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Pyrolysis of Coconut Coir and Shell as Alternative Energy Source

Khalimatus Sa'diyah✉, Fatchur Rohman, Winda Harsanti, Ivan Nugraha, Nur Ahmad Febrianto

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Politeknik Negeri Malang, Jalan Soekarno-Hatta No.9 Malang, Indonesia

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Abstract

Biomass waste can be used as raw material for bio-oil manufacture. One of the biomass is coconut coir and shell waste, commonly used as a substitute for firewood and handicraft materials. Therefore it takes effort to use coconut coir and shell to increase its economic value. One of the waste processing efforts is through pyrolysis process. Pyrolysis is the heating process of a substance in the absence of oxygen and produces products of solids, liquids and gases. The product of pyrolysis liquid is called bio-oil which can be used as alternative energy source. In this study, coconut coir and shell was pyrolysed as bio-oil. It also studied pyrolysis operating temperature and the amount of yield of bio-oil produced. The pyrolysis process was carried out in a reactor with a pressure of 1 atm and a varying operating temperature of 150 °C, 200 °C and 250 °C for 60 minutes. The reactor was equipped with a condenser as a cooling column. The mass of raw materials used was 500 grams with a size of 0.63 mm. The results of the research show that the higher the temperature, the more volume of bio-oil produced. For coconut coir pyrolysis it was obtained the highest yield of 34.2%, with density of 1.001 g/ml and viscosity of 1.351 cSt. As for coconut shell pyrolysis it was obtained highest yield of 45,2% with density of 1,212 g/ml and viscosity of 1.457 cSt. From the result of analysis using FTIR, the functional group of bio-oil was the most compound of phenol and alkene.

**This is a revised and extended version of an article which had been presented at SNTK UNNES 2017, Semarang, Indonesia, September 20th, 2017.*

INTRODUCTION

Coconut coir and shell is a downstream product of coconut that is still often considered as solid waste. The existence of such waste creates problems for the environment because it is difficult to decompose or degrade naturally in the environment. The components of coconut solid waste consist of 21.07% cellulose and 43.44% lignin, while the coconut shell component consists of 27.31% cellulose and 33.30% lignin (Noor, 2014). Coconut coir and shell is a biomass that has the potential to be increased its usefulness and economic value. One of them is through pyrolysis process.

Pyrolysis is the chemical decomposition of organic matter through the heating process with no or little oxygen or other reagents, in which raw materials will break the chemical structure into gas phase. Pyrolysis which leaves only carbon as a residue is called carbonization. There are usually three products in the pyrolysis process: gas, liquid product, and charcoal. The vapor produced in the pyrolysis process contains carbon monoxide, methane, carbon dioxide, volatile tar and water. The steam is then condensed into a liquid. Pyrolysis is known as bio-oil (Laird et al., 2009). Bio-oil is a liquid fuel produced from biomass in a process known as fast pyrolysis to increase its viscosity. Bio-oil is also referred to as pyrolysis oil, liquid pyrolysis, wood liquid, wood oil, liquid smoke,

✉Corresponding author:
Politeknik Negeri Malang,
alan Soekarno-Hatta No.9 Malang, Indonesia
E-mail: khalimatus22@gmail.com

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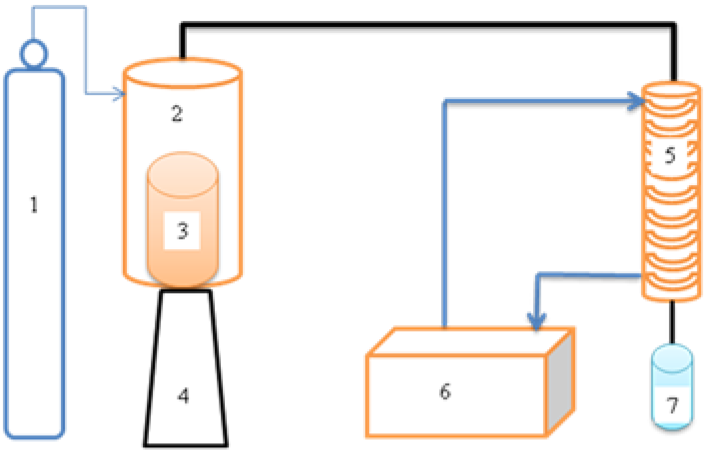


Figure 1. Sketch of Pyrolysis Apparatus


Figure 2. Pyrolysis Reactor Equipped with Condenser

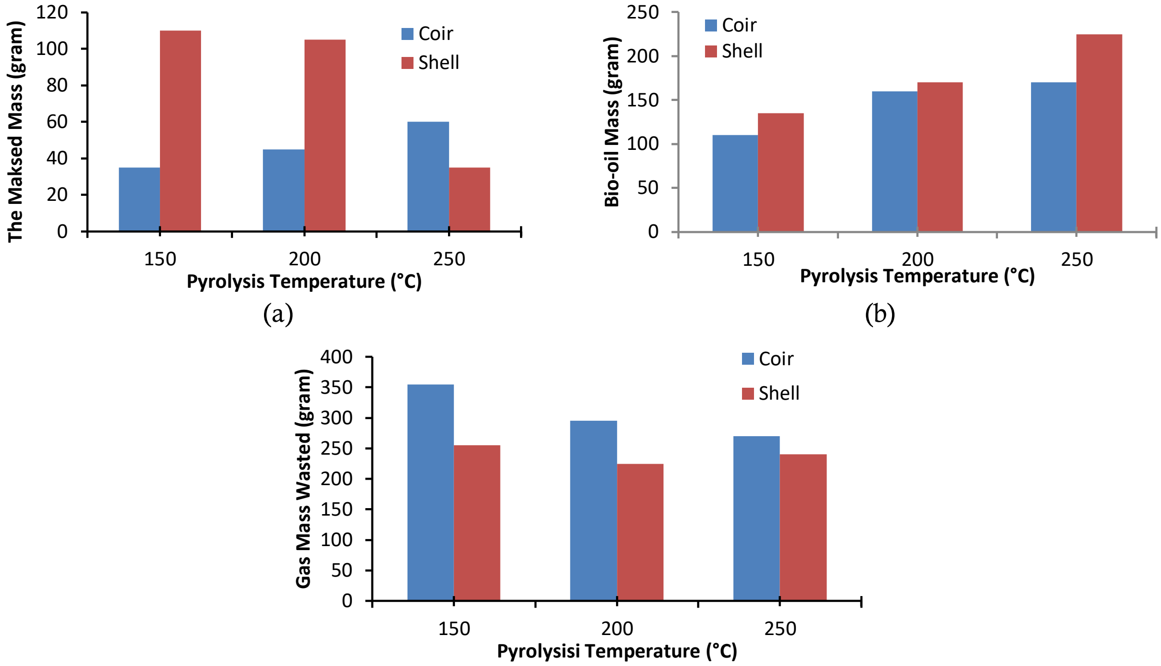
wood embroidery, and liquefied wood. Bio oil is acidic (its pH ranges from 2 to 4) and can be corrosive (Mohan et al., 2006).

According to Tahir (1992), in the pyrolysis process produced three kinds of classification of products are the gases released in the carbonization process are mostly CO_2 gas and some are flammable gases such as CO, CH_4, H_2 and other low-level hydrocarbons; distillate in the form of liquid smoke and tar, the main compositions of the product are methanol and acetic acid and the other part is a minor component of phenol, methyl acetate, formic acid, butyric acid and others; residue (carbon): wood has almost the same components. The content of cellulose, hemicellulose and lignin in wood varies depending on the type of wood. In general, wood contains two parts of cellulose and one part of hemicellulose, and one part lignin. As for the pyrolysis process there is a decomposition of its compounds.

Technology development of biomass pyrolysis into fuel has been widely used to produce better fuel and wider use. In this research it will be studied about the effect of pyrolysis temperature and quantity and quality of liquid product from coconut coir and shell pyrolysis. Pyrolysis liquid product is strongly influenced by the condensation process. It is expected that the liquid or bio-oil product produced has the quality of density, viscosity, pH and functional groups corresponding to the fuel fraction.

RESEARCH METHODOLOGY

The raw materials used for the manufacture of liquid smoke in this study are coconut coir and shell which has been dried, milled and sieved with size <0.63 mm. The raw materials used pyrolysis 500 grams. The Pyrolysis process was carried out in an unstirred stainless steel spring batch reactor which operates at atmospheric pressure 1. The pyrolysis reactor was equipped with a condenser as a cooling column as shown in Figure 1.



(a) (b)

(c)

Figure 3. Results of Pyrolysis Processes at Temperature Variables: (a) The Masked Mass Time of Pyrolysis; (b) Bio-oil Mass Result of Pyrolysis; (c) Gas Mass Wasted on Pyrolysis Processes

At the time of the pyrolysis process the sample was heated according to the temperature variables of 150, 200 and 250 °C with a residence time of 60 minutes. Then the pyrolysis solid product was weighed by the weight of the ash and for its bio-oil analyzed by weight, volume, density, viscosity, pH and functional group content using FTIR.

RESULTS AND DISCUSSION

The results of this study found solid product in the form of ash residual pyrolysis process that has not vaporized and liquid products in the form of bio-oil. The ash and bio-oil mass produced in the pyrolysis process is shown in Figure 3.

According to Figure 3, coconut coir pyrolysis produces less ash and bio-oil mass than the coconut shell pyrolysis, but much less wasted or non-condensed mass. Water content in the coconut coir was 25.09% while in the coconut shell of 14.47% (Noor, 2014). Coconut coir which has higher moisture content than coconut shell tends to produce more condensate because the water content in the volatile material. So that the pyrolysis residual ash mass in coconut coir becomes smaller.

From Figure 3.b, the bio-oil mass of the coconut shell was relatively larger because the hemicellulose and coconut shell cellulose are higher than the coconut coir. Coconut coir has 8.5% hemicellulose; 21.44% cellulose and 29.23% lignin, while coconut shell has 19.27%hemuselulase; 33.27% cellulose and 36.51% lignin (Nurhasanah, 2008). In pyrolysis process there are some reaction process that is decomposition, polymerization, and condensation. The processes that occur during pyrolysis of biomass are: removal of water from wood at a temperature of 120-150 °C, hemicellulose pyrolysis at a temperature of 200-250 °C, cellulosic pyrolysis at a temperature of 280-320 °C and lignin pyrolysis at 400 °C (Maga, 1988; Girrard, 1992). In this study the pyrolysis temperature used was <250 °C. So the more decomposed components are hemicellulose and cellulose.

The non-condensed vapor in this study will be wasted into the environment. In the coconut coir, the mass wasted was more than the coconut shell. This was because the coconut coir consists of fiber and pitch that easily decomposes into tar or fly ash making it difficult to condense and wasted into the environment.

From Figure 4 it is found that the yield of bio-oil obtained from coconut coir and shell pyrolysis, the higher the pyrolysis temperature, the higher yield of bio-oil would be. Most bio-oil yields are produced in coconut shell pyrolysis of 45.20% at a temperature of 250 °C. Pyrolysis is affected by time, water content of materials, temperature, and size of materials. High process temperatures will decrease the ash yield, while the liquid and gas yields increase. This is due to the increasing number

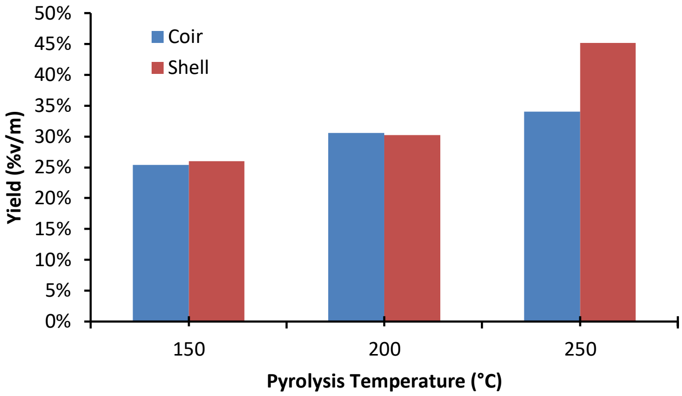


Figure 4. Yield of Bio-oil obtained from Pyrolysis

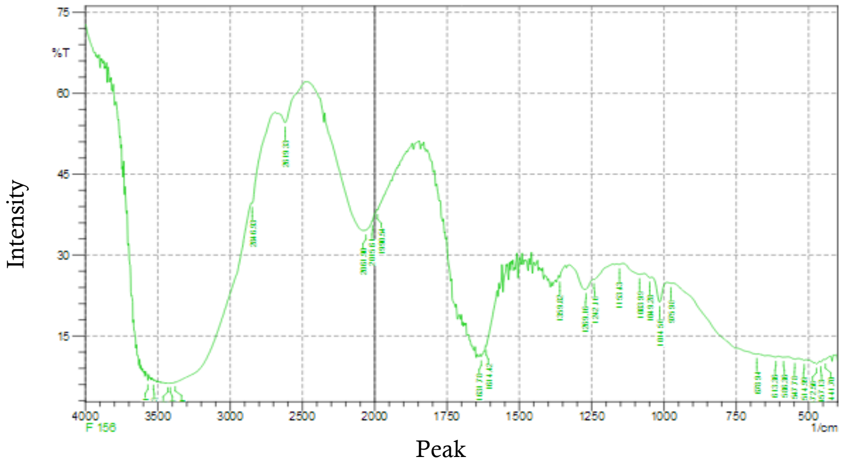


Figure 5. FTIR result for Bio-oil from coconut coir

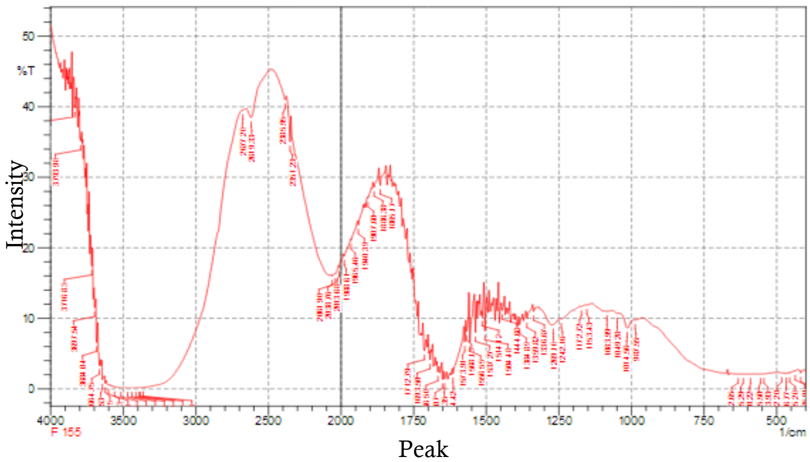


Figure 6. FTIR result for Bio-oil from coconut shell

of substances that decompose and evaporate. Therefore there would be more condensed vapor (Budhijanto, 1993).

The bio-oil density is affected by the heating temperature. Based on SNI 7182-2015 bi-oil density resembles biodiesel that is 0.850-0.890 gram / ml. The higher the pyrolysis temperature, the resulting bio-oil density is smaller and closer to the SNI value. If compared to the density of SNI 7182-2015, the pyrolysis bio-oil density is higher and closest to the SNI value is at 250 ° C. The bio-oil density of coco fiber pyrolysis is closer to the value of SNI than the bio-oil of coconut shell which is 1.0012 gram/ml.

Table 1. Physical characteristic Bio-Oil of Pyrolysis

Raw Material	Temperature (°C)	Bio-Oil		
		Density (gram/ml)	Viscosity (cSt)	pH
Coir	150	1.0412	1.3610	3
	200	1.0152	1.4574	2
	250	1.0012	1.3507	3
Shell	150	1.0212	1.4056	2
	200	1.0172	1.5411	2
	250	1.0120	1.4574	3

Viscosity describes the internal resistance of the fluid to flow. The lower the viscosity of a fluid, the greater the movement of the fluid would be. Based on SNI 7182-2015 the viscosity of bio-oil is 2,3-6 mm^2/s (cSt). Bio-oils from pyrolysis have lower viscosity than SNI. This is due to the considerable water content in the condensed liquid (Wahyu Widodo et al., 2012).

The pH value of bio-oil resembles the pH of biodiesel which is 5. Bio-oil pyrolysis result has lower pH than commercial bio-oil. This can be caused by two factors, namely the low content of acid compounds and increased water content in the bio-oil. High acidity levels in bio-oil cause corrosive properties that cannot be applied as fuel (Wahyu Widodo et al, 2012).

Bio-oil from coconut fiber and shell which has the greatest yield is analyzed by FTIR to determine its functional group. FTIR results are shown in Figure 5 and 6.

From the FTIR results it is found that the wave numbers in the highest powder and shell pyrolysis of bio-oil are the same which was in the 3200-3600 cm^{-1} wave indicating the presence of hydrogen or phenol bond and at wave 1610-1680 cm-1 indicating the presence of cluster C = C alkene. The phenol compounds present in the biomass are generally aromatic hydrocarbons composed of benzene rings with a number of bound hydroxyl groups. In the fuel the aromatic hydrocarbon groups can increase the octane number (Fauziati & Sampepana, 2015). Alkena group function C = C as n-paraffin is the main constituent of bio-oil to be fueled (Sa'diyah et al., 2015).

CONCLUSION

The highest yield of coconut coir pyrolysis was 32.4%, while the highest yield of coconut coir pyrolysis was 45.2%. The optimum pyrolysis temperature was 250 °C. Physical properties of bio-oil from coconut coir and shell were density, viscosity and pH, not in accordance with SNI 7182-2015 about bio-oil characteristics. FTIR results for bio-oil from coconut coir and shell contain phenolic and alkene groups which have the potential to be used as fuel.

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