Production of Liquid Smoke From the Combination of Coconut Shell and Empty Fruit Bunch through Pyrolysis Process

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Abstract. This study aims to produce liquid smoke that will be used as plant pesticide by means of pyrolysis of a mixture of two types of biomass, coconut shells (CS) and empty fruit bunches (EFB). The parameters used are the ratio of the mixture of the two materials and the pyrolyse temperature ranges from 300 to 500 ^oC. A reactor of 2 kg capacity with indirect heating is used for this study. Heat is obtained from LPG combustion using a burner. Feedstock used in the form of pieces of coconut shells aproximately 5 x 5 cm^2 and the EFB of 3-5 cm in length are first dried using sun energy until they reach a standard dryness. Three difference of feedstock mixture composed of CS and EFB based on mass ratio (Mr) of 25:75, 50:50, and 75:25 are used to know their effect on the liquid product yield. During the process, the smoke is passed through the cyclone to reduce tar content, and then flows into the condenser with a water cooling fluid. After the specified duration of pyrolysis is reached, the LPG is turned off and the furnace is left for cooling. After that, the pyrolysis products; the liquid smoke and the char are collected. The influence of operating parameters such as temperature, heating rate, process duration, and the feedstock mass ratio were considered associated with the quality of the liquid smoke.

Keywords: Empty fruit bunch, Coconut shell, Pyrolysis, Liquid smoke

1. Introduction

Currently, the agricultural sector in Indonesia still mostly uses chemical pesticides as plant pest control by killing pests that attack plants. However, the effect of using this material becomes very dangerous if it is not managed seriously because it can be toxic to the plants themselves, microorganisms in the soil, and humans as consumers of agricultural products. Therefore, a healthy and sustainabe agricultural culture must be built by finding solutions to chemical pesticide substitutes. Pesticides from biomass such as empty bunches of oil palm and coconut shells can be called biopesticides or biological pesticides and are known to be used to replace chemical pesticides. The form of this pesticide is in the form of liquid smoke that has an aroma and is not liked by pests, so its nature is to reject pests and not to be pest-eating. Apart from being a pest control method, liquid smoke can also increase plant immunity. Liquid smoke is a result of condensation or condensation of vapors from combustion directly or indirectly, which is called the pyrolysis process, from materials containing carbon compounds, especially from plants.

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Along with the development of knowledge and technology, pesticides from biomass, such as empty bunches of palm oil and coconut shells, can be called biopesticides or biological pesticides, and are known to be used to replace chemical pesticides. This form of this pesticide is in liquid form that has an aroma and is not liked by pests, so its nature is to reject pests and not to be pest-based. Apart from being a pest control method, liquid smoke can also increase plant immunity. Liquid smoke is a result of condensation or condensation of vapors from combustion directly or indirectly, which is called the pyrolysis process, from materials containing carbon compounds, especially from plants.

The production of liquid smoke has begun to be carried out for use as an organic fertilizer. Industries that use wood as a raw material to produce wood charcoal also produce liquid smoke. Usually wood is burned directly to get thermal energy with uncontrolled air so that it causes emissions and combustion fumes that are simply released into a free environment, which of course results in air pollution. However, in addition to producing thermal energy contained in combustion smoke, it turns out that hot smoke itself still has very useful substances and has high economic value [1, 2], and can even be exported abroad, as done by the industry's P.T. Bio Energi Rimba, assisted by PT KIM, which processes wood into wood charcoal and is marketed abroad

P.T. Bio Energi Rimba's superior products are liquid smoke and wood charcoal. The process used is the lamba pyrolysis process, using a furnace made of clay. It takes several large-capacity furnaces to increase the production of wood charcoal according to market demand. The smoke that arises is converted into a liquid form by lowering its temperature using a cooling device. By using simple equipment, namely using several series of drums with natural cooling, smoke is condensed there to convert it into liquid smoke.

With a simple process, P.T. Bio Energi Rimba produces liquid smoke, but it is still in the grade three category with a typical blackish-brown color because it still mixes with tar. By allowing liquid smoke for a few days, the tar content will settle, and liquid smoke can be used in agriculture. Currently, liquid smoke has also been widely used as a pesticide to replace chemical pesticides [3, 4]. Currently, P.T. Bio Energi Rimba is developing a liquid smoke business so that its quality can be improved so that it is suitable for use as a pesticide. The content of liquid smoke, both in quality and quantity, can be increased through *co-pyrolysis efforts*, where two or more biomass/raw materials are processed in one reactor. The physical and chemical properties of liquid smoke can be improved through such means.

This study aims to identify the components of liquid smoke that will be used as pesticide ingredients by means of pyrolysis mixed with two types of biomass: *empty fruit bunches* and coconut *shells*. The parameters used are the ratio of a mixture of both raw materials and the pyrolyse temperature, which is between 250 and 450 ^oC. The characteristics of liquid smoke obtained are better than the results of pyrolysis individually, which can be used mainly as an environmentally friendly plant pest control compared to chemical pesticides.

2. Literature study

2.1 *Liquid organic pesticides*

Pesticides are herbs used to control pests and plant diseases. In addition to chemical pesticides, organic pesticides taken from organic wastes, biomass, animals, and microorganisms can also be used as pest control and are known to be more environmental friendly and secure for human life. Until now, the agricultural sector in Indonesia mostly uses chemical pesticides as plant pest control by killing pests that attack plants. However, the negative effect of using this material becomes very dangerous if it is not managed seriously because it can be toxic to the plants themselves, microorganisms in the soil, and humans as consumers of agricultural products. Therefore, a healthy and sustainable agricultural culture must be built by finding a solutions to chemical pesticide substitutution.

Pesticides from biomass such as coconut shells and empty fruit bunches are named biopesticides or biological pesticides and highly potential to be used to replace chemical pesticides. This pesticide is in the form of a liquid, which has a scent and is not liked by pests, so its nature is to reject pests and not to terrify them. Apart from being a pesticide, organic pesticides can also increase plant immunity. This pesticide is resulted from condensation of vapors of a thermochemical process, which is called the pyrolysis process, from materials containing carbon compounds, especially from plants.

2.2 Liquid smoke

Liquid smoke, also known as bio-oil, contains a wide range of compounds such as phenols, carbonyls, acids, furans, alcohols, lactones, hydrocarbons, aromatic polycyclics, and others. Liquid smoke products resulting from pyrolysis at medium to high temperatures, often referred to as wood vinegar, are known to have potential to be used as a flavor enhancer in the food industry. The liquid smoke produced from the biomass pyrolysis process can reach products by about 30% to 70% by weight.

To produce liquid smoke products in accordance with the purpose of product application, whether as bio-fuel or other products such as wood vinegar or pestide, a deeper study of the effects of important parameters in the pyrolysis process is needed. In addition to liquid smoke, there are several products produced from the biomass pyrolysis process, namely tar, solids, and non-condensed gases. The composition of liquid smoke obtained from the biomass pyrolysis process is grouped according to the type of chemical components, namely phenol compounds, carbonyls, ketones, aldehyde acids, polycyclic compounds, and aromatic hydrocarbons. Phenol compounds act as antioxidants so that they can extend the shelf life of the product. Acidic compounds in liquid smoke have an antibacterial role and form the taste of absorbed products.

In the processing of crumb rubber, the use of liquid smoke can speed up the drying process of rubber sheets. The drying time can be faster by 3 to 4 days compared to using formic acid. It can also reduce the odor from the rubber plant. Even rubber farmers in Bandar Mataram, Central Lampung, have used liquid smoke to remove the smell of rubber sap rot or latex.

2.3 Coconut shell (CS) and Empty fruit bunch (EFB)

The main components present in CS and EFB are hemicellulose, cellulose, and lignin. Hemicellulose is composed of pentosane and hexosane. Pentosan is found in hardwoods while hexosanes are found in softwoods. Pentosan undergoing pyrolysis produces furfural, furan, and its derivatives as well as carboxylic acids. In addition to hemicellulose, the CS and EFB contains cellulose and lignin. The most important products of cellulose pyrolysis are acetic acid and phenol in small quantities. While lignin pyrolysis produces aromas that play a role in fumigation products. One of the processes for making liquid smoke uses coconut shells, which are the remaining waste after making coconut oil. In the coconut shell, there is a liquid smoke content that has phenol content that plays a role in preserving food naturally.

Liquid smoke is prepared from a single wood pyrolysis or from a mixture of biomass or copyrolysis. Liquid smoke components must be dissolved in water or organic solvents or carried by binders such as herbs, sugar, flour, salt, or fat. Coconut shell smoke distillate has the ability to preserve foodstuffs due to the presence of acidic compounds, phenolics, and carbonyls. The liquid smoke contains more than 400 components and has the function as an inhibitor of bacterial development, which is quite safe as a natural preservative, including acids, phenolics, and carbonyls.

Empty fruit bunches are one of the by-products in the form of solids from the palm oil processing industry. EFB of oil palm have considerable potential to be utilized and processed into liquid smoke. In Indonesia, the production of empty bunches is very abundant; it can reach 30-35% of the weight of fresh fruit bunches per harvest. It is known that empty bunches of palm oil also contain high lignocellulose ingredients, consisting of three main fiber-type components, namely lignin, cellulose, and hemicellulose.

2.4 Co-pyrolysis

Coconut shell and empty fruit bunch have a complex structure, which shows differences in thermal decomposition. Thus, allowing a synergistic effect between them, both in quantity and quality, when pyrolyzed together, or co-pyrolysis. Several researchers have conducted studies to find out the beneficial of co-pyrolysis of coal and biomass. The position of pyrolysis technology among thermochemical processes is superior because it can produce high-value products and relatively easy to use. The gasification process indeed has the advantage of producing high calorivic value producer gas, but in terms of reactor and operation, it is more complicated than pyrolysis [5-10]. Slow pyrolysis is the most preferred by industrial of wood processing enthusiasts because it can produce high-grade charcoal and bio-oil for trading. Usually, the thermochemical process route of biomass as shown in Fig. 1.

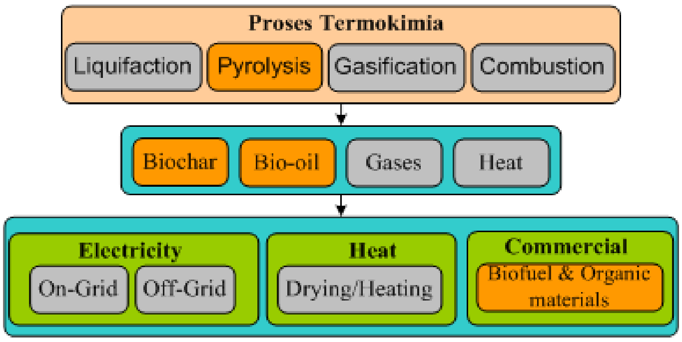

Figure 1. Thermochemical route of biomass conversion

Pyrolysis is a very dependent on heat supplied but allows chemical reactions to occur that can improve the quality of the product with regard to residence time [11, 12]. Not only organic materials, but an-organic materials such as plastics, can also be processed to produce liquid fuel [13]. From the rapid search conducted by the research team at Scopus, a lot of research on the pyrolysis or carbonization process, even today, continues to be carried out, but only limited to bench-scale experiments, also in the form of modeling or analysis [14, 15], where pyrolyse furnaces use thermal energy from electricity or other sources [16-19], or even use micro-waves

[20, 21]. Theories of pyrolysis and product quality improvement such as biochar and bio-oil are very much discussed and researched [22, 23]. However, research on the co-pyrolysis process is rarely studied. Such pyrolysis is potential to improve the quality of the liquid smoke [24].

The pyrolysis process does not need oxygen, but the process itself requires thermal energy (an endothermal process). Therefore, an independent heating system is needed to make the pyrolyze furnace design more flexible and very easy to control [24]. After all, the industry will prefer it when the energy source for the production process is obtained at a low price. In addition, the source of thermal energy for the pyrolysis process can actually be obtained from biomass combustion furnaces with a relatively high combustion smoke temperature [25-28].

It is undeniable that the operational temperature of the furnace is the most basic thing in the pyrolysis process. To date, the effect of temperature and heating rate on product quality has become the most studied [29-33]. However, the operational temperature of the process is actually very difficult to maintain, which is very dependent on the energy source used. Regarding pyrolysis furnace technology, fixed-bed type furnaces are the most popular in the industry because their operation is relatively easier compared to fluidized-bed types. Research that examines the pyrolysis process with relatively large wood sizes is also very rare. Most researchers are only interested in small biomass sizes, which are, of course, easy to pyrolyze.

This study aims to improve the quality of liquid smoke by the pyrolysis of two types of biomass in one reactor. The slow pyrolysis method was chosen to achieve the intent and purpose of producing as much good liquid smoke as possible.

3. Materials and Method

Materials as feedstock used in this study were coconut shells (CS) and empty fruit bunches (EFB). Both materials are cut according to the size of the specimen under investigation and dried in the sun to reduce moisture content as shown in Fig. 2. The CS were cut to aproximately 5 x 5 cm^2. Such the CS size produce the best liquid smoke quailty of the single CS pyrolysis [34]. Whilst the EFB was cut into average 5 cm length. The mass ratio (Mr) of CS and EFB of 25:75, 50:50, and 75:25 respectively are used to study their effect on the liquid smoke product yield.

Figure 2. Coconut shell and empty fruit bunch

Tabel 1. Chemical composition of coconut shell and empty fruit bunch

Substance	Coconut shell (%)	Empty fruit bunch (%)
Lignin	33.30	29.4
Sellulose	30.58	26.5
Hemicellulose	26.70	27.7

The total 2 kg of the feedstock with a dryness standard was inserted into the pyrolysis system as shown in Figure 3. The hot gas stream from the combustion of LPG is used as heat energy to raise the temperature in the reactor to a recommended working temperature ranges from 300 to

500 °C [35]. As a result of heating, the feedstock begins to undergo decomposition to produce volatile substances that can be condensed, hereinafter referred to as smoke. With a set pyrolysis time (29 minutes) for slow pyrolysis models [36], that is, the standard time for slow-type pyrolysis processes with the main products being charcoal and bio-oil.

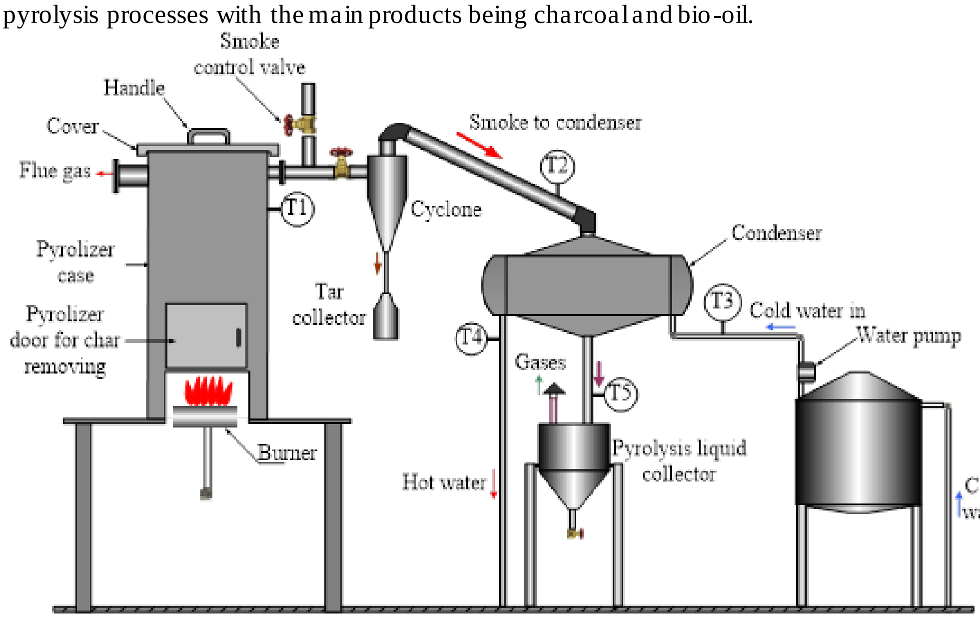

Figure 1. Schematic diagram of experimental rig used

Several thermocouples are used to monitor the temperature during the process, especially the temperature inside the pyrolysis chamber. This temperature is very important because it will determine the temperature conditions in the pyrolysis chamber. The temperature of the hot flue gas in and out of the reactor is measured to find out the thermal energy needed (kW_{th}) during process. Heating time is also under monitored as it responsible to determine the product quality. In this study, heating time was set at 40 °C/min [36]. A cyclone is used to reduce the tar content in the liquid smoke before enters the condenser. With the water cooling fluid in the condenser and with the established construction and operational parameters, the smoke will condensed.

For the purposes of analyzing the performance of the condenser, the smoke temperature (T_2), the water cooling temperature in (T_3), and out (T_4) of the condenser are measured. It is possible that flammable gases are also formed and come out of the condenser. During the pyrolysis process, the yields of liquid smoke, biochar, and the gases are collected and calculated by using equations (1) to (3).

$$\text{Liquid smoke } = \frac{\text{Yield}}{\text{Feedstock}} \times 100\% \tag{1}$$

$$\text{Biochar } = \frac{\text{Char}}{\text{Feedstock}} \times 100\% \tag{2}$$

$$\text{Gases } = 100\% - (\%\text{liquid} + \%\text{ biochar}) \tag{3}$$

4. Result and Discussion

4.1 Reactro temperature profile

One of the important parameters in carrying out pyrolysis is the operational temperature. Fig 4. shows the test results of the pyrolysis reactor used related to the operational temperature that can be achieved. T1 indicates the temperature of the pyrolysis reactor where the thermocouple is placed on the feedstock, while T2 indicates the temperature at which the hot smoke is located and maintained over a period of time. The operational temperature of the pyrolysis process ranges from 250 to 600 °C. In this study, the operational temperature of the reactor of 500 ^{0}C can be achieved in approximately 45 minutes. This condition is sufficient for a slow pyrolysis category process.

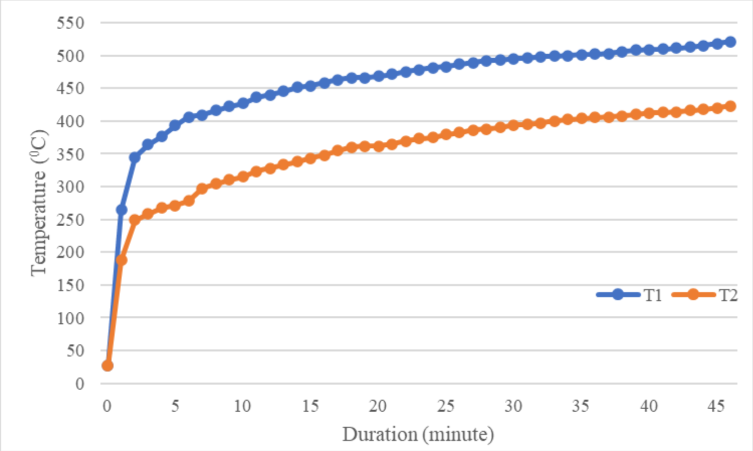

Figure 4. Temperature profile of the reactor

4.2 Data representation

Fig. 5 shows the yield of liquid smoke obtained during the pyrolysis process. From the picture it can be seen that the yield of liquid smoke obtained occurs at a temperature of about 400 °C. When the operational temperature is raised, the liquid smoke products decrease and produce more gas and charcoal. This is because at temperatures above 400 ^{0}C there is a follow-up reaction where volatiles are associated with the existing oxygen.

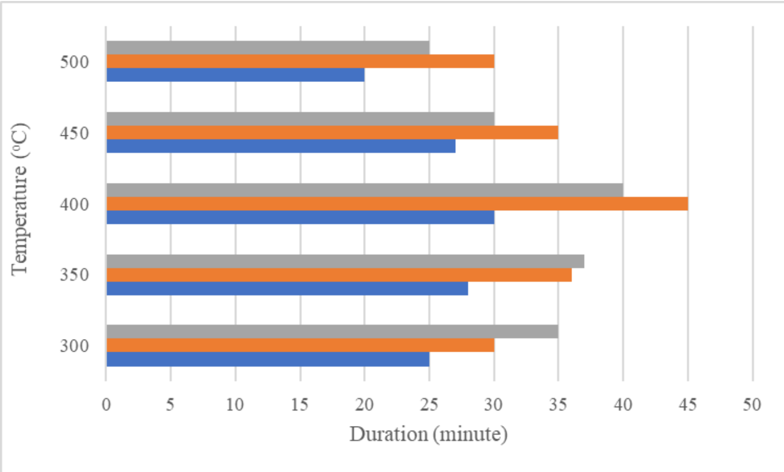

Figure 5. Data representation of copyrolysis in this study

4.3 Liquid smoke yields

The production of liquid smoke from coconut shell copirolisa and tankos increased by 17.5 % when compared to the acquisition of liquid smoke from coconut shell pyrolysis at the same mass and temperature [34]. This is due to the increased potential of liquid smoke that can be processed from the contribution of the two biomass used as shown in Table 1. The study also had similarities with the results of combined pyrolysis of palm shells with coconut shells [37]. Because the characteristics of biomass is vary, copyrolysis has the potential to improve the yield and quality of the liquid smoke produced [38, 39].

4.4 Effect of feedstock ratio on the liquid smoke product

In carrying out mixed pyrolysis, it is very necessary to pay attention to the dominant factor, where feedstocks that have a tendency in chemical composition are made to have a higher portion of the mixture [40]. In this study, it was found that coconut shell has a greater chemical content than empty fruit bunches. However, this study showed that at a ratio of 50:50, the yield of liquid smoke was the largest and higher than that of the coconut shell pyrolysis alone. The production of liquid smoke from empty fruit bunches also increases when mixed with coconut shells. With relatively the same heating rate and temperature, a yield of 40% is obtained which is greater when pyrolyzing empty fruit bunch is carried out alone by 35% [41]. So it is indeed very profitable when the pyrolysis is done together between coconut shells and empty bunches.

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