is located near the USM Engineering Nibong Tebal campus in Penang. Both EFB and Pome were taken from the factory's fresh stock. The purpose of this study was to optimise the following parameters which are pH, moisture content, volatile solids, phosphorus and potassium, carbon to nitrogen ratio, electric conductivity, and lignin, cellulose, and hemicellulose. The method of composting used in this study is passive aeration composting. Finally, this composting laboratory was conducted in 500ml conical flasks for 5 weeks.

1.5 IMPORTANT OF RESEARCH PROJECT

Composting has a number of advantages, including the fact that it is economically viable, reduces greenhouse gas emissions, it contributes to source reduction by reintroducing treated organic wastes into their process (Nur and Naher, 2017). Composting contributes to environmental sustainability by binding soil particles together and preventing erosion. It aids in waste management and recycling, aids in bioremediation of polluted soil, increases soil biodiversity by attracting insect pests, organisms, bacteria, and other microbes to the crop, and they are allowed to treat in a controlled environment where they do not persist indefinitely (Ayilara et al., 2020). EFB aid in erosion prevention and soil moisture retention (Suhaimi and Ong, 2010). Apart from being nutrient-dense, oil palm EFB improve the bodily and chemical characteristics of the soil as a mulch such as they add organic matter to the soil content, improve soil structure, and so on (Hassan and Abd-Aziz, 2012).

The composting of EFB with zeolite can thus reduce the composting rate. Zeolite can lower adverse effects of loss of N, high mobility of HM, emission of GHGs, enrich antibiotic-resistant people and improve compost quality (Soudejani et al., 2019). Zeolite additives can help composting EFB processes emit less greenhouse gases and ammonia (Soudejani et al., 2019)

1.6 AN GENERAL SUMMARY OF EACH CHAPTER OF THE RESEARCH

Chapter 1: This chapter will provide an overview of the study background about composting, the aims to be accomplished, the study's scope and crucial of this research.

Chapter 2: A review of the literature was conducted on the composting of EFB with the addition of POME and natural zeolite to enhance the composting characteristics of EFB. The elements influencing the composting, compost consistency and the application of compost are reviewed. This section will discuss the history of EFB, POME, and natural zeolite, as well as their function.

Chapter 3: This chapter contains two part which are about preparation of materials and samples such EFB, POME and zeolite for composting study and The following part will cover the techniques for co-composting investigations on a laboratory scale and the methodology, the methods for performing physical and chemical tests on the sample, and the techniques for estimating the EFB lignocellulose during the process.

Chapter 4: Analyzation with the proper explanation of the outcomes achieved by the experiments. This chapter consists of two parts. Part one assesses physical changes in the colour following samples. Then the next part discusses about the effect of two controlled temperatures on all parameters.

Chapter 5: This chapter will be the place where the findings in this study will be summarised. At the end of this chapter, the recommendations are stated for another works to improve the quality of composting in the future research study.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss about the literature reviews on composting that involve EFB, POME and zeolite as main materials in this research study. There will be discussion of the influence factors on the composting process, compost quality and application. In this part the background info on EFB, POME and zeolite will be reviewed.

2.1 OIL PALM INDUSTRIAL WASTES

Malaysia has plenty of nature, a good atmosphere in which crops such as oil palm are commercially grown. A total of 4,487,957 hectares of oil palm plantations were found in Malaysia in 2008 (Ibrahim, 2021). Currently, Malaysia's oil palm farms cover more than 3 million hectares (Alkarimiah and Rahman, 2014). Malaysia's palm oil board states that an average of 53 million tonnes, with a 5 percent yearly prediction for growth, is produced in Malaysia by palm oil biomass residues per year. In 2010, the solid waste of palm oil biomass amounted to 80 million tonnes, with considerable increases to 100 million tonnes in dry biomass by 2020 (Umar et al., 2013).

Oil palm trash, like oil palms, is generally a good source of biomaterials, such as bunches of oil pavement, palm oil, oil and palm oil ash. In field and palm oil mills, the oil palm business has generated several waste biomasses from palm oil. Mill trash consists of pressed fruity fibres (PFF), empty fruit bundles (EFB), oil palm shells (OPS), palm oil mill waste (POME), and the other debris from planting includes oil palm trunks (OPT) and palm oil shrubs (OPF) (Panel and In, 2021b).

Empty Fruit Bunches (EFB) and Palm Oil Mill Effluents (POME) are two significant waste streams generated during the palm oil extraction process. (Alkarimiah and Rahman, 2014). Out of a total of 100% FFB, 22% is EFB, the second largest product after sterilisation and stripping, and 67% is POME (Nasidi et al., 2018). The researchers' primary objectives are to bio convert this biomass (EFB and POME) into valuable products and to commercialise them (Alkarimiah and Rahman, 2014). Figure 2.1 shows the types of oil palm biomass in Malaysia.

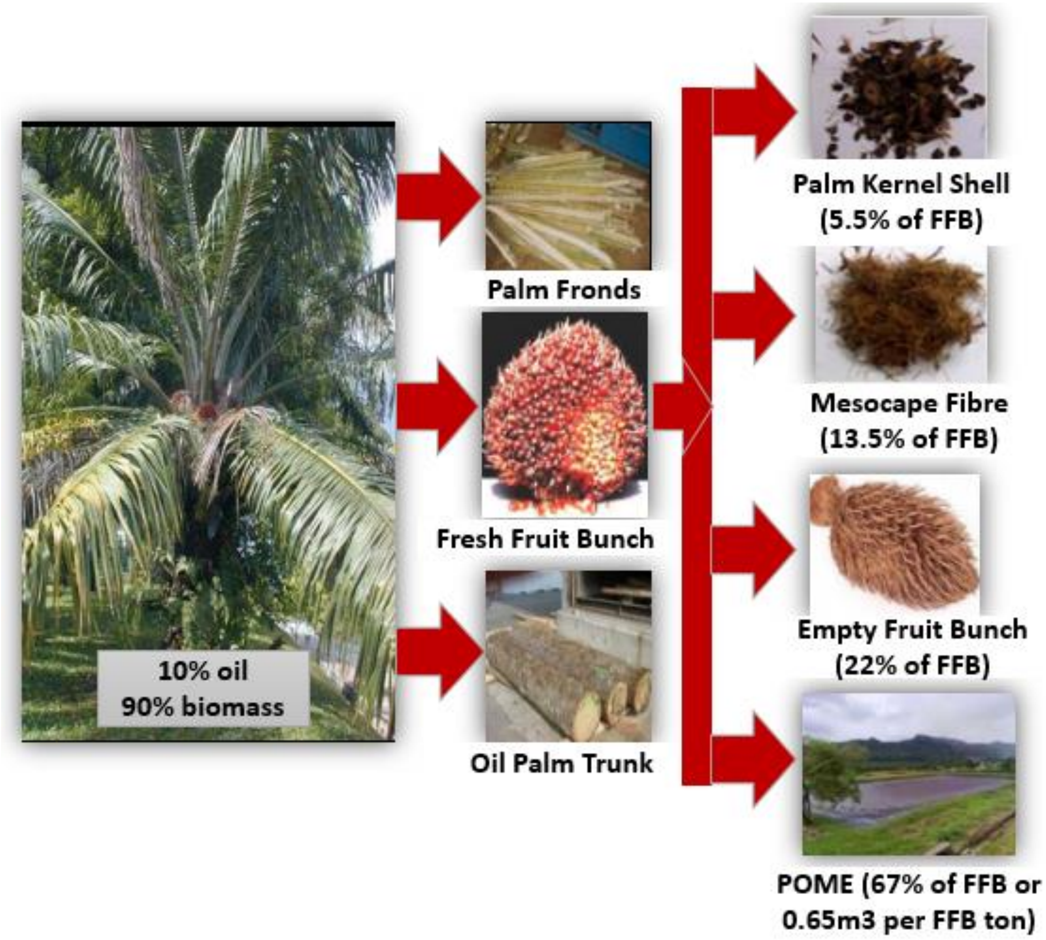

Figure 1: Types of Oil Palm Biomass (Archives and Oil, 2021)

2.2 INTRODUCTION OF COMPOSTING PROCESS

Composting is a biochemical process in a controlled aerobic environment, when thermophilic microorganisms stabilise organic wastes in valuable products that look like humus (Nur and Naher, 2017). The composting process takes place by a diverse population of mainly aerobic micro-organisms which break down organic material to grow and reproduce (Graves, 2000). Composting is widely recognised as an efficient way of converting agricultural waste into useful organic products (Wu et al., 2020).

Composting is considered to be one of the most widely used environment-friendly and economical practises for Organic Solid Waste (OSW) management, which can stabilise organic matters (OMs) and nutrients as organic fertilisers and soil conditioners (Soudejani et al., 2019). Composting is an aerobic thermophilic process that requires oxygen to stabilise organic waste and optimised humidity content (MC) for the development of micro-organisms (Ibrahim, 2021). The composting process involves three stages which are high composting, stabilisation and maturation to degrade organic waste, destruct pathogenic micro-organisms and build stabilised materials (Nur and Naher, 2017).

Throughout the composting process temperatures vary as a reaction to the microbial activities and can be divided into four separate phases, which are mesophilic, thermophilic, cooling and maturation.(Fruit et al., 2016). The initial compost age phase is characterised by psychrophilic or mesophilic temperatures, which depend on the ambient temperature and composted material temperatures (Graves, 2000). The volume of the mixture can be reduced by 40% to 50% via successful pathogen destruction through metabolic heat in the thermophile process, decomposition of a large number of hazardous organic pollutants, and the production of a final product suitable for soil modification or fertilisation (Singh, 2010). A temperature of 40-55℃ during the composting process is most desirable to improve microbial activity and reduce nitrogen loss (Fruit et al., 2016).

The rate of decomposition is determined by the following factors: temperature, pH, moisture content, and carbon nitrogen ratio (Quazi, 2020). With the goal of speeding up the composting process and improving the finished compost's quality, numerous adjustments have been made to the process (Ibrahim, 2021).

2.2.1 AEROBIC COMPOSTING

Aerobic composting is the most frequently used waste disposal method owing to its flexibility, efficiency, and the diffusion of air from waste (Quazi, 2020). The mixture was rich in moisture during the first stage, so a bulk agent was added in order to prevent anaerobic conditions and provide aerobic conditions (Waqas et al., 2019). Due to its high porosity, the high water retention capacity of zeolite allowed excess moisture to be collected and the favourable aerobic process for quicker oxygen uptake of the degrading microbes (Waqas et al., 2019). Reported that zeolite can be used for anaerobic digestion as an efficient way of increasing the production of CH_4 through the removal of potassium inhibition and NH_3 inhibition in pig compost age (Soudejani et al., 2019). The decomposition is promoted through adequate aeration in the aerobic composting process, and a minimum oxygen concentration of 5% is essential for aerobic decomposition (Fruit et al., 2016).

2.2.2 PASSIVE AERATION

Passive aeration can reduce energy costs while providing the same level of efficiency as forced or active aeration in composting (Barrington et al., 2021). Aeration is a vital component of composting; it contributes oxygen to aerobic biochemical processes and eliminates heat, moisture, carbon dioxide, and other decomposition materials (Access et al., 2021). Aeration assists in destroying anaerobic regions within the pile, accelerates the composting process, and ensures that mature compost contains a sufficient amount of nitrogen. However, if the rate of aeration is too high, energy transfer increases, resulting in a temperature decrease (Fruit et al., 2016). Treatments with passive aeration resulted in temperatures exceeding 57℃ (Barrington et al., 2021).

2.3 FACTORS EFFECT OF COMPOSTING PROCESS

This sub-topic briefly discusses about the factors affect the composting process. The speed at which it decomposes depends on these factors temperature, pH, moisture content, and carbon nitrogen ratio (C/N) (Quazi, 2020). This following sub-chapter discuss about the effect of pH, moisture content, electric conductivity, volatile solid, phosphorus, C/N ratio and lignocellulose in composting EFB with pome and zeolite. It will briefly discuss about the standard and optimum value for these parameters in composting process.

2.3.1 THE EFFECT OF pH

pH is primarily used in composting to monitor the decomposition process (noor mohammad, 2012). Initially, most of pH of the compost was 5.71. The pH remained relatively constant throughout the composting process, hovering around 5-6 (Kabbashi et al., 2007). The pH initially decreased due to the formation of organic acids, but gradually increased to alkaline levels due to bio-oxidation of composting materials, ammonia (NH_3) formation, and acid consumption (Waqas et al., 2019). Due to the high pH of the majority of manure-based compost, they are incompatible with acid-loving plants (Sullivan et al., 2018).

pH is critical for microbe nutrition, heavy metal solubility, and, more broadly, microbial metabolism. The pH of the solution should be between 6 and 9. The process's low pH causes corrosion, odour, and sluggish decomposition, resulting in wasteful use of the facilities, poor compost quality, and difficulty reaching temperatures high enough for adequate sanitization (Zaha et al., 2013).

Microorganisms grow at pH levels of 5.5 to 8. Organic acids are formed during the initial stages of decomposition. Acidic conditions favour fungal development and lignin and cellulose breakdown. Composting reduces the organic acids in the soil, and mature compost normally has a pH of between 6 and 8. Then, the alkaline conditions strengthen the role of the composting material because they may prevent pathogens, such as fungi, from surviving at low pH (Irvan and Muhammad Rahman, 2019).

2.3.2 THE EFFECT OF MOISTURE CONTENT

The initial moisture content concentration is strongly dependent on the physicochemical and biological properties of the composting material (Li et al., 2021). The moisture content of compost is a critical factor that influences its characteristics. (noor mohammad, 2012). The feed mixture's moisture content was kept between 75 and 80 percent by watering twice a week and maintaining a pH of 6 – 8 (Hayawin et al., 2014). The greater the moisture content, the less organic matters there is per tonne of compost (Sullivan et al., 2018).

The optimal moisture content of the starting material varies according to the physical state and size of the particles, as well as the composting system used. Generally, a moisture content of 60% is considered satisfactory (Kulkarni et al., 2021). To ensure that microbial life is favoured, the moisture content of a compost must be kept between 40% and 60%. With a moisture level of above 80%, death is caused by a lack of oxygen for aerobic bacteria (Irvan and Muhammad Rahman, 2019).

2.3.3 THE EFFECT OF VOLATILE SOLID

Volatile Solid (VS) parameters are used to investigate the kinetics of compost material changes (Alkarimiah and Suja, 2020). The content of volatile solids decreased with composting time for all treatments due to the loss of organic matter through microbial degradation (Wong et al., 2001). The level of organic material in a sample is measured using the metric Volatile Solids (Waqas et al., 2019). All treatments caused the total volatile solids content to decrease, resulting in an overall organic matter loss through microbial decomposition (Wong et al., 2001).

When composting results in a decrease in volatile solids, it is directly related to increased microbial activity (Waqas et al., 2019), because microbial activity is influenced by temperature. In an increase in temperature, microbial activity is more quickly initiated, which helps accelerate the breakdown of organic matter. Basically. the reduced organic matter decomposition in samples was correlated with a lower pH and a higher MC, which resulted in anaerobic conditions conducive to poor composting.

2.3.4 THE EFFECT OF PHOSPHORUS

Composting also contain important macro and micronutrients for plant nutrition, such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), and boron (B) (Sullivan et al., 2018). Market wastes consume variety of nutrients, including nitrogen, phosphorus, and potassium, which aid in the growth of various plants (Kulkarni et al., 2021). According to studies analysing the chemical parameters of compost made from organic waste, the phosphorus content of matured compost should be between 0.3 and 3.5 percent (Kulkarni et al., 2021).

2.3.5 THE EFFECT OF C/N RATIO

C/N ratio is a very important parameter of compost maturity and stability (Zaha et al., 2013). The carbon-to-nitrogen ratio is widely regarded as a critical factor affecting the composting process and compost quality. The compost C/N ratio is an imprecise indicator of compost maturated and is used to determine the compost's N fertiliser replacement value (Sullivan et al., 2018). Nowadays, researchers are most concerned with reducing the composting period and achieving a low C/N ratio in the compost product (Alkarimiah and Rahman, 2014).

When carbon is present in excess of nitrogen and the C/N ratio exceeds the optimal range, the composting process is slowed. Nitrogen availability is the limiting factor in this case (Graves, 2000). Composting that contain a high proportion of manure or green plant material, regardless of whether they are fully composted or not, will have a low C/N ratio (Sullivan et al., 2018). Due to the lengthening of the composting process, the C/N ratio decreased (Nassereldeen Ahmed Kabbashi, 2013). Table 2.1 show the literatures reviews on C/N ratio done by others studies.

Table 2.1: Literatures reviews on C/N ratio

Compost mixtures	Authors	C/N ratio
Empty fruit bunches (EFB) mixed with activated liquid organic fertilizer (ALOF)	(Trisakti et al., 2018)	C-N ratio for each EFB pieces size variation is below 20, it means the compost is already mature and appropriate with the quality of the standard of CN ratio of compost mature in the range of 10-20.
Composting of EFB and POME Using a Step-Feeding Strategy in a Rotary Drum Reactor	(Alkarimiah and Suja, 2020)	Studies reveal that the ideal C/N ratio for composting is 20-25 and 25-30. However, a C/N ratio of 10-15 is commonly accepted as a figure indicating the development of humic acid and increased stability of a compost. C/N ratio is high because the high carbon content of EFB fibre increases the C/N ratio in compost. The C/N ratio drops rapidly as it is utilised by microbes as a primary energy source. Increased temperature resulted in decreased C consumption due to the annihilation of certain bacteria. Increased nitrogen content may be a result of mineralization and active microbial cellulolytic destruction of complex molecules, which releases N and other ions into the compost and their subsequent reduction owing to nitrogen loss to the environment in the form of ammonia.
Production of compost from non-shredded empty fruit bunches mixed with activated liquid organic fertilizer (ALOF) in tower composter	(Irvan and Muhammad Rahman, 2019)	The C/N ratio remained reasonably steady at 19–20 from day 20 to day 40. The C/N ratio was 19.94 at the end of the composting process, suggesting that the compost matured after 10 days, as the C/N ratio of a normal matured compost is between 10 and 20. The C/N ratio decreased as the C content decreased or the N content increased during composting. This occurrence occurred as a result of organic matter decomposing during microbial activity.
Mixed Composting of Palm Oil Empty Fruit Bunch (EFB) and Palm Oil Mill Effluent (POME) with Various Organics	(Hau et al., 2020)	The fact that EFB had the greatest final C/N ratio indicates that it decomposes slowly, owing to the significant amount of lignocellulose material present, which is difficult to decay naturally. According to certain studies, a C/N ratio less than 20 indicates that composts have matured. Further research revealed that

		a fall in the C/N ratio below 20 demonstrated an advanced degree of organic stability, indicating a compost's maturity.
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2.3.6 EFFECT OF ELECTRIC CONDUCTIVITY

Electric conductivity was used to determine the concentration of total ions and the changes in inorganic ion levels during the composting process. Increased EC values indicated an excess of soluble salts, which were considered to be detrimental to plant growth and development (Waqas et al., 2019). On the other hand, because the majority of soluble salts are also soluble nutrients, compost with a high salt content may be an excellent source of nutrients when applied at a low rate (Sullivan et al., 2018).

Electrical conductivity (EC) is related to the release of easily decomposable compounds into solution and determines whether the total soluble ions in composts jeopardise the quality of compost used as fertiliser. According to the others literature, electrical conductivity values between 2.0 and 3.5 µS/cm are excellent for compost use in agriculture (Zaha et al., 2013). Table 2.2 shows the research about electric conductivity by previous studies.

Table 2.2: Literature reviews on electric conductivity by previous studies

Compost Mixtures	Authors	Electric Conductivity
Production of compost from non-shredded empty fruit bunches mixed with activated liquid organic fertilizer (ALOF) in tower composter	(Irvan and Muhammad Rahman, 2019)	Composting reduces the EC directly as a result of the rising concentrations of nutrients such as nitrate and nitrite. The increase in EC could be a result of the release of mineral salts such as ammonium and phosphate ions during the decomposition of organic matter.
Effective composting of empty fruit bunches using potential Trichoderma strains	(Nur and Naher, 2017)	Soil electrical conductivity is a critical indicator of soil properties that affect crop productivity and nutrient availability in plants, such as soil texture, cation exchange capacity (CEC), organic matter content, salinity, subsoil characteristics, and the activity of soil microorganisms that influence key soil processes. The EC value can be used to determine the presence of ions or salt compounds such as nitrates, potassium, sodium, chloride, sulphate, and ammonia. Calculating the EC of soil can assist in calculating the quantity of available nitrogen (N) for plants.
Potential of zeolites in optimization of food waste composting	(Waqas et al., 2019)	High EC values indicated an overabundance of soluble salts, which were thought to be harmful to plant growth and development. Due to the decomposition of complex OM, the concentration of soluble salts rose during the composting process. The value of EC was significantly less than the value of a normal addition, and their concentrations were significantly different due to the reduced degradation. The other cause for the lower EC is a lack of cation species to buffer the soluble anionic species produced in the aqueous phase.
Reducing nitrogen loss and salinity during 'struvite' food waste composting by zeolite amendment	(Chan et al., 2016)	Compost with a high EC content produces an excess of soluble salts, which has a harmful influence on plant growth and output. Composting always results in an increase in the concentration of soluble salts due to the decomposition of complex organic matter. After eight weeks, the EC gradually climbed to about owing to the modest deterioration. The addition of zeolite dramatically decreased the EC of the composting mass, which was directly proportional to the rate of zeolite amendment. Due to the molecular sieve structure and high cation exchange capacity, it may accommodate and allow the interchange of ions

		easily on its surface and adsorb the ions of zeolite, resulting in a fall in the EC.

2.3.7 EFFECT OF LIGNIN, CELLULOSE AND HEMICELLULOSE

Lignocellulose biomass is made up of cellulose, hemicellulose, and lignin. It accounts for more than 60% of all plant biomass generated on the planet. The samples' cellulose, hemicellulose, lignin, and ash contents were assessed using the techniques for neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) (Soplah et al., 2009). The decomposition of cellulose, hemicellulose, and lignin is critical to the effectiveness of the composting process (noor mohammad, 2012). Lignocellulose is the primary structural component of woody plants like grass and is a significant source of renewable organic matter (Kabbashi et al., 2010). Following lignin degradation, cellulose and hemicellulose could be efficiently degraded (Fruit et al., 2016). Table 2.3 shows composition of palm oil mill biomass and table 2.4 shows the literature reviews about of lignin, cellulose and hemicellulose previous studies.

Table 2.3: Enzymes content in palm oil biomass (Halid et al., 2019) (Baharuddin et al., 2011)

Types of biomass	Cellulose (%)	Hemicellulose (%)	Lignin (%)
EFB	38.3	35.3	22.1
POME	36	21.5	28

Table 2.4: Literature reviews about of lignin, cellulose and hemicellulose previous studies

Topics	Authors	Enzymes
Evaluation of cellulose content by infrared spectroscopy	(Jóvér et al., 2017)	Cellulose is one of the most abundant organic chemical compounds on the planet and is used as a raw material in a variety of industries. Cellulose is a fundamental component of the cell wall that coexists with hemicelluloses and lignin, complicating the determination procedure.
Lignin from oil palm empty fruit bunches (EFB) under subcritical phenol conditions as a precursor for carbon fibre production	(Karunakaran et al., 2020)	EFB also has a significantly higher amount of lignin than other forms of oil palm biomass. The carbon content of the recovered lignin is another critical condition for considering it as a precursor for the manufacture of carbon fibres. Lignin's ash content is composed of salt, potassium, calcium, aluminium, magnesium, and silicone. For all reaction periods, the ash content increased with temperature. The rise in ash concentration with increasing temperature is due to the ash's increased condensation rate with the intermediates formed during lignin degradation in subcritical phenol conditions.

2.4 COMPOSTING EFB AND POME

EFB is generated when the fruits are removed from the FFB (Anyaoha et al., 2018). EFB is frequently high in moisture, which reduces the combustion temperature and thus the energy efficiency (Han and Kim, 2020). EFB is produced at palm oil mills and has a very high moisture content of up to 60% and has a very low bulk density in comparison to others, which makes transportation difficult (Anyaoha et al., 2018). The solid leftovers, primarily EFB, account for more than 20% of the weight of the fresh fruit. EFB is a frequently used raw ingredient in composting. Other ingredients, most notably chicken manure and POME, are frequently added (Singh, 2010). Table 2.5 shows characteristics of empty fruit bunch (EFB) parameter carried by (Irvan and Muhammad Rahman, 2019).

Table 2.5: Characteristics of empty fruit bunch (EFB) Parameter (Irvan and Muhammad Rahman, 2018)

Parameter	Empty Fruit Bunches (EFB)
pH	7.8
Water Holding Capacity (%)	62
Moisture content (%)	43.83
C/N Ratio	33.48
Nitrogen (%)	0.99
Carbon (%)	33.15

Palm oil mill effluent, or POME, is without a doubt the largest waste stream generated during the oil extraction process (Kabbashi et al., 2007). It is estimated that the mill discharges 0.5–0.75 tonnes of POME to each tonne of palm oil FFB (Hassan and Abd-Aziz, 2012). The extraction of crude palm oil is a mechanical process in which the fresh fruit bunches are sterilised, digested, and the oil is extracted. However, all of these processes generate palm oil mill effluent (POME), which has a negative impact on the environment (Kabbashi et al., 2007). POME is composed of cellulose, fat, oil, and grease. Exposing an untreated wastewater stream to the environment can result in significant difficulties (Ibrahim, 2021).

In 2004, Malaysia produced over 699 million tonnes of POME through 372 mills (Hassan and Abd-Aziz, 2012). Around 2.5 tonnes of POME are generated for every tonne of crude palm oil extracted through milling (Sulaiman et al., 2009). In year 2005, 66.8 million tonnes of POME were generated (Ibrahim, 2021). Moreover, in the year 2009 there were around 80 million tonnes of palm oil and 57.4 tonnes of palm oil mill effluent (POME) (Alkarimiah and Rahman, 2014).

Additionally, palm oil mill effluent has an unpleasant odour and can contribute to odour pollution (Hassan and Abd-Aziz, 2012). It is colloidal, containing 95%–96% water, 0.6–0.7% oil and 4–5% solid, including 2–4% solid suspended. The pH content of Raw POME is low. If discharged directly into the waterways, it can have adverse environmental effects (Hassan and Abd-Aziz, 2012). Table 2.6 shows the characteristics of palm oil mill effluent (POME) done by Baharuddin et al., (2010).

Table 2.6: Characteristics of palm oil mill effluent (POME) (Baharuddin et al., 2010)

Parameter	Palm Oil Mill Effluent (POME)
pH	4.33 ± 0.3
Moisture content (%)	98.21 ± 0.2
C (%)	36.36 ± 3.8
N (%)	2.71 ± 0.9
C/N (%)	13.4
Oil and grease (mg/L)	2151 ± 50.1
COD (mg/L)	11391
Cellulose (%)	38.36 ± 5
Hemicellulose (%)	23.21 ± 2.9
Lignin (%)	26.72 ± 3. 4

Aktif, (2019) performed a study in which empty fruit bunches (EFBs) were composted in a tower composter using activated liquid organic fertiliser (ALOF). The purpose of his study was to investigate the composting of EFB in a tower composter and to describe the degradation of non-shredded EFB combined with ALOF. On the basis of the average temperature of the composting material, two states of microbial growth were observed during composting: thermophilic state (1st to 15th) and mesophilic state (day 16 to day 40). Composting non-shredded EFB in a box-shaped tower composter with ALOF as a microbial and nutrient source and moisture content buffer could produce mature compost in ten days.

Composting of EFB and POME was carried out by Alkarimiah and Suja, (2020). Analysing the influence of active aeration and mixing ratio on composting performance using a step-feeding strategy in a Rotary Drum Reactor. Within a 2 to 3 weeks composting period, organic waste can be successfully digested in a rotational drum composter. Continuous aeration is ineffectual at creating a thermophilic environment inside the drum. Additionally, the mixed mixture of fresh EFB, recycled compost, and POME sludge is critical for achieving the optimal C/N ratio during composting. As a result, a variety of organic matter plays a critical role in achieving an optimal composting process temperature. By maintaining a thermophilic temperature for an extended period of time, pathogens and parasites in the compost product can be eliminated.

Nur and Naher, (2017) experimented with culturing isolated strains of Trichoderma in decomposing fruit bunches in a composting setting. Using two prospective Trichoderma strains, this research examined the composting of empty fruit bunches (EFB) from the oil palm industry. Initially, pH analysis revealed that the soils were slightly acidic. However, after composting, it was discovered that the soils were alkaline. The benefit of this study is that waste materials can be converted into a profitable by product in a short amount of time. Composting the EFB took only 30 days.

The resulting compost is a good source of micronutrients (N, P, and K) and increases the acidity and conductivity of the soil.

Hau et al., (2020) carried out the mixed composting of palm oil empty fruit bunch (EFB) and palm oil mill effluent (POME) with various organics as additives to achieve specific initial C/N values. The purpose of this study is to determine the final macronutrient composition and physical features of EFB and POME. By composting all of the organic wastes with worm composting, the decomposition rate was much improved while at the same time, the compost had higher nutrient quality than standard composting. EFB mixed composts need around 40 days to reach maturity.

Lim et al., (2015) carried out experiments on composting to determine the effects of microbial additive on the physiochemical and biological properties of oil palm empty fruit bunches compost (EFB). The physical, chemical, and biological aspects of compost were examined during the composting process. Significantly, microbial inoculated compost lowered total organic carbon and the carbon-to-nitrogen ratio during composting, while increasing pH and microbial population. The pH of compost grew to 5 during the first week of composting and then steadily increased to roughly 8 at the end of the procedure. The results suggested that organic acids were degraded during composting. Compost can achieve temperatures of up to 50-55°C during the thermophilic phase. Compost seeded with bacteria boosted the total microbial population, particularly actinomycetes and total bacteria, towards the conclusion of composting. Compost injected with microbial organisms was expected to accelerate the composting process of oil palm EFB from 64 to 50 days.

Trisakti et al., (2018) was carried out the field study about effect of pieces size of Empty Fruit Bunches (EFB) on composting of EFB mixed with activated liquid organic fertilizer. The sizes of the EFB pieces were varied into <1, 1-3, 4-7, 8-11, and 12-15 cm. The parameters analysed during the composting were temperature, pH, MC, compost weight, water holding capacity (WHC), CN ratio, and the quality of the final compost. Activated liquid organic fertiliser (ALOF) was mixed with oil palm empty fruit bunches (EFB) for 40 days and the best result obtained was between 1 - 3 cm for fruit pieces of this size. Smaller particle size will cause the surface area of the particle to be large, so the decomposition process becomes faster. Table 2.7 shows the literature review done for composting EFB and POME by other studies.

Table 2.7: Summary of the results available in the literature concerned with composting of EFB and POME

Substrate	Parameter	Conclusion	References
Production of compost from non-shredded empty fruit bunches mixed with activated liquid organic fertilizer in tower composter	Temperature, pH, CN ratio, moisture content, electric conductivity carbon, and nitrogen	Composting was completed in 40 days, even though EFB turned to dark brown on day 10, indicating that the compost was mature. ALOF addition to EFB may enrich composts with high nutrient and microbial sources.	(Aktif, 2019)
Composting EFB and POME by Step-feeding strategy in a rotary drum reactor	C/N ratio, total organic carbon (TOC), carbon, nitrogen, temperature and moisture content	It is concluded that run with higher amount of recycle compost used is the best mixture without active aeration since thermophilic temperatures have been achieved and thermophilic temperature maintained within 20 days.	(Alkarimiah and Suja, 2020)
Composting EFB and strains of Trichoderma	Temperature, pH, CN ratio, moisture content, electric conductivity carbon, nitrogen, and potassium	The result of this research is that waste materials can be turned into a useful commodity in a short time. It took only 30 days to compost the EFB. The resulting compost is a strong source of micronutrients and increases soil acidity and conductivity.	(Nur and Naher, 2017)