BIOCHAR AMENDMENT ON PALM OIL BIOMASS: EFFECT ON PHYSICOCHEMICAL PROPERTIES AND FIBRE DEGRADATION

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By

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ABSTRAK

Tandan buah kosong mempunyai struktur kompleks yang sukar dipecahkan semasa proses kompos kerana kandungan lignoselulosa yang tinggi yang terdiri daripada Hemiselulosa, Selulosa, dan Lignin. Objektif kajian ini adalah untuk mengkaji kesan biochar dalam perubahan fizikokimia dalam kompos buah kosong (EFB) dan menentukan degradasi serat tandan buah seperti Lignin, Selulosa, dan Hemiselulosa selama proses pengkomposan. Sampel kompos terdiri daripada EFB sahaja, EFB dan POME dan EFB, POME dan Biochar. Campuran EFB: POME: Biochar disediakan dalam nisbah 10: 1: 5. Terdapat beberapa parameter yang perlu diukur yang terdiri daripada pH, kekonduksian elektrik (EC), kandungan kelembapan, pepejal mudah meruap (VS), nisbah Karbon dan Nitrogen (C/N), jumlah Fosforus dan serat untuk memerhatikan tingkah laku pengkomposan buah kosong. Parameter ini dikaji di makmal persekitaran yang lengkap dengan pH meter, YSI meter untuk kekonduksian elektrik, oven makmal dan Furnace 550 °C. Hasil keseluruhan untuk keadaan pengkomposan EFB, EFB POME dan EFB POME Biochar menunjukkan hasil yang hampir sama dalam bentuk nisbah pH, pepejal tidak stabil, kandungan lembapan, nisbah fosforus dan C/N. Kekonduksian elektrik dan gentian menunjukkan profil yang berbeza kerana ciri kompos yang berbeza dengan biochar dan tanpa biochar. Lebih-lebih lagi, kadar kompos dengan kehadiran biochar menghasilkan kompos yang lebih cepat kerana adanya ciri-ciri seperti keliangan yang besar, luas permukaan yang besar dan memangkin pertumbuhan mikrob yang meningkatkan aktiviti mikrob. Kehadiran biochar dalam proses pengkomposan dapat menghasilkan kompos yang berkesan dan mengurangkan masa yang diperlukan untuk menstabilkan produk EFB semasa proses pengkomposan.

ABSTRACT

Empty fruit bunch has a complex structure that difficult to break during the composting process due to the high lignocellulose content that consists of hemicellulose, cellulose, and lignin. The objective of this study was to examine the effect of biochar in physicochemical changes in empty fruit bunch (EFB) composting and determine the degradation of Lignin, Cellulose, and Hemicellulose of empty fruit bunch fibre during the composting process. The composting sample was consist of EFB only, EFB +POME and EFB+POME+Biochar.The mixture of EFB:POME: Biochar was prepared in the ratio of 10:1:5 respectively. There are several parameters that need to measure that consist of pH, electric conductivity (EC), moisture content, volatile solid (VS), Carbon and Nitrogen ratio (C/N), total Phosphorus and fibre to observe the behaviour of composting process of empty fruit bunch. This parameter was examined in an environmental laboratory that complete with pH meter, YSI meter for electric conductivity, laboratory oven and Furnance 550°C. The overall result for EFB, EFB +POME and EFB+POME+Biochar composting trend is quietly similar in pH, volatile solid, moisture content, total phosphorus and C/N ratio. Electric conductivity and fibre show different profiles due to the different characteristics of composting with biochar and without biochar. Moreover, the composting rate in presence of biochar produces rapid compost due to it characteristic such as large porosity, large surface area and favoring the microbial growth that increases the microbial activity. The presence of biochar in the composting process can produce effective compost and reduce the consuming time to stabilize the EFB product during composting process.

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LIST OF ABBREVIATIONS

ADL	Acid Detergent Fibre
ADL	Acid Detergent Lignin
C/N	Carbon/ Nitrogen
C	Carbon
EC	Electric Conductivity
EFB	Empty Fruit Bunch
MC	Moisture Content
MSW	Municipal Solid Waste
N	Nitrogen
NDF	Neutral Detergent Fibre
P	Phosphorus
POME	Palm Oil Mill Effluent
VS	Volatile Solid
TS	Total Solids
SS	Suspended Solids
COD	Chemical Oxygen Demand
DLS	Dynamic Light Scattering

CHAPTER 1

INTRODUCTION

1.1 Background Study

Currently, Malaysia is the one of the world's largest palm oil exporter. Malaysia have produce and export 25.8% and 34.3% the crude palm oil to support the palm oil demand around the world. The land use for palm oil agriculture production is about 4.49 million hectares of land area to planting the palm oil tree in Malaysia. The result of planting the palm tree in huge area can give a big amount of palm oil product that can reach 18 million tonnes of palm oil and 3 tonnes of palm kernel oil (MPOB 2020). The palm oil industry in Malaysia have achieve the successful in economical part because of the high demand from another country. However, there are some issues regarding to sustainability and environmental demand due to palm oil biomass that produce after crude oil extraction (Kushairi et al., 2018) .

The problem linked to the biomass that produced when the palm oil fruit or fresh fruit bunch (FFB) extracted to remove the oil from the palm oil fruit. This process will produce the palm oil biomass such as empty fruit bunch (EFB), mesocarp fibre, shell and palm oil mill effluent (Yazid et al., 2014). The increase of palm oil demand will affect to the excessive biomass production in Malaysia. This will give a big impact to the Malaysia environment to have the pollution and natural disaster due to the untreated biomass waste production. Therefore, proposing the treatment to reduce the biomass waste are needed to prevent the environment pollution occur in the future.

This study focusing on empty fruit bunch (EFB) biomass that provide many benefit to agriculture sector such as improve the soil nutrient by amendment on it. In changing the structure of empty fruit bunch into the stable structure, composting process are required because of the natural process are needed to produce the better product in specific condition. According to (Camps & Tomlinson, 2015), composting can be define as a treatment method for biodegradable waste for treatment purpose or disposal purpose. Moreover, the composting process is frequently used in agriculture because of its ability to convert poorly stabilised materials into well-stabilized products (Dias et al., 2010). However, every treatment have their deficiency that need to prevent and improve to achieve the true way in conducting the treatment process. Composting process have a high demand in time consuming due to the natural process by microbial as a catalyst in composting process. Composting also can affect the air quality due to the gaseous released such as ammonia gas (NH_3), methane (CH_4) and nitrous oxide (N_2O). Composting by adding the bulking agent is the answer for the time consuming and pollution problem. Biochar mostly use in agriculture industry for example in pollutant removal, carbon sequestration and soil amendment (Oliveira et al., 2017a). Biochar can be defined as a high carbon materials that produced by slow pyrolysis of biomass (Dias et al., 2010). Biochar have a high demand in composting process due to its favourable physicochemical properties (e.g. large porosity and surface area, high cation exchange capacity, enabling interaction with major nutrient cycles and favouring microbial growing in the composting pile) can provide an effective composting process by increasing the temperature in thermophilic phase to reduce the composting time and faster stabilization of the composting material (Sanchez-Monedero et al., 2018).

1.2 Problem Statement

Evaluating the mechanism of biochar in composting process is very important to gain the understanding of effect on physicochemical and fibre degradable on empty fruit bunch (EFB) composting process. The understanding will be produce the effective way to compose the degradation waste in perfect condition. However, there are limited amount of information on composting empty fruit bunch (EFB) with biochar (Dias et al., 2010). Empty fruit bunch known as a lignocellulose biomass that have a complicated structure (Zainudin et al., 2014). The proper compose need to conduct to break the complex structure of lignocellulose biomass by increasing the rate of microbial activity. Moreover, the primary challenge in composting process is the loss of nutrients and the emission of greenhouse gases (GHG) during the composting process especially the ammonia gas and nitrous oxide gas. Therefore, the aim of this work is use biochar as a bulking agent to examine the physico-chemical changes of empty fruit bunch (EFB) and determine the fibre degradation of EFB.

1.3 Objectives

The study was carried out to fulfill several objectives as below:

i. To examine the effect of biochar in physico-chemical changes in empty fruit bunch (EFB) composting.

ii. To determine the degradation of Lignin, Cellulose and Hemicellulose of empty fruit bunch fibre during composting process.

1.4 Scope of Work

i. The scope of work in this study is start with the determination of empty fruit bunch and biochar as a bulking agent characteristic by doing some research.

ii. After that, the mixture ratio of empty fruit bunch, biochar and sludge is very important to verify by refer to previous thesis to obtain the good result or product in composting process.

iii. Start the experiment by considering the control parameter which mean two sample need to examine. One sample is composting empty fruit bunch with sludge only and another sample is composting empty fruit bunch with biochar and sludge.

iv. Evaluate all parameter by doing the experiment in the laboratory.

1.5 Significance Study

Based on this study, the main purpose for conducting this project is to examine the effect of biochar in physico-chemical changes in empty fruit bunch (EFB) composting. This can create the complete understanding on biochar behaviour in composting process to upgrade the composting rate to produce the better product. Furthermore, the next purpose of this project it to determine the degradation of lignin, cellulose and hemicellulose of empty fruit bunch fibre during composting process. This is because lignin, cellulose and hemicellulose are mostly found in crude biomass such as palm oil biomass. Moreover, the understanding of degradation can lead to produce many benefit in manufacturing product such as lignin mostly use in carbon fibre production, hemicellulose use in ethanol production and cellulose is widely use in papermaking industry.

1.6 Dissertation Outline

The dissertation outline for this study is consist of five chapter that explain the overall of project progressing in term of report. Firstly, Chapter 1 is about the project introduction that consist of background of study, problem statement, objectives, scope of the study and significance of the study. After that, Chapter 2 is the discussion part on the previous study that related to our study to justify the important message for precaution or guideline to conduct the related project. Based on that, the literature review can be produced that contains the introduction of composting aerobic, factors affecting the composting process, the statistic of empty fruit bunch, and the application of compost product. Chapter 3 is the technical part that explains the illustration in preparing the composting sample until collecting the composting product. This stage also includes the procedure of laboratory experiment, material needed, and the list of laboratory apparatus. Furthermore, Chapter 4 is the data tabulation part that present the project result in table view, graph form and bar chart. Finally, Chapter 5 is the last part in this thesis that will conclude the overall comment for this project to provide the suggestion for the other project purpose.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Chapter 2 is the literature review part that gathering the information for composting empty fruit bunch as a preliminary study before conducting the real experiment for the final year project study. This chapter is about to review the previous paper from other researchers that conducting the related study in composting empty fruit bunch. The information can prepare the average value of standard reading for every parameter in composting empty fruit bunch (EFB). Moreover, the comparison of the examine data by the various researchers can be conducted in Chapter 4 easily by referring the summary of literature review in Chapter 2.

This chapter is very important to understand the behavior of empty fruit bunch (EFB) in composting process with various composting methods. Meanwhile, the clear understanding of related factors that affect the composting process also can be illustrated. Finally, various precaution steps can be generated from the previous study to avoid the same mistake while conducting the final year project experiment.

2.2 Palm oil mill industry in Malaysia

The palm oil mill business was initially brought to Malaya (now Malaysia) as a commercial facility in 1917 at the Tennamaram Estate in Selangor, laying the groundwork for the growth of Malaysia's oil palm sector. From a modest 55 000 hectares area in 1960 to 5.74 million hectares in 2016, the oil palm cultivated area had grown exponentially. Along with the development of land, the output of palm oil increased dramatically, from less than 100,000 tonnes in 1960 to over 17.32 million tonnes in 2016 (Nambiappan et al., 2018).

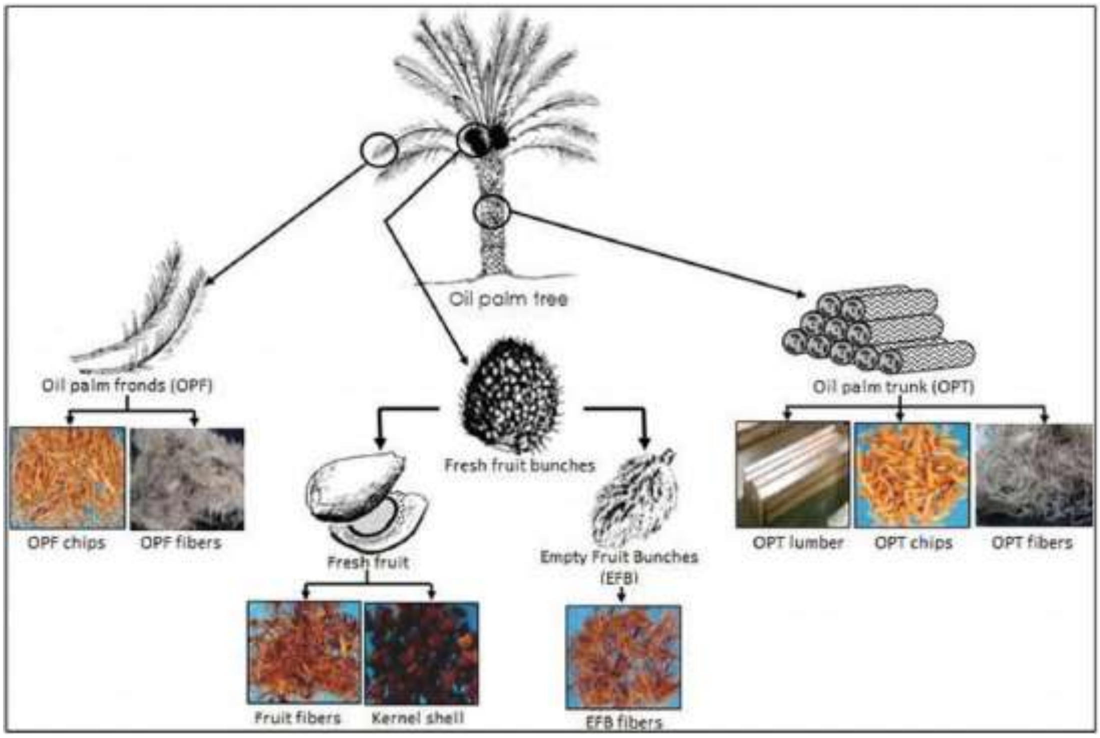

Figure 2.1: Palm oil biomass (Ramlee et al., 2021).

Figure 2.1 shows the palm oil biomass that produce after the extraction process of fresh fruit bunch (FFB) in generating oil palm. The oil palm tree (*Elaeis guineensis)* is a land-efficient agricultural oil crop that has increased worldwide output from 15.2 million tonnes in 1995 to 62.6 million tonnes in 2015 (Md. Tahir et al., 2019). Malaysia produces 39 percent of the world's palm oil and is one of the world's major exporters of palm oil. Malaysia and Indonesia are some of the biggest world's supplies of palm oil that produce 86% of palm oil production (Villela et al., 2014). Among all nations, Indonesia and Malaysia have been reported as the leading and second-biggest palm oil providers, exporting over 90% of their palm oil output, which accounts for around 80% of global palm oil.

In 2017, Malaysia alone produced 19.92 million tonnes of palm oil and exported 16.56 million tonnes of palm oil (Tan & Lim, 2019). In another word, Malaysia as a largest producer of palm oil have increase the production by time in supply the world demand in palm oil industry. This is because palm oil is one of the main source to supply the Malaysia country in economy sector. As a prove, Andiappan et al. (2018) have stated an estimation of RM 80 billion have produce in 2018 from palm oil industry that have increase the gross domestic product (GDP) in Malaysia at about 8.7%.

Moreover, there are about 4.49 million hectares of land use in Malaysia that serve for palm oil tree planting. This agriculture activity in a huge area can result in producing 18 million tonnes of palm oil for resident use and export to other country (MPOB 2020). In summary, the palm oil mill industry in Malaysia have growth follow the year to improving the production of palm oil in increasing the gross domestic product to support the Malaysia economy in the future. Table 2.1 shows the summary of Palm Oil Tree Plantation Status in Malaysia from the related previous study.

Table 2.1: Palm Oil Tree Plantation Status in Malaysia.

No.	Sources	Title	Summary
1	(Villela et al., 2014)	Status and prospects of oil palm in the Brazilian Amazon.	Malaysia and Indonesia is one of the biggest world's supply of palm oil that account 86% of palm oil production.
2	(Md. Tahir et al., 2019a)	Diversity and characterization of lignocellulolytic fungi isolated from oil palm empty fruit bunch, and identification of influencing factors of natural composting process.	Malaysia produces 39 percent of the world's palm oil and is one of the world's major exporters of palm oil.
3	(Tan & Lim, 2019)	Feasibility of palm oil mill effluent elimination towards sustainable Malaysian palm oil industry.	In 2017, Malaysia alone produced 19.92 million tonnes of palm oil and exported 16.56 million tonnes of palm oil.
4	(Andiappan et al., 2018)	Cooperative game theory analysis for implementing green technologies in Palm oil milling processes.	An estimation of RM 80 billion have produce in 2018 from palm oil industry that have increase

			the gross domestic product (GDP) in Malaysia at about 8.7%.
5	(Nambiappan et al., 2018)	Malaysia: 100 years of resilient palm oil economic performance.	The output of palm oil increased dramatically, from less than 100,000 tonnes in 1960 to over 17.32 million tonnes in 2016.

2.3 Empty Fruit Bunch Composting

According to Krishnan et al. (2017), composting is known as the mediated biological decomposition of organic substrates by successive microbial communities that combine mesophilic and thermophilic activities. Other than that, Camps and Tomlinson (2015) have stated that composting can be defined as a treatment method for biodegradable waste for treatment purposes or disposal purposes. In this study, composting of empty fruit bunch and palm oil mill effluent are the main issues that need to focus. Composting EFB, on the other hand, is a time-consuming method that makes it inefficient for commercial use. By incorporating qualified fungi into an ideal EFB composting method, the composting process can be sped up (Md. Tahir et al., 2019).

Composting of EFB and POME has piqued interest as a potential alternative use for these wastes. Because of the aforementioned environmental concerns, palm oil mills are more likely to market raw EFB and POME as low-cost fertiliser, which helps in effectively minimise the organic loading of these waste products on treatment facilities. Composting process are recommended because of the traditional ponding method for treating palm oil mill effluent (POME) not only contributes the most pollutants to the atmosphere, but it is also the least profitable system (Ravindra, 2015). The authors suggested that nutrients from POME and EFB can be used in the composting process (Ravindra, 2015).

According to Singh et al. (2010), composting is beneficial for trash recycling because it creates a chemically stable substance that may be utilised as a fertiliser source and to improve soil structure. The ultimate result is high in humus and plant nutrients, and the composting process produces carbon dioxide, water, and heat as by products (Singh et al., 2010). Moreover, composting also is one of the problem solution for reducing the palm oil biomass such as empty fruit bunch that can cause the environmental pollution due to high organic content. Therefore, the proper management in handling the palm oil waste is important to safe the environmental condition. In summary, Table 2.2 shows the composting behaviour in empty fruit bunch composting pocess.

Table 2.2: Summary of Empty Fruit Bunch Composting

No.	Sources	Title	Summary
1	(Krishnan et al., 2017)	Oil palm economic performance in Malaysia and R&D progress in 2017.	Composting is known as the mediated biological decomposition of organic substrates by successive microbial communities that combine mesophilic and thermophilic activities.
2	(Camps & Tomlinson, 2015)	The use of biochar in composting.	Composting can be defined as a treatment method for biodegradable waste for treatment purposes or disposal purposes.
3	(Md. Tahir et al., 2019)	Diversity and characterization of lignocellulolytic fungi isolated from oil palm empty fruit bunch, and identification of influencing factors of natural composting process.	Composting empty fruit bunch (EFB) is a time consuming method that can be sped up by incorporating qualified fungi.
4	(Ravindra, 2015)	Advance in bioprocess technology.	Composting process contribute many pollution to the atmosphere and one

			of the least profitable system.
5	(Singh et al., 2010)	Composting of waste from palm oil mill: A sustainable waste management practice.	Palm oil biomass is dangerous to the environment and need he proper management such as composting process to reduce the waste and pollution.

2.4 Composting with Biochar

Composting is a time-consuming method that required the suitable condition and composting sample (Md. Tahir et al., 2019). This is because the composting rate is depend on the composting material. Therefore, the introduced of bulking agent are very important due to their primary function as structural and drying amendment, providing structural support to prevent the physical compaction of the pile and increasing the air voids allowing the aeration of the pile (Dias et al., 2010). The focusing bulking agent for this study is biochar.

Biochar mostly use in agriculture industry for example in pollutant removal, carbon sequestration and soil amendment (Oliveira et al., 2017). Biochar can be defined as a high carbon materials that produced by slow pyrolysis of biomass (Dias et al., 2010). Recently, the agricultural sector practise the new method for composting to improves compost nutrient content by adding artificial N, P, and K components, which supports plant growth but produces an unfavourable soil condition and degrades the environment. As a result, there has been a lot of interest in improving the nutrient properties of empty fruit bunch compost by mixing it with different organic additives to help protect the environment (Hau et al., 2020).

Therefore, by adding the bulking agent such as biochar, the composting rate for empty fruit bunch composting can be upgrade for stable product. Reducing the nitrogen loss in composting process as well as the stable C/N ratio are present (Yu et al., 2019). In addition, biochar also have a high demand in composting process due to its favourable physicochemical properties that have large porosity and surface area, high cation exchange capacity, enabling interaction with major nutrient cycles and favouring microbial growing in the composting pile as shown in Figure 2.2. It can provide an effective composting process by increasing the temperature in thermophilic phase to reduce the composting time and faster stabilization of the composting material (Sanchez-Monedero et al., 2018).

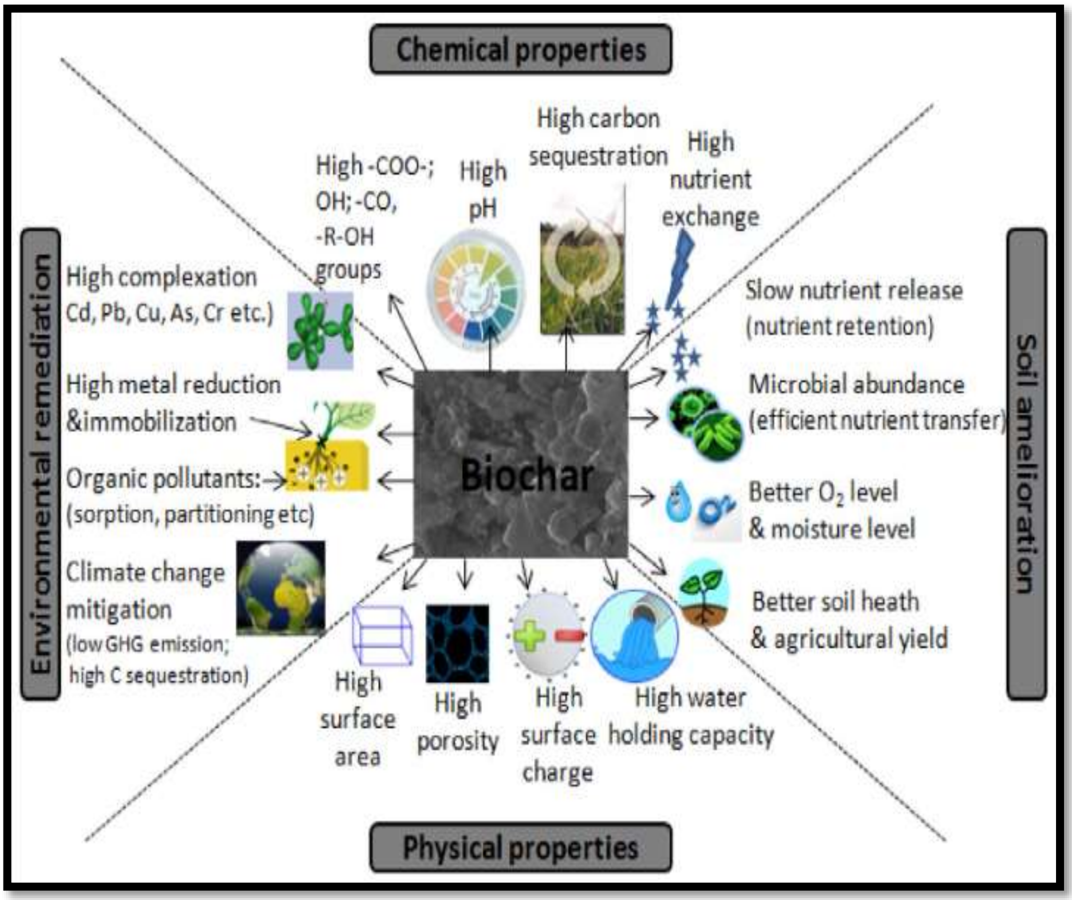

Figure 2.2: Biochar characteristic and suitability for specific applications(Oliveira et al., 2017b)

Table 2.3: Summary of Composting with Biochar.

No.	Sources	Title	Summary
1	(Dias et al., 2010)	Use of biochar as bulking agent for the composting of poultry manure: Effect on organic matter degradation and humification.	The presence of bulking agent can providing structural support to prevent the physical compaction of the pile and increasing the air voids allowing the aeration of the pile
2	(Oliveira et al., 2017a)	Environmental application of biochar: Current status and perspectives.	Biochar as a bulking agent in composting process can be the pollutant removal from soil, water and gas due to the biochar component that rich with commercial activated carbon.
3	(Hau et al., 2020)	Mixed Composting of Palm Oil Empty Fruit Bunch (EFB) and Palm Oil Mill Effluent (POME) with Various Organics: An Analysis on Final Macronutrient Content and Physical Properties	In helping to preserve the environment, there has been a lot of interest in enhancing the nutritional qualities of empty fruit bunch compost by combining it with various organic additions.
4	(Yu et al., 2019)	The changes in carbon, nitrogen components and humic substances during organic-inorganic aerobic co-composting.	The presence of biochar in composting process will catalyst the composting rate for empty fruit bunch (EFB) composting for the stable compost product.
5	(Sanchez-Monedero et al., 2018)	Role of biochar as an additive in organic waste composting.	Biochar is an excellent biological substrate for reducing the duration of the composting process and increasing the value of compost.

2.5 Factor that affects the composting of empty fruit bunch (EFB)

Composting process of empty fruit bunch (EFB) is the common activity in recycle or treat the palm oil biomass into the useful product. The composting process need to face the proper composting process or achieve the optimum composting rate to produce the high quality composting product in the stable form. This can ensure the accumulated nutrient can be produce in the stable composting process. Therefore, some factor that affects the composting process such as type of aeration, pH, electric conductivity (EC), Volatile Solid (VS), Moisture Content (MC), nutrient (Phosphorus), Carbon and Nitrogen (C/N) and fibre need to control and evaluate to understand the behavior of composting process.

2.5.1 Passive Aeration

Composting is about the controlling process to stabilize the unstable organic matter into the stable condition. One example of the controlling method is aeration, which ensures the growth of sufficient aerobic microbe populations and the development of stable temperatures (Barrington et al., 2003). Aeration is an essential and natural part of composting since it supplies oxygen for aerobic biochemical processes while still removing sunlight, excess moisture, carbon dioxide, and other decomposition materials (Shimizu 2017). Aeration is necessary to provide oxygen to composting piles for productive microbial activities and effective organic matter (OM) decomposition.

Aeration pipe orientations and perforations must be properly engineered to efficiently provide ventilation to the piles (Ogunwande & Osunade, 2011). In a simple word, passive aeration required the suitable model to supply enough oxygen for composting purpose. The controlled aeration from the early stage of experiment will resulted the larger heat losses, higher microbial activity, faster decomposition, and a faster rise in pH (Sundberg & Jönsson, 2008). In support the previous statement, (Sundberg & Jönsson, 2008) reported that larger heat losses, higher microbial growth, faster decomposition, and a faster rise in pH resulted from improved aeration concentrations at the start of the process. Aeration was improved, which resulted in a more robust finished product. Therefore, controlling aeration give a good impact on composting process and product.

2.5.2 pH

According to Ameen et al. (2016), when the conditions of a compost pile change from mesophilic to thermophilic, the pH becomes more alkaline. Microbial growth is inhibited by low pH, resulting in lower decomposition efficiency. Furthermore, they discovered that a decrease in microbial activity was associated with a low pH in the composting content and that a transition from mesophilic to thermophilic conditions occurred simultaneously with a pH shift from acidic to alkaline during the early stages of composting (Wang et al., 2017). This is because the release of organic acid and alkaline ammonium ions from the microbial ingestion of organic matter in the compost resulted in a fluctuating pH interval of high and low pH (Hau et al., 2020).

However, Md. Tahir et al. (2019a) have reported that the pH value will increase naturally in the 20^{th} week of natural composting. Previous research has also discovered that when microorganisms degraded substrates (such as POME, EFB, and soil), the pH of the degraded substrates increased (Siddiquee et al., 2017).

In additional, the composting requirements include keeping the pH of the compost pile is about 6 to 8 pH (Wang et al., 2017). According to Ameen et al. (2016), In the pH range of 7 to 8, the bacteria degrade the most. However Lai et al. (2014) have stated that, in preventing the delayed decomposition of organic matter, the pH value throughout the composting process should be maintained above pH 6.0. Therefore, the suitable range of pH value that need to control in composting is from 6 to 8 pH for a better composting rate.

2.5.3 Moisture Content

Ameen et al. (2016) reported that the moisture in compost sample will promotes microbe development by speeding up metabolism. When there is a lack of moisture, microbe activity is at a minimum. Moisture content influences both microbial activity and physical structure in the composting process, and thus has a major impact on organic material biodegradation. The optimum moisture content for composting has previously been stated to be between 50% and 70% (Alkarimiah & Suja, 2020). Furthermore, the temperature of the ambient air has a direct impact on the moisture content of empty fruit bunch (EFB). When the lignocellulose substance has achieved a water content balance with its atmosphere and is no longer receiving or losing moisture, it is said to have reached equilibrium moisture content (EMC) (Araújo et al., 2016).

Throughout the experimental phase, the steady decrease in moisture content and residual oil, as well as the increase in pH values in EFB samples, resulted in decreased fungal growth and diversity (Md. Tahir et al., 2019a). This also can be proved by Sundberg and Jönsson (2008) statement that pointed on the end product's dry matter composition was close to that determined after 8–9 days of composting, indicating that the majority of the drying took place during the first process. The aeration rates, and hence the drying rates, were lower in the later phases, and the drying was compensated by the water added. Therefore, evaluating the percentage of moisture content is important in composting process due to it effect to the microbial growth for accelerating the composting process.

2.5.4 Volatile Solid

According to Wong et al. (2001), due to the lack of organic matter due to microbial decay, the content of volatile solids decreased with composting time with all therapies. The increased organic matter loss suggested that aeration by turning aided organic decomposition in co-composting. But, if the composting sample are rich with fibre component, the volatile solid can increase in long term of composting (Wong et al., 2001).

Basically, the amount of volatile solid that degrade at the early stages are the highest (Wang et al., 2017). This is because the large amount of volatile solid that can be degrade by microbe in the first stage of composting process. These readily decomposable volatile solids were almost depleted in the middle and last stage of composting that leaving only more refractory components like hemicellulose and lignin. These findings showed that increasing the initial pH promotes the development and activity of microorganisms and, as a consequence, improves volatile solid decomposition.

2.5.5 Phosphorus

In general, phosphorus is essential for the synthesis of nucleic acids, nucleotides, co-enzymes, phospholipids, and phytic acids. According to Amira Dayana et al. (2011), phosphorus content is likewise greater for both composts as they mature, since phosphorus is not lost via volatilization or lixiviation throughout the composting process. Phosphorus content rises as composting progresses. Kala et al. (2009) have reported that, palm oil mill effluent or palm oil sludge is the main catalyst to make the higher phosphorus concentration due to the high amount of phosphorus in palm oil mill effluent.

The present of palm oil mill effluent in empty fruit bunch composting will increase the nutrient value follow the composting time.

However, mineralization of the product and leaching of the elements produced as a result of wastewater applications or rains were definitely responsible for nutritional losses. As a prove, Salètes et al. (2004) have determine an about 50% of phosphorus, 70% of the potassium, 45% of the magnesium and between 10% and 20% of the calcium was lossed in week tenth due to mineralization. This was related with high moisture content can reduce the nutrient amount in the final product. Therefore, by conducting the own project, the clear understanding on nutrient phosphorus behaviour in the composting can be generate.

2.5.6 Carbon and Nitrogen Ratio (C/N)

Generally, the value of C/N ratio was high at the start of the analysis. This is because the present of empty fruit bunch (EFB) fibers contain high carbon (in the form of lignin, cellulose, and hemicellulose) increased the C/N ratio in compost. The mineralization and active microbial cellulolytic degradation of complex molecules, which releases N and other ions into the compost, may be the cause of the increase in N content (Alkarimiah & Suja, 2020).

Since there is insufficient nitrogen in the compost, the microbes that live in it take longer to absorb nitrogen from other soil matter, resulting in extremely slow decomposition (Hau et al., 2020). This also can be proved by Hau et al. (2020) statements which are the because of the high lignocellulosic content present in the EFB, which is difficult to degrade naturally, Empty Fruit Bunch has a high C/N ratio and a slow decomposition rate. Moreover, carbon and nitrogen ratio analysis also play the main important in reducing the pollution occurs by decreasing the nitrogen loss in stable carbon and nitrogen ratio (Yu et al., 2019).

In summary, any studies have studied the effects of C/N ratio on composting, and the range of 20 to 30 is usually suggested as the optimal C/N ratio (Sadaka et al., 2013). Moreover, Kumar et al. (2010) also have stated that the C/N ratio of 25 to 30 is generally regarded as the optimal ratio for composting. However, the C/N ratio of 10 to 15 is commonly accepted as a value representing humic acid formation and improved compost stability (Alkarimiah and Suja, 2020). In conclude the preferred C/N ratio value, Table 2.4 shows the summary of accepted C/N ratio reading along composing process based on the various study.

Table 2.4: Summary of C/N ratio reading.

No.	Sources	Title	Summary
1	(Sadaka et al., 2013)	Effects of Aeration and C:N Ratio on Household Waste Composting in Egypt.	The range of 20 to 30 is usually suggested as the optimal C/N ratio
2	(Kumar et al., 2010)	Co-composting of green waste and food waste at low C / N ratio.	The C/N ratio of 25 to 30 is generally regarded as the optimal ratio for composting.
3	(Alkarimiah and Suja, 2020)	Composting of EFB and POME Using a Step-feeding Strategy in a Rotary Drum Reactor: The Effect of Active Aeration and Mixing Ratio on Composting Performance.	The C/N ratio of 10 to 15 is commonly accepted due to stable compost can be produce event in low C/N value.

2.5.7 Electric Conductivity (EC)

According to Wong et al. (2001) the electric conductivity reading will rise in the early stage of composting process. The rise may be attributed to the release of mineral salts as organic matter decomposes, as well as the concentration effect caused by net dry mass loss (Ogunwande and Osunade, 2011). Moreover, during the first seven days, electrical conductivity increased from 1.5 dS m to a high of about 2.0 dS m. This rise was most likely due to weight loss and the release of other mineral salts such as phosphate and ammonium ions as organic compounds decomposed (Wong et al., 2001). Other reporter also have reported that the release of mineral salts such as phosphates and ammonium ions from the decomposition of organic compounds could account for the initial rise. Moreover, the first increase in EC due to the release of mineral salts such as ammonium-based compounds after microbial degradation and breakdown of organic matter components present on the substrates (Rawoteea et al., 2017).

Based on Tatàno et al. (2015), increase in electrical conductivity, which parametrically reflects the matrix's salinity. An additional indicator of success in the composting process, since the progressive breakdown of organic waste is typically accompanied by a rise in the relative concentration of various mineral ions. This will lead to the phytotoxic behaviour to occur. If used undiluted or in significant quantities in potting mixes, this phytotoxic behaviour may be of concern, particularly in the specific use of compost as potting material.

However, the decline in electric conductivity (EC) during the latter stages of composting may be due to the volatilization of ammonia and the deposition of mineral salts (Huang et al., 2004). The concentration of extracted dilution is the main factor for the decrease value of electric conductivity (EC) in composting process. Based on (VanderGheynst et al., 2004), the best indicates high dilution ratios as opposed to low ratios when the salt's solubility becomes a dominating role in its dissolving. However, VanderGheynst et al. (2004) have mention that salts were either incompletely extracted or did not completely diffuse from the particle core to the extractable solution at lower dilution ratios. Therefore, evaluating the value of electric conductivity is important to measure the rates of mineral and nitrogen loss during the composting process.

In conclusion, electrical conductivity values between 2.0 and 3.5 mS/cm are ideal for utilising compost as fertiliser in agriculture (Zaha et al., 2013). This value are the optimum one to produce the stable composting rate in accelerate the composting process. However, Rawoteea et al. (2017) also specified a maximum of 3.000 mS/cm for stable composts, thus the final composts generated in this research were likely stable. Therefore, the reading below 3.5 mS/cm is acceptable to make sure the salinity condition in composting process are achieve the optimum one.

2.5.8 Lignin, Cellulose and Hemicellulose

The fibre content in empty fruit bunch such as cellulose, hemicellulose, and lignin are the principal components of oil palm residues. This component (cellulose and hemicellulose) content can be converted to simple sugars and used to make biofuels and bio-chemicals (Hamzah et al., 2019). Hemicelluloses are a type of cellulose that has a complex structure and is one of the most important components of the plant cell wall. During the composting process, hemicelluloses can be degraded into carbohydrates, which can provide nutrients for microorganism proliferation.

The key skeletal structure of the plant cell wall is cellulose. Hemicelluloses are intertwined and adhere to the surface of the cellulose microfiber (Yu et al., 2019). The presence of EFB fibres, which are rich in carbon (in the form of lignin, cellulose, and hemicellulose), improved the C/N ratio in compost (Alkarimiah & Suja, 2020). The crystalline cellulosic fraction of lignocellulosic biomass is sheathed by lignin and hemicellulose in its natural state.

Furthermore, Yin et al. (2019) have stated that the cellulose activity was determined by measuring the quantity of glucose produced after incubating compost samples with carboxymethyl cellulose, with cellulose activity defined as the amount of enzyme needed to create 1 mg of glucose every 24 hours. This is because cellulose is a key enzyme in carbon metabolism, and its activity may used to predict organic matter breakdown during agricultural waste composting.

Due to the durability and homogeneous unbranched crystalline structure of its connected D-glucose units, cellulose deteriorated at temperatures ranging from 280 to 360 °C 24). Meanwhile, hemicellulose and lignin degrade at lower temperatures ranging from 200–320 °C to 140–600 °C, respectively (Khalid et al., 2019). High molecular weight chemicals are mostly found in the solid residue at subcritical pressures and at high temperatures, while low molecular weight compounds are primarily found in the liquid residue. This adds to the high level of particle matter. It may be inferred that obtaining lignin with a reduced particle matter concentration necessitates a greater temperature range.

According to Baharuddin et al. (2010), Lignin, along with cellulose and other carbohydrates, creates a good strength barrier that prevents cellulolytic enzymes from penetrating. However, the decrease in cellulose content may be attributed to microbial consumption, while the increase in lignin content may be related to the buildup of non-degradable compost material and the addition of POME sludge to the composting heaps during the treatment. Hence, the organic matter deterioration limits the composting process and the quality of the compost products. Table 2.1 shows the chemical composition of empty fruit bunch.

Table 2.5: Chemical composition of empty fruit bunch (EFB).

No.	References		Fibre	
		Hemicellulose (%)	Cellulose (%)	Lignin (%)
1	(Baharuddin et al., 2011)	26.1	50.3	18.0
2	(Khalid et al., 2019)	35.3	38.3	22.1
3	(Sudiyani et al., 2013)	14.62	37.26	31.68
4	(Baharuddin et al., 2010)	24.8	52.8	15.7

2.6 Policy in Biomass Palm Oil

Initially, Malaysia's palm oil industry is strategically important as a major producer of bioenergy in the creation of renewable power and the manufacture of liquid transport fuels such as biodiesel. Palm oil biomass is made up of solid biomass (lignocellulosic waste such as fronds, plantation trunks, empty fruit bunches, mesocarp fibre, and shells) and biogas from palm oil mill effluent (POME), a liquid by-product of the palm oil extraction process. However, the disposal of palm oil biomass may be cause many environment pollution such as air pollution.

According to Bakar and Anandarajah (2015) Malaysia ranked 26th in the world in terms of total greenhouse gas (GHG) emissions in 2004, and was the third biggest emitter among Southeast Asian nations behind Thailand (which ranked 22nd) and Indonesia (ranked 14th). In 2000, its GHG emissions were estimated to be about 223 Mt CO2 equivalent. As in other developing nations, the country's energy-related CO2 emissions accounted for 66 percent of total GHG emissions and were potentially contributed by economic development activities. Therefore, Malaysia has pledged to decrease its carbon emission intensity (per GDP) by up to 40% below 2005 levels by 2020.

Moreover, Malaysia is implementing sustainable forest management as a result of its international commitment made at the 15th Conference of the Parties (COP 15) in Copenhagen 2009 to maintain forest cover on 50 percent of its land area for the foreseeable future (Umar et al., 2013). In a research done on the need for land and the worldwide market share of vegetable oils, it was shown that palm oil production requires less than 5% of the world's agricultural land, yet supplies 33.6% of the global market share of vegetable oils. Hence, despite the present availability of resources, it is critical to recognise and include the palm oil industry's contribution to long-term environmental and food security.

According to Malaysia's National Biomass, the proposed objective in 2020 was 800 MW (38%) installed capacity from biomass and 54 MW (17%) installed capacity from municipal solid waste by 2020, respectively. The installed capacity of biomass is projected to grow by 67.5 percent by 2030, with 1340 MW added. As a result, the mechanistic research on fluid dynamics and rheological behaviour of sludge for EFB delignification is also consistent with the Malaysian government's efforts to promote the use of biomass. In summary, the present of biomass policy in Malaysia is very important to enhance the sustainability of the environmental safety for a better management in biomass production and elimination.