Design and construction of mobile Biochar Kiln for small farmers

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Abstract. Biomass is a renewable energy that attracted the global attention. Biochar is a product of pyrolysis of agricultural biomass under limited oxygen condition and the fire is lit at the top of the biomass. There was a variety of method or technique to produce biochar. A simple, practical and affordable unit of pyrolysis kiln was designed and fabricated to ease the small farmer to produce the biochar efficiently at low cost. Biochar samples were prepared from the pyrolysis process by using waste wood from the harvest site. Furthermore, pH level, surface area and other biochar characterization had been studies through laboratory test. Surface area of biochar observed through Scanning Electron Microscope (SEM). Gas emission was observed during the trial run of the pyrolysis kiln. The portable biochar kiln can be constructed easily by the small farmer by using available metal. This is one of the methods which utilises the biomass efficiently and use it as soil nutrient supplement. This approach is more environmental friendly compare to open burning of waste wood at the harvest site. The general performance of the portable biochar kiln is satisfactory and is suitable for burning the waste biomass to produce biochar.

Keywords. Pyrolysis; Biochar; Biomass; Kiln; Characteristic; Soil

1. Introduction

The use of biomass in agricultural activities had continued to get global attention over this few decades. Biochar which produced industrially had high potential to become one of the raw material for the bio-based economy in future world. As construction, waste water treatment, textile and other industries will be competing for the biochar, biochar which produced commercially will sell at higher price for farmers. For small farmer, since their amount of product and profit is relatively low, they will have some difficulties in purchasing the costly biochar which produced industrially. However, the small farmers have other alternative ways to produce their own biochar by using some natural sources of raw material available at their farms such as waste-wood, agricultural by-product and crop residue. The resource loop can be completed by farmers on their own farms and biochar help in enrichment for soil due to the larger surface area and highly porous structure [1].

Production of charcoal and biochar in larger quantities will become the causes for the deforestation. Normally, the charcoal produced used for heating and cooking for a family. For industrial purposes, the charcoal was used to heat the ceramics, to melt the ore or produce lime. However, when finer charcoal fraction combine with the organic wastes can be used to improve the fertility of the soil and increase the production of crop in agriculture [1].
This project seeks to present the design of biochar kiln which is simple for small farmers to fabricate with low cost. The use of waste from agricultural was used by farms, the small farmers to produce a sufficient amount of biochar by using biochar kilns. The unit of biochar kiln is mobile and it is easy for the small farmers to move the biochar kiln to desired place. It can help the small farmers to save time in carrying a larger amount of feedstock available periodically but not regularly in a specific location of their farm to approach the biochar kiln for combustion purposes. The general concept of pyrolysis technology was applied in the design of biochar kiln. The optimum size of the biochar kiln is designed which can produce sufficient amount of biochar for small farmers. Normally, after the crops have been harvested, most of the waste is thrown away without consideration for other uses. The waste can be processed into biochar through pyrolysis for soil enrichment by using biochar kiln. Waste management plays a significant role in sustaining the global cleanliness. Normally, they dispose the agricultural residues by using open burning method which will lead to air pollution for our environment and further lead to climate change. Offering the small farmers an option to utilize the waste by providing a biochar kiln will help them to avoid the waste generation and air pollution. Through this project, the agricultural residue will be utilized for production of biochar to improve the quality of the soil and also reduce the quantity of fertilizer used by the small farmers.

2. Literature review

2.1. Biochar
Biochar is a type of predominantly stable carbon rich product which is obtained through biomass pyrolysis [2]. The source materials of biochar are feedstock such as woodchips, wheat residue, crop residues, maize straw pellets and animal manure [3]. Pyrolysis is the thermal decomposition of biomass under low oxygen concentration conditions at relatively low temperatures below 700 degrees Celsius [4].

When the pyrolysis temperature increases, the total surface area of biochar also increases. This will facilitate the higher sorption of chemicals, for example pesticides. Bio-char consists of ash, carbon (C), oxygen (O), hydrogen (H), nitrogen (N) and sulphur (S) in different proportions which strongly correlates with the heating rate, temperature and time maintained during production. Therefore, it contributes in locking the amount of carbon present in the plant biomass through carbon sequestration. Biochar is a highly porous substance which can improve the water holding capacity of the soil by increasing total surface area of the soil for soil amendment [5].

In recent years, bio-char is very important in improving the soil nutrient content through a more concentrated carbon content, high calorific value, absorption capability and good porosity due to its high specific surface area and structure [6].

2.2. History of Biochar
Biochar is one of the key components of soil properties found in the Amazon Basin, known as Terra Preta di indio (black earth) to describe the black soil that had been found [7], [8]. It had been discovered that the soil’s depth is up to two meters throughout the terra preta region in the Amazon Basin [5]. Mostly, it occurs along the river banks at fringes of Terra Firme and overlies in weathered soils [9].

It is a dark coloured soil, rich with nutrients that contain high organic content to support agricultural needs. Terra preta has the ability to accumulate the stable organic carbon which can increase fertility and carbon storage in soil. Early studies had shown that terra preta soils were formed by Amerindians and pre-Columbian as they practiced “slash and char” technique in agriculture [10]. The techniques involved ignition of vegetation and combining it with biomass within a small plot but only allowed it to burn without smoke. Then, it was buried under the soil to form terra preta [5].
2.3. Existing product

2.3.1. Earth Kilns. In United States, the forerunners of kiln design were earth kiln. During the nineteenth century, it was replaced by “beehive kiln”. Earth kiln as shown in figure 1 can be simple create in the same area of the source of the biomass such as logging site as the wood can be obtained easily from that area and hence reduce the freight charges.

![Figure 1. Earth mound kiln [11].](image)

The soil can be used to prevent the oxygen attack and protect the wood from the outside air because the oxygen attack can cause loss of products. The wood is mounted over by the earth to provide a firm closure. It is not so tightly to prevent the air from leaking through to the wood. Some of small pieces lit wood filled the chimney to ignite the charge. When the earth kiln reached optimum combustion, there is no more fuel is added. The vents are opened from the top and working downwards to allow the combustion products to escape. The cooling stage is begin when there is no smoke produced and cover the stack with a layer of moist earth for a few days. Continuous attention is required for three to fifteen days depending on the kiln size [11]. The earth is removed and the production of biochar is separated from the imperfectly carbonized portion. Although earth kiln can be constructed easily but the rain can affect the quality of the biochar. The condensed pyroligneous gases from the foliage layer and outer covering layer of earth will get washed down by the rain and reabsorbed by biochar [12]. Furthermore, it produced low quality product and only had eight percent to fifteen percent of efficiency. Hence, it had high consumption of feedstock [11].

2.3.2. Adam retort Kiln. Adam retort kiln as shown in figure 2 has a pyrolysis chamber and a separate firebox to generate the combustion heat. The firebox is filled with feedstock to start the pyrolysis process then ignited it. The combustion gases flow into pyrolysis chamber. The gas will heat and reduce the moisture in the feedstock.

![Figure 2. Adam retort [13].](image)
The gas temperature will reach above 100 °C when the gases emerge in primary chimney. Then the primary chimney will be closed to allow direct pyrolysis-off gases back to firebox. Next, the retort combustion gases will direct into a channel system which located under the pyrolysis chamber to exchange the heat to the feedstock. This can help to sustain the pyrolysis process before the gases escape to the air through the second chimney. The feedstock should have porosity to allow gases to flow freely through the kiln [12].

2.3.3. The drum retort Kiln. The drum retort kiln as shown in figure 3 is an improvement of earlier drum based kiln which is using gas recovery concept. The feedstock is directly loaded in the drum by using a tray and a lid is used to cover the pyrolysis chamber tightly.

![Figure 3. Drum retort Kiln [12].](image)

Compare to Adam retort, the combustible material is directly placed below the pyrolysis drum. In retort mode, the gases will flow at the lower part of the drum for ignition and sustain the pyrolysis process to occur in the drum retort kiln. For pressurized drum system, dense material such as rice husk can undergo pyrolysis directly without pelletizing. The limitations of drum retort kiln are its requirement of more combustible material for ignition, higher cost and lower capacity [12]. However, the drum retort kiln is less efficient than the brick kiln [14].

2.3.4. Brick Kilns. Brick kilns as shown in figure 4 is entirely built by brick and mud as mortar. It consists of two opposite doors for loading and unloading purposes.

![Figure 4. Brick Kiln [11].](image)
The production of brick kiln required a long time because it can be harvested after 13 to 14 days. Since brick kiln is stationary, it must be built near to the harvest site. The wood must be cut into desired shape and water supply is required to prepare the mortar. The brick kiln required very high cost construction.

2.4. Production of Biochar

2.4.1. Pyrolysis. Pyrolysis as an example shown in figure 5 is a process of thermos-chemical conversion of biomass under low oxygen concentration condition [15]. It can be divided into three categories which fast pyrolysis, intermediate pyrolysis and slow pyrolysis, depending variables such as peak temperature, heating rate, residence time of the vapor phase, pressure, particle size and flow rate of sweeping gas [6], [16]. The conditions of pyrolysis can influence the amount of the three products such as bio-oil in liquid form, biochar in solid form and syngas in gas form [17].

Figure 5. The example of match shows how the flame excludes oxygen and allows pyrolysis to take place [1].

Based on the analog of the match, actually the wood does not burn. When the wood is heated, it emits combustible gas and the flame ignites the gases that released from the wood. Since the wood is charred under the flame, oxygen penetrates into the porous structure of wood and turn the carbon into ash. The process is shown in figure 6.

Figure 6. Biomass, waste recycling and soil remediation [34].
This process will continue under the heat from burning pyrolysis gases. The wood does not burn and it undergoes carbonization because the gas flame consumes all the oxygen which results in the pyrolysis zone. A smokeless fire can be created when the load is lit from the top so that the fire in the uppermost layer heats the next lower layer. Hence, the gas rises up through the flame where it is burned. The principle of smokeless fire is very important for the design of biochar kiln [1].

Table 1. Rate of initial feedstock mass between products of pyrolysis process [5], [18].

| Process                | Liquid (bio-oil) | Solid (biochar) | Gas (syngas) |
|------------------------|-----------------|-----------------|--------------|
| Fast pyrolysis         | 75%             | 12%             | 13%          |
| Moderate temperature (~500°C) Short hot residence time (<2s) | (25% water)     |                 |              |
| Slow pyrolysis         | 30%             | 35%             | 35%          |
| Low-moderate temperature Long residence time | (70% water)     |                 |              |
| Gasification           | 5% tar          | 10%             | 85%          |
| High temperature (>800°C) Long vapour residence time | (5% water)      |                 |              |

2.4.2. Fast pyrolysis. Chemical reaction kinetics play a significant role since fast pyrolysis occurs within short vapor residence time approximately 2 second at temperature between 500 until 550 degrees Celsius depends on very quick heat transfer [19]. It can minimize the exposure of biomass particles to surrounding environment with intermediate temperature [5]. It yields about 12 percent of biochar, 13 percent of syngas and 75 percent of bio-oil. The main product of biomass that undergoes fast pyrolysis is the formation of bio-oil and less formation of biochar.

2.4.3. Slow pyrolysis. Slow pyrolysis, has a long heating rate and long vapor residence time in order to produce bio-char [19]. This process is usually carried out within a few days at atmospheric pressure. Generally, the energy source from the combustion of produced gas and the partial combustion of biomass feedstock. From the table 1, the amount of bio-char product yield through slow pyrolysis is the highest compared to fast pyrolysis and gasification. Under slow pyrolysis, about 35 percent of biomass ends up as bio-char, 35 percent as syngas and 30 percent as bio-oil. It can turn the waste into safely disposable substances which can retain up to 50% of the feedstock carbon [3]. Slow pyrolysis can be applicable to small scale farmer production of bio-char.

2.4.4. Gasification. Gasification is a thermochemical conversion at high temperature under limited amount of oxygen in the production of combustible gases. It mainly consists of hydrogen [(H) _2], methane [(CH) _4] and carbon monoxide (CO) [5]. Gasification is more efficient to produce syngas which reaches 85 percent of syngas since the syngas can be combusted at a higher temperature which is more than 800 degrees Celsius [19].

2.5. Quenching
When the small farmer filled the feedstock into the biochar kiln, the feedstock should be maximum ten centimeters below the top edge to create stable gas-air vortex and the last two to three layers must consist of easily charred material such as dry grass or thin branches. Quenching is a post pyrolysis procedure that control the dust and pore volume [20].
There were two ways of quenching direction take place either from the top or start from the bottom. If it works from the bottom, the small farmers must open the water tap 20 minutes before the last layer had been pyrolysis so that the water flow in from the bottom of the kiln. In this condition, when the water meets the hot coal, the water will be evaporated into steam. The steam rises through the char bed to create slow quench and partially activates the biochar. The hot steam plays an important role to react with condensates that came from the biochar pores. Hence, the biochar can be cleaned and also increasing the inner surface of the biochar. Besides that, quenching process can increase the pore volume of the biochar and activated the biochar. It will create higher surface area if quenched the biochar from the top because the top layer is very hot and will not snuffed by the steam [1].

Dry quenching is not suitable because biochar will have more condensate and richer in pollutants such as polycyclic aromatic hydrocarbons (PAHs). PAHs are pollutant which will produce during incomplete combustion of organic feedstock. Dry quenching can be simply achieve by close the kiln by using an airtight lid to allow it completely cool but this process will consume a long time and loss of biochar [1].

The quench water can be left in the biochar kiln for few hours or few days and it can be drain out through the water tap at the bottom part of biochar kiln. The clean quench water is transparent and soapy. It consists of high pH value due to the ten percent of ash production from the biochar during slow pyrolysis process. It produces soap when the ash react with the pyrolysis oil that expelled from the pore. The quench water is very useful in agricultural field because it can be used to pour on plants. It acts as tonic to the plants because it protects the plants against fungus and snails.

2.6. Storage of Biochar
Biochar is very stable when cooled but some precautions must be taken to prevent any combustion during storage. This is due to the tendency of biochar to absorb oxygen when it removed from the kiln which can lead to combustion. Biochar should be clean and it must be located in open dry area for few hours before storage. Furthermore, it should be protected from rain during the cooling period. Once there is no heat store inside the biochar, it is safe for warehouse storage [21].

2.7. Advantages of Biochar
Agricultural productivity has decrease due to depletion in nutrients of soil and soil organic matter. Fertilizers that contain chemical compounds had increases in agricultural productivity but the soil fertility is not a sustainable approach. Chemical fertilizer mostly consists of nitrogen which can deteriorate the soil environment and mineralize the organic matter. Hence, the biochar which is produce by biomass play a vital role which provides benefit to both agriculture and environment. In recent years, production of biochar through pyrolysis is a technique used to improve the soil quality. It is also helpful in coping with greenhouse gases (GHG) and increase in sequestering carbon. A lot of studies and evidence had been done to show the application of bio-char is useful [22].

2.7.1. Improving soil for crop production. Production of bio-char through the pyrolysis of biomass in combination of organic matter is more stable in nature compare to biomass which undergoes degradation that releases carbon back into surrounding environment, as it helps in recovering almost 50 percent of the amount of original carbon in the biomass gets trapped in its structure. Therefore, performance of bio-char in restoration of soil fertility more effective. The use of biochar can improve the soil productivity as its application to soil can remain persistent for approximately two to three years. When the soil fertility increase, the yield of agricultural crop also increases [22].

Apart from increasing the soil fertility, it can help in reducing the soil pollution of the soil which the land is originally consists of inorganic chemicals. Furthermore, bio-char also increase the soil-water storage which helps in water retention as it is a highly porous substance and has a large surface area [5].

2.7.2. Nutrient availability in soil. Biochar also helps in increasing the cation exchange capacity (CEC) which reduces the leaching of nutrient by providing binding sites. The binding sites provide space for
microorganisms which can bind the significant anions and cations. Therefore, it increases the nutrient of soil for crop production and prevents from getting washed away due to rain water. Furthermore, biochar can increase the pH value of the soil and thus improve the amount of phosphorous and potassium in the soil and suppress the activity of enzyme involve in the nitrite to nitrous oxide conversion [22]. Hence, it increases the availability of nitrogen in the soil and reduces the need of chemical fertilizer [5].

2.7.3. Role in dealing with climate change. Hence, it increases the availability of nitrogen in the soil and reduces the need of chemical fertilizer [5]. Rapid industrialization and unsustainable development have increased greenhouse gases (GHG) which has caused changes in global climate and global warming. Production of bio-char has been proven to be a method to sequester carbon dioxide from the atmosphere. The carbon (C) removed by the plant during its lifetime and will be stored in its structure due to decomposition. Although this method does not directly sequester the carbon from the atmosphere, it converts the feedstock into a highly stable form and thus decreases the emission of carbon dioxide from the soil due to decomposition. Therefore, bio-char undoubtedly is very important in creating an environmentally friendly method to mitigate the problem of greenhouse gases and control the amount of methane and nitrogen dioxide that is released from the soil [5].

2.7.4. Reducing the pollution of waterways. Biochar is a highly porous structure and it is an effective method to remove the pesticides, chlorine and certain metals due to its principle of absorption. The maximum surface area of biochar will lead the impurities and contaminants to interact with it active site which will increases the absorption capacity. It helps to reduce the pollution and also decrease the risk of nutrient leaching of the soil into the groundwater. Besides that, bio-char reduce the amount of nutrient loss that is caused by erosion due to surface water flow [22].

3. Methodology

3.1. Preparation of raw material
From the view of production, it is significant to classify the feedstock into dry and wet condition. It is determined by the initial moisture content of the feedstock. For dry biomass such as branches, waste wood or agricultural residues are considered as feedstock that have low moisture content of less than 30% after harvested [7].

In additional, biomass that has moisture content that exceeds 30% is considered as wet biomass. It is typically referred to biomass which are freshly harvested such as algae, animal or human excreta and sewage sludge [23]. The wet biomass required additional drying process before undergoes the pyrolysis process. The employment of waste biomass is very ecofriendly and it also helps the small scale farmers to utilize the waste effectively [7]. The small farmers can fully utilize the feedstock that is near to the harvested site for the biochar production.

3.2. Design
After the ample literature review, a cone shape biochar kiln as depicted in figure 7 was selected based on the principle of pyrolysis process by using local available material to produce a desirable outcome that has a top view as shown in figure 8.
Figure 7. SolidWorks drawing of cone shape Biochar Kiln (right view).

The biochar kiln with front view as shown in figure 9 was designed to have an angle sides cone to control the combustion process. It will only allow the oxygen flow to the top layer of feedstock where the starting ignition occur.

Figure 8. SolidWorks drawing of cone shape Biochar Kiln (top view).

A steep cone shape of biochar kiln was selected with an upper diameter of 0.8 meter and a height of 0.28 meter. The wall of inclination of 63° was chosen so that a consistent fire front at the surface is created. It is very important to act as a barrier to oxygen during the pyrolysis process of biochar because it will provide consistent fire front at the surface. Small scale farmer must hand fed the feedstock during the entire period of operation.

Figure 9. SolidWorks drawing of cone shape Biochar Kiln (front view).
A smokeless fire in biochar production can be made to work like a match. Ignition starts from the top, the fire in the uppermost layer will heat the layer of the feedstock below such as wood and lead to outgas. During pyrolysis process as shown in figure 10, the gases released will rise through the flame and burn cleanly. In other words, the fire which ignites will cause the wood layer to release the gas. The cone shape biochar kiln will use the burning pyrolysis gases that exposed on the surface to expel the air in the kiln body and heat the wood [25].

![Figure 10. Schematic diagram of Kiln operation [24].](image)

The combustion air will roll over the edge of the metal biochar kiln and flow into the kiln body. At the same time, the escape burning pyrolysis gases will rise upwards. At the center of the cone shape biochar kiln, a rotate vortex will be created and stabilize the supply of air to the fire zone. Since the gases releases from the wood is denser than the air, it will remain in the vortex until completely burned. When no more visible flame, the process is completed and slow quenching with water from the top of the biochar kiln to cool down the biochar. This action can partially be activated the biochar and prevent the biochar from further burning or continuous cracking within the organic molecules [26].

### 3.2.1. Design consideration

The following factors are taking into consideration:

- Smoke Reduction
- Safety
- Cleanliness
- Durability
- Portability
- Affordability
- Production possible by UCTS mechanical workshop
- Time saving as it is the fastest way to produce biochar at the harvest site
- A variety of feedstock can be used
- Low cost of fabrication
- User friendly design

### 3.3. Material selection

After the conceptual design of a cone shape biochar kiln, several factors need to be considered before fabrication. Material selection is one which will interact between several other factors. The factors include availability of materials, resistance of corrosion, ability of fabrication, consideration of manufacturing process, thermal stability and cost of the material [27].

#### 3.3.1. Material comparison

Some of the important criteria had been considered and compared during material selection which are listed in table 2 between mild steel, cast iron and high carbon steel.
Cast iron had been selected for the fabrication at one of the workshop in Sibu. It can be used for a long period since it does not corrode readily and the cost is cheaper compared to mild steel and high carbon steel.

| Properties               | Cast Iron          | Mild Steel          | High Carbon Steel  |
|--------------------------|--------------------|--------------------|-------------------|
| Carbon content           | 0.5 -1.5%          | 0.1 -0.29%         | 2-4%              |
| Structure                | Crystalline coarse granular structure | Bright fibrous | Fine granular |
| Mechanical Properties    | Less tough and less elastic | Tougher and elastic than cast iron | Tough and elastic than mild steel |
| Hard and Brittle         | Malleable and ductile | Readily forged and welded | Brittle and less ductile than mild steel |
| Can be Welded            | Readily forged and welded | Not easily to be forged and welded |
| Melting Point            | 1200°C             | 1400°C             | 1300°C            |
| Rusting                  | Does not rush readily | Rusts readily | Rust rapidly |
| Shock Absorbing          | Cannot absorb      | Absorb shock       | Absorb shock      |

3.4. Performance testing of Biochar Kiln

3.4.1. Total time of Biochar production. The student requires to record the total burning time for the biochar kiln by using different diameter size of wood. The total burning period is divided into two different phase which is initial combustion phase and pyrolysis phase. Furthermore, the duration of the quenching process is importance in this project [27].

3.4.2. The temperature during pyrolysis process. The temperature of the pyrolysis process during production of biochar is measure by using thermocouple. This can clearly determine the highest temperature that can reach in the fabricated biochar kiln in this project. The biochar kiln was designed to have several holes at two different layer. Normally, the feedstock in the biochar kiln was burned layer by layer [24]. Hence, the thermocouple can be used to determine the differences between the temperatures of these two layers in the biochar kiln when the pyrolysis process take places. Normally, the temperature of the bottom perform is higher than the biochar during the process.

3.4.3. Scanning electron microscopy image. Scanning electron microscopy (SEM) as shown in figure 11 is used to evaluate the structural characteristic in biochar particles before and after the pyrolysis process.
SEM images can indicate the surface structure and pore structure of the biochar [28]. The irregular shape solids containing of variety pores which consists in different size can be observed easily [29]. Figure 12 shows the sample image of biochar under SEM at magnification × 80.

3.4.4. Laboratory test. Biochar pH is a very important chemical property when applying biochar to the soil because the pH value of the biochar will influence the soil pH. Generally, low ash content of biochar such as woody feedstock has lower pH values compare to higher ash content biochar [28]. Typically, grass and crop residue contain high ash content of biochar. Figure 13 shows pH meter setup.
Biochar pH can be measured in several ratios of biochar and deionised water such as 1:10 and 1:20 biochar: water ratio. Biochar: water ratio of 1:5 is not recommend because it is not enough solution to inert the electrode due to the high water absorption capacity and porous structure of the biochar. Mechanically shake the centrifuge tube which contain desired proportion of biochar and deionised water for one hours for 25°C. Allow the mixture suspension to stand for approximately 30 min then measure it by using pH meter. First, the pH meter calibrated by using pH 7 and pH 10 buffers. If the pH of the biochar is less than pH 7, then calibrated the pH meter by using pH 7 and pH 4 buffers [30].

Ash content was measured by determine the weight loss. The biochar required to oven dried for 24 hours at temperature of 105°C. Then, take 5 grams of oven-dried biochar to combust it at 750°C for six hours. Next, place the sample on desiccator and let the sample to cool down to room temperature and weight it to obtain the weight of ash [31]. Electrical muffle furnace is used to measure the ash content of the biochar by using the equation below [32].

\[
\text{Ash content (\%)} = \frac{\text{Weight of Ash}}{\text{Weight of Biochar}} \times 100
\]  

3.4.5. Laboratory test. Biochar pH is a very important chemical property when applying biochar to the soil because the pH value of the biochar will influence the soil pH. Generally, low ash content of biochar such as woody feedstock has lower pH values compare to higher ash content biochar [28]. Typically, grass and crop residue contain high ash content of biochar. Figure 12 shows pH meter setup.

3.4.6. Observation during the operation. The student required to observe the condition during biochar pyrolysis to detect the presence of the smoke. Once, the kiln reaches a certain high temperature, it is hardly to observe the smoke. The combustion air from the top that drawn down onto the burning surface will undergoes preheated and it reduces the cooling of unburned gases. Hence, it will reduce the smoke production and generate more stable combustion dynamics.

3.5. Biochar yield
The efficiency of the biochar yield is calculated using the equation (2) [33].

\[
\text{Yield}_{\text{biochar}} = \frac{m_{\text{biochar}}}{m_{\text{raw}}} \times 100\%
\]  

Where:
\[
\text{Yield}_{\text{biochar}} = \text{mass yield of biochar in percentage (\%)}
\]
\[
m_{\text{biochar}} = \text{mass of biochar (kg)}
\]
\[
m_{\text{raw}} = \text{mass of raw biomass (kg)}
\]

4. Conclusion
This study had demonstrated that small farmer can produce biochar easily by using biochar kiln which can be fabricated easily by themselves. The production of biochar from the biomass must undergo pyrolysis process. Hence, the design specification of biochar kiln had been done through SolidWorks. The design is simple and easy to fabricate and use by small farmer with less maintenance and low operating cost and it is safe. After the fabrication of the biochar kiln, various tests run were conducted at the site near Skim B, Meradong. The general performance of the pyrolysis kiln is satisfactory under limited supply of oxygen. Furthermore, the farmer was trial run with this portable kiln. Small farmer can reduce their cost by produce biochar by themselves rather than buy the commercial biochar from the market at high cost. Biochar can be produced from different agricultural by-products such as forest residue, organic, agricultural waste biomass feedstocks that can easily obtainable from the harvest site under a pyrolysis process condition. Biochar is an effective tool for soil application such as pH buffering, soil aggregation, moisture retention and nutrient enrichment. By converting the biomass as soil nutrient
is very efficient way to manage the soil fertility and health. The structure of the biochar was observed under Jeol's Benchtop Scanning Electron Microscope (SEM). Pore structure of biochar sample that produced by using the fabricated biochar kiln had been study by using x27, x54, x80 and x170 magnification including the cross-sectional view and the top view of the biochar. In addition, experimental tests for characteristics such as pH level was conducted though a standard procedure. The result shown that biochar is alkaline property. Hence, it can be very effectively when apply the biochar for acid soil reclamation due to the alkaline property of the biochar. Other characterization of the biochar sample is still in progress.

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