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# Utilization of Pili *(Canarium ovatum)* sawdust in bio-crude oil production and the identification of potential by-products through thermochemical conversion

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**Abstract:** This study aimed to utilize Pili sawdust in the production of bio-crude oil and identify its potential by-products through thermochemical conversion. To obtain all the essential data, this research sought to answer the questions: (1) How much bio-crude oil can be produced at constant factors such as temperature and amount of Pili (*Canarium ovatum*) sawdust? (2) What are the physical characteristics of the generated bio-crude oil after conducting thermochemical conversion? (a) Color, (b) Appearance, and (c) Viscosity (3) What other potential by-product can be generated out of Pili (*Canarium ovatum*) sawdust after conducting thermochemical conversion. (4) What are the physical characteristics of the generated by-products after conducting thermochemical conversion? (a) Color and (b) Appearance. Experimental-descriptive method was used in perceiving the physical properties of the by-products and its bio-crude oil production, presented in milliliters (mL) and to be expressed in percentage respectively. Based on the gathered observation record results, data revealed that 1000 g of Pili sawdust in 340 $^{o}$C temperature, yields 30% or 300mL of brownish bio-crude oil in color, with a high degree of viscosity. Consequently, the generated by-products are biochar and synthesized biogas. The 242.2g of biochar which yields 24.52%, resulted being porous and coarse-grained in texture. While the synthesized biogas generated 433.4g of net weight yields 43.34%, resulted in having a high flammability. For the betterment of similar study, future researchers are encouraged to evaluate the agricultural potential of the generated biochar and to distillate bio-crude oil for possible commercial use.

**Keywords:** Viscosity, Distillate, Thermochemical Conversion, Pyrolysis Method, By-product, Flammability and Combustibility, standardization.

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## INTRODUCTION

Wood bioenergy is created from the direct or indirect conversion of biomass from trees and woody shrubs. This energy can be derived by directly burning the wood, or burning the wood in combination with coal or other fuel sources that is considered to be renewable or "non-depletive" in nature. It is the prominent reason why wood bioenergy is considered a viable alternative to traditional depletive sources within energy discussions in the United States and around the world. Wood bioenergy resources come from wood biomass that is created in trees and woody shrubs due to growing processes. In its simplest form, wood biomass is a combination of water, cellulose, hemicellulose, and lignin. Wood biomass is produced on all trees and performs several critical functions [1]. These mentioned properties of wood biomass show similarities to wood sawdust.

Wood sawdust (WSD) is an industrial biomass waste produced by wood processing units and other furniture-based industries [2]. Sawdust is produced through the cutting, sizing, re-sawing, edging, trimming, and smoothing of wood. In general, processing of 100 kg wood in sawmill produces around 12–25 kg sawdust [3].

On the other hand, the abandonment of sawdust at sawmills causes aesthetic impacts; while abandonment along the roadside causes air quality impact because of wind, which often blows and suspends the wood dust into the atmosphere. This practice causes respiratory problems in humans and air pollution.

Furthermore, industrialization and growth of world population and the current requirement of energy demand is mainly fulfilled by fossil fuels (coal, petroleum, and natural gas) and continuous use of these fuels and their gradually degrading quality is posing a serious threat to the energy security and environmental sustainability. Therefore, along with the depletion of world oil reserves and environmental issues, the utilization of biomass as a source of new and renewable energy is being carried out among all the global renewable energy research in terms of published literature, biofuels contribute the share of 56% followed by 26, 11, 5 and 2% by solar energy, wind power, geothermal and hydropower, respectively, which reveals the potential of bioenergy development.

The decomposition of organic matter of the algal biomass as a process of thermochemical conversion process to produce biofuels including liquid that may have a higher caloric value than other oxygen fuels (such as methanol) and is only slightly lower in caloric value than diesel and other light fuel oils [4], gaseous, and solid.

## MATERIALS AND METHODS

The Modified Alternative pyrolysis reactor is crafted dependent to be availability of the resources without compromising the quality. The reactor was comprised of standard base quality pressure cooker (B) with 26 cm diameter which had been subjected to heat coming from the liquefied petroleum gas (LPG) (A) with constant specific temperature of 340 °C, degradation of the Pili (*Canarium ovatum*) Sawdust (C) inside the alternative reactor begins to form hydrocarbons in the form of heavier gases and vapor. These gases and vapor travels to the metal tube (D) 80cm long towards the container 1 (E) with 13 cm of diameter.

The vapor will directly fall into the container in liquid form, while the hydrocarbon steam undergo condensation. It will then be cooled down by the alternative cooling system (F) to avoid the shrinkage of the container 1. As the heavier gases enter the container 1, the remaining vapor which is light dense will directly traveled to each three meters long plastic hose (G) and fall to the 13 cm in diameter container 2 (H) with tolerable temperature. The lighter gases then leave container 2 and travel across the plastic hose towards the tire (I) with the capacity of 900-20 TR78A as the alternative storage of the biogas. While the air controller (J) controls the flow of the gases entering the tire by limiting and avoiding the tire to exceed its air capacity.

The study did not use any catalyst to further increase the chemical reactions and the maximization of the bio-crude oil yield. The choice to use a non-catalytic pyrolysis process is to provide a cheaper, simpler, and more particularly safe to its targeted benefactor. Statistical treatment $P = \frac{F}{N}$ x 100 is applied in the computation of the production of bio-crude oil [5]. Determining the production of bio-crude oil will be presented in percentage using the equation:

$$\%Yield = \frac{amount\ of\ bio - crude\ oil\ yield}{total\ amount\ of\ feedstock} \times 100$$

Where:

P = Percentage of product yield

F = Amount of bio-crude oil yield

N = Total amount of feedstock

## PROCEDURE

The non-catalytic pyrolysis reactor operated at a constant temperature of 340 °C was used to determine the amount of 1000 g Pili (*Canarium ovatum*) sawdust oil yield at one hour (10:42 – 11:42am) of conversion. Physical characteristics such as color, appearance of the bio-crude oil and its by-products (biochar and biogas), while the thickness or viscosity which only applicable to the bio-crude oil, are all determined based on the observable data and characteristics of each product.

The production of bio-crude oil was determined by using a percentage formula by dividing the oil yield in mL into 1000 mL and multiplied by 100%.

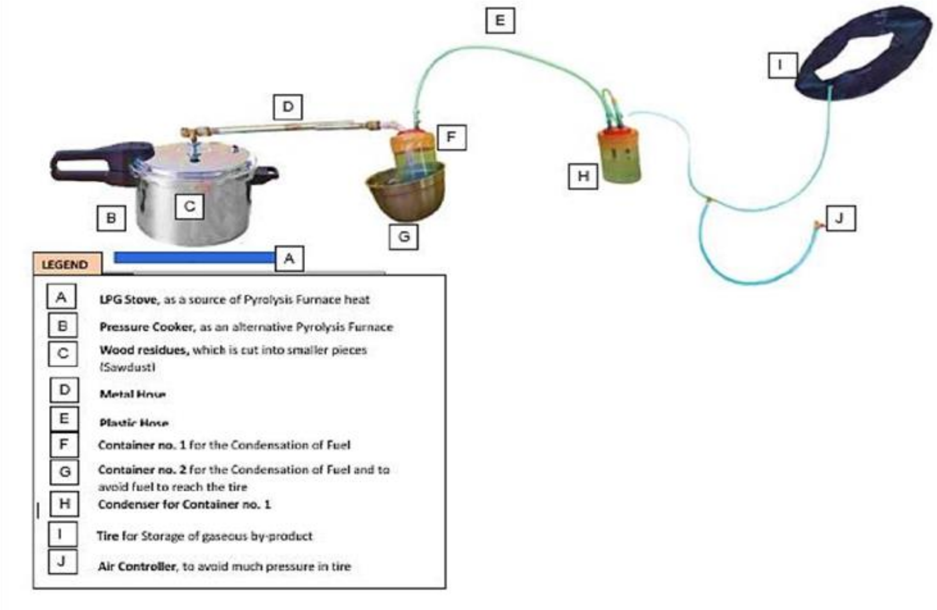


**Figure 1.** *Modified alternative pyrolysis reactor, adapted from Cooper et al. 2015* [6]

**Table 1.** Generated Bio-crude Oil Yields at Different Time Intervals

| Time interval in bio-crude oil production | Bio-crude oil's yield |
|---|---|
| 11: 02 (20 minutes) | **47 mL** |
| 11: 22 (40 minutes) | **102 mL** |
| 11: 42 (60 minutes) | **151 mL** |

The conversion of wood sawdust into bio-crude oil started at 10:42 am. After 11 minutes, the production of hydro-carbonated steam started to condensate in the container which collected 47 mL of bio-crude oil. 40 minutes after the concentration of the additional 102 mL, production of bio-crude oil becomes darker brown in color with bio-crude oil clots. After one hour of conversion, 151 mL additional amount of the generated bio-crude oil has been added to produce the 300 mL of bio-crude oil yields. The by-products, on the other hand, are difficult to measure during the process, as the net weight of the produced biogas can only be get after the process, similar to the biochar.

## RESULTS AND DISCUSSION

### Amount of Bio-crude Oil Produced at a Constant Factors such as Temperature and Amount of Pili (*Canarium ovatum*) Sawdust

The production of bio-crude oil is dependent to the constant factors such as temperature and the amount of the Pili (*Canarium ovatum*) sawdust. Standard nomenclature and measurements of these constant factors are conducted by the researchers themselves. The 1000 grams of Pili (*Canarium ovatum*) sawdust undergo the process of thermochemical conversion through the slow pyrolysis method in a non-catalytic alternative reactor with the temperature of 340 °C based on the protocol used by Wretborn (2016) [7].

Aworabhi et al. (2021), stated that cellulose, hemicelluloses, and lignin as the organic components of wood are thermally decomposed when subjected to a high temperature [8]. Which shows that the degree of temperature as well as the amount of Pili sawdust found a direct relationship, wherein the heating rate and temperature used in pyrolysis of sawdust affect the yield of biochar and bio-crude oil according to the study of Guida et al. (2020) [9].

The slow pyrolysis of thermochemical conversion process produced 300 mL of generated bio-crude oil, which represents 30% yields that surpasses the resulted outcome of the study of Wretborn (2016) [7], having 25% of bio-crude oil produced with the same degree of temperature (340 °C). Similarly, the study of Ben (2019) with a 29.18% oil yield took up one hour time conversion [10], aligned to the protocol used by Dimin et al. (2014) with a retention time ranging from 1-3 hours [11].

The production of bio-crude oil in a non-catalytic slow pyrolysis method of thermochemical conversion process, shows that the oil yield is comparable to the production yield in a catalytic pyrolysis method with versatility in thermal and materials used

[12], with production of pyrolysis conversion of up to 77.6% can be obtained at maximum according to the study of Yildiz [13].

### Physical Characteristics of the Generated Bio-crude Oil after Conducting Thermochemical Conversion Process

The physical properties of the bio-crude oil involve the color, appearance, and its viscosity. The table that follows presents the physical characteristics of the generated bio-crude oil in terms of its color, appearance, and viscosity. The condensation of the hydrogenated steam results to the build-up of the bio-crude oil.

**Table 2.** Physical characteristics of the generated bio-crude oil after conducting thermochemical conversion process.

| Time interval | Color | Physical characteristics | Viscosity level |
|---|---|---|---|
| 11: 02 (20 minutes) | Brown | Liquid | + |
| 11: 22 (40 minutes) | Dark brown | Liquid (with clots) | ++ |
| 11: 42 (60 minutes) | Dark brown | Liquid | + |

Note: Bio-crude oil's color, appearance, and viscosity (viscosity level: + low; ++ high) at different time intervals

Observation of the bio-crude oil's production are observed in three-time intervals. Wherein, the bio-crude oil's color of the generated bio-crude oil in the peak of the conversion became dark brown [14] from a lighter hue of brown in the first 20 minutes of the process. The differences in terms of color are caused by the concentration of the hydrogenated steam together with the clots in appearance which resulted in a dark brown hue.

In terms of the level of viscosity, the generated bio-crude oils in 20 minutes of conversion have a low state of viscosity based on how it flows in the transparent container. At 11:22am, 40 minutes after clots of bio-crude oil have been shown which affects the concentration making it more viscous. The production of some clots began after 40 minutes of thermochemical conversion making the viscosity of the bio-crude oil to be much free fluidity state of oil yields [15]. While the overall heat transfer coefficient or the temperature, the amount of feedstock as well as the possible water content directly affect the production of bio-crude oil in terms of its viscosity. Showing that the temperature, water content, and solid content are seen as the major factors which play a significant role affecting the viscosity of the bio-crude oil. Pyrolysis oils are emulsion-like fluids and can be 400 times more viscous than water. With that, an increase in the possible water content according to the study decreases the viscosity of the bio-crude oil, if an insertion of oxygen in the process takes place.

### By-products Produced after Undergoing Pili (Canarium ovatum) Sawdust in Thermochemical Conversion Process

After 1 hour of converting Pili (*Canarium ovatum*) sawdust in thermochemical conversion process, whereas the changes in feedstock's composition taking place in a standard protocol involving right temperature to generate by-products such as biochar and the synthesized biogas.


**Figure 2.** Amount of the generated bio-crude oil

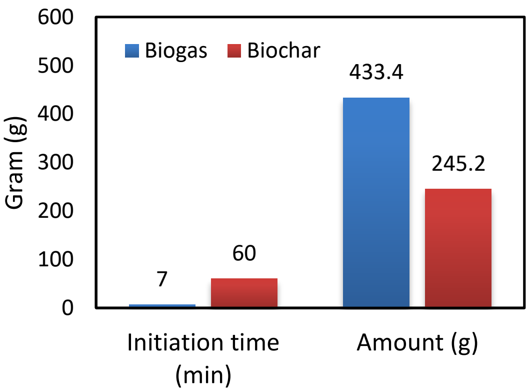


**Figure 3.** Production of the bio-crude oil's by-products in grams (g)

The figure 3, shows that biochar was produced after 1 hour of conducting slow pyrolysis. On the other hand, biogas starts to produce in 7 minutes while undergoing the slow pyrolysis process.

Slow pyrolysis of Pili (*Canarium ovatum*) sawdust at 340 °C, generated 242.2 g of biochar which yields 24.52 % and 433.4 g of biogas which yields 43.34 %. The generated biochar is in a solid state while biogas is in a gas state.

The study of Zhu et al. (2018), stated that biochar can be produced from a solid residue formed in the pyrolysis of biomass [16]. Pyrolysis is the thermochemical decomposition of biomass at a temperature between 350-700 °C in the absence of oxygen. It was concluded that temperature and heating rate have a significant effect on the production of biochar and other by-products. Similar to the study of Guida et al. (2020), which shows that the yield of biochar and biofuel is being affected by the heating rate and temperature that is being used in the process of pyrolysis [9].

Another by-product that can be produced out of wood residue in the process of thermochemical conversion is the biogas. According to the study of Nahil, (2016), biogas is proven to be produced out of wood residues [17]. They also stated that the composition of the product gases was also influenced by the heating rate.

**Physical Characteristics of the Generated By-products After Conducting Thermochemical Conversion**

The by-products' characteristics will also be described upon their physical composition. In the case of biogas in which physical appearance cannot be described, the researchers tend to present its potential and chemical affiliates which aligned to the significance of the research study.

After the Pili (*Canarium ovatum*) sawdust undergoes thermochemical conversion process for one-hour, generated by-products such as biochar and biogas from the production of bio-crude oil were produced.

Table 3 shows the results of the slow pyrolysis in terms of the physical characteristics of the generated by-products. At 340 °C, flammable biogas was produced, and biochar is black in color. The biochar is in a solid state with a porous appearance while the biogas is in a gaseous state.

The study of Chen et al. (2011), shows similarities as they stated in their study that the biochar produced has the appearance of fine-grained and porous substance [18], similar to the appearance of charcoal that is produced by pyrolysis of biomass under oxygen-limited conditions. It is also observed that the temperature has a great influence on the production of biochar. As the temperature increases, by-products can also change. The study of Uzun et al. (2006), stated that as the temperature increased, the appearance of biochar undergoes changes in form, size, and bulk volumes [19]. In their study, they describe biochar as a fibrous substance in terms of its appearance.

**Table 3.** Physical Characteristics of the Generated By-products After Conducting Thermochemical Conversion.

| By-products | Color | Appearance |
|---|---|---|
| Biochar | Black | Porous and coarse grain |
| Biogas | Transparent | Gas in nature |

According to Selvarajoo (2022), the biochar is considered as good fuel with enhanced combustion characteristics and performance in comparison to raw biomass and can ignite nor flame if an external source of ignition occurs, such as static discharge or heat from friction [20]. Showing that the biochar is low in degree of flammability yet, by means of external heat, it can create a flame as the porosity and the fined coarse-grained of it are capable of sustaining flame once being ignited.

The study of Carvalho et al. (2017), states that an analysis of the flammability limits of the pyrolysis gas showed that it is flammable most of the operation time [21]. It supports that the biogas produced in the production of bio-crude oil using thermochemical conversion process specifically pyrolysis method is flammable.

This chapter presents the experimental-descriptive utilization of Pili (*Canarium ovatum*) sawdust in the production of bio-crude oil and the identification of the synthesized by-products using thermochemical conversion. It involves the presentation, analysis, and interpretation of all the data gathered for the production of the bio-crude oil and the synthesized by-products which focused on the physical characteristics in terms of color, appearance, and viscosity.

**CONCLUSION**

The production of bio-crude oil under thermochemical conversion generated 30% oil yields from the total 1000 g of Pili (*Canarium ovatum*) sawdust after 1 hour of the thermochemical conversion, which been attested flammable in its chemical nature. Showing that the production of bio-crude oil in a non-catalytic slow pyrolysis method of thermochemical conversion process. In the peak of the conversion process, the presence of some clots in the synthesized bio-crude oil resulted in a low state of viscosity. This factor also affects the color of bio-crude oil to have two hues, brownish on the first 20 minutes arrival and a dark brown color at the rest of the conversion process.

A change in temperature has a significant effect to the appearance of generated by-products such as biochar and biogas, as a low level of temperature from 340 °C protocol used in the study, will create a less efficient flammable biogas as it will create moisture to the reactor causing biogas to unsustain the flame when burn up. Biogas yields 433.4 g or 43.34 % in the production. The subtraction method was utilized by the researcher to identify the difference of the weight of the tire prior and post experiment weight which represent the production yields of the biogas. In terms of the production time, biogas exhibited a shorter time compared to the production of biochar as it can be gained after the conversion is done.

The thermochemical conversion process generated 242.2 g of biochar which yields to 24.52 % which resulted being porous and coarse grain in nature which make it flammable in nature when expose to ignition, but low in degree compared to the generated biogas which resulted high in terms of flammability with a thin smoke and a clear bluish color when ignited.

## RECOMMENDATIONS

The researchers recommend analyzing how biogas production under the thermochemical conversion process is to be pressurized in a collector for an ergonomic acquisition of the synthesized biogas. In addition, the analysis of the difference between the synthesized biogas from the slow pyrolysis under thermochemical conversion and the commercial liquified petroleum gas in terms of flammability and efficiency. It is also recommended to test if the porous physical characteristic of the biochar has a water-absorbent trait as it can open an opportunity to be used in the agricultural industry. The researchers also recommend compacting the biochar to become a brick coal subjected for potential commercial use and to test the potential of the biochar for agricultural benefits as its porosity and high-water absorbance can produce potentials in terms of agricultural needs.

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