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Characterization of Pyrolysis and Gasification Product of Cashew Nut Shell Waste

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Abstract

This research examines the characteristics of pyrolysis and gasification product of cashew nut shell waste. Pyrolysis products such as charcoal, oil, and tar were analyzed using proximate testing, scanning electron microscope, x-ray diffraction, and chromatography at pyrolysis temperature of 600°C and 900°C. The gasification products such as tar and gas were analyzed using chromatography at the addition of oxygen and the absence of oxygen and heating time was observed. The result shows that charcoal products of pyrolysis obtained higher heating value (HHV) equal to 6853 kcal/kg and 6474 kcal/kg at 600° and 900°C of pyrolysis temperature respectively. Scanning electron microscope result of charcoal shows a non-uniform pore size of 2 to 10 µm. Oil viscosity was obtained at 0.9528 cP and tar content was dominated by phenol compound group of 46.52%. The gas content of the gasification product of cashew nutshell waste was dominated by propane of 44.20% with a higher heating value of 938.24 kcal/kg. The heating time with the addition of oxygen takes a longer time of 10% to 45% than in the absence of oxygen.

1. Introduction

The cashew tree (anacardium occidentale) is a tropical evergreen tree that originally came from Northern South America. Later on, this plant grows in some tropical countries including Indonesia. In Indonesia, it is locally named as *Jambu Mete* and mainly planted in several regions including west Sumatra, Lampung, north and southeast Sulawesi, west Nusa Tenggara, central and east Java[1]. The cultivation process is relatively easy. Data reported by Indonesian ministry of agriculture on 2009, there are 570,000 ha of cashew tree cultivated area with production of cashew nut around 142,000 metric tons/year[2]. The main products of the cashew are pseudo fruit (cashew apple) and cashew nut. The cashew nut consist of the shell nut and the kernel. The shell of the nut is approximately 1/8 inch thick and become a potential agriculture byproduct to produce cashew nutshell liquid.

Previous studies have reported the utilization of cashew nutshell liquid (CNSL). A single cylinder compression ignition engine was successfully operated using neat CSNL with various blends of oxygenated, alcohols, and vegetable oils[3]. In material application, CSNL was used as bio-resin, that when it combined with glass or carbon, the composite materials will have a greater renewable content and minimizing greenhouse gases typically associated with petroleum based resin[4][5]. The cashew nutshell extract was also reported as the most prominent source of antioxidants compare to coconut oil and groundnut hull[6]

Several attempts have been made to produce CSNL. A number of researches have reported pyrolysis method of cashew nutshell. Pyrolysis process comprises the thermal degradation of materials in the absence of oxidizing agents leading to the formation of solid (char), liquid (bio-oils), and gaseous products. Two step pyrolysis of cashew nutshell in a fixed bed pyrolysis reactor with temperature of 175°C was reported produced dark brown oil and combustible oil fraction.

These oils were found to have a unique characteristic with the presence of long linear chain in the compounds, which is become an excellent solubility in diesel oil and light lubrication oils[7]. CNS oil with caloric value of 40 MJ/kg, near to that of petroleum fuel was produced in a packed bed vacuum pyrolysis unit. At pyrolysis temperature of 500°C, the optimum yielding of the maximum percentage of oil was obtained[8]. In a laboratory-scale fixed bed reactor, a feasibility of obtain solid and liquid fraction usable as a fuel was demonstrated at the pyrolysis temperature between 400 and 600 °C[9].

At the higher temperature rather than pyrolysis process, studies of the gasification process of cashew nutshell have been explored. Gasification is a thermochemical process at high temperature (800 – 1100°C) in the presence of gasifying agents such as air, steam, and oxygen to produce a gaseous products. A simple downdraft fixed bed gasifier was developed to consider the potential use of cashew nutshell as replacement fuel for wood. A high energy content and similar chemical composition of gas was obtained and generated less waste[10].

2. Experimental

The experimental apparatus scheme is shown in fig.1. A 0.5 g of cashew nutshell was put in the reactor then heated using a burner. In the pyrolysis step, cashew nutshell was heated at vacuum condition of -15 Psi until temperature reach 600 °C and 900 °C. The pyrolysis of cashew nutshell generated products such as gas, oil, and char. At the gasification step, an oxygen of 10% and 25% was injected in the reactor respectively at the same temperature of pyrolysis step. The gasification generated products of gas and char. Pipeline was used to distribute and separate oil and gas products of pyrolysis and gasification process. The proximate analysis (moisture, ash content, volatile matter, fixed carbon, and heating value) of char produced after pyrolysis was analyzed, and a scanning electron microscope (SEM) was used to study the surface feature of char produced. A viscometer was used to analyze oil and tar product. Gas composition characterization of gasification product was conducted using gas chromatograph.

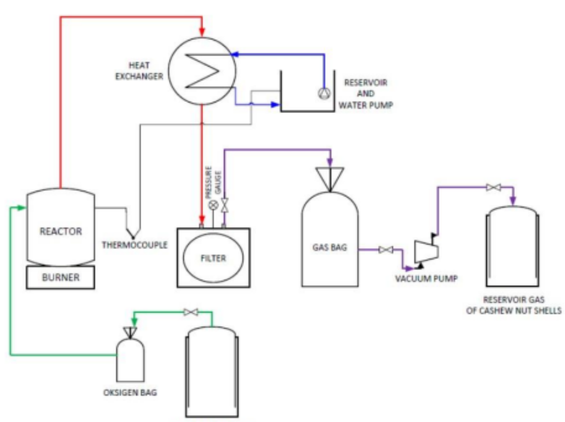

Fig. 1 Experimental apparatus scheme

3. Result and Discussion

3.1. Proximate Analysis

Table 1 summarized the solid products characteristics that were determined in this study. Char present a moisture in a range of 2.72 to 3.81 %, decrease around 80% at gasification step with temperature of 600°C with addition of 10% O_2. Low moisture content can ensure good quality gas production[11]. In the pyrolysis step, increasing temperature from 600°C to 900°C resulted decreasing content of volatile matter and moisture content, while increasing fixed carbon and ash content. These trends are in accordance with those studies reported in literature[9]. In the gasification process, increasing temperature will decrease moisture content and fixed carbon, while ash content and volatile matter tend to increase. At the gasification temperature of 600°C, the addition of O_2 from 10% to 25% result in the decreasing of moisture content and fixed carbon, while ash content and volatile matter were slightly increase. A high HHV of 7020 Kcal/kg was obtain in gasification step with addition of 25% of O_2.

Table 1. Characteristic of char produced

Condition	Composition (%)				HHV (Kcal/Kg
	Moisture	Ash	Volatile Matter	Fixed Carbon	
raw CNS	13.61	1.77	73.67	10.95	1962
600	3.78	12.64	26.04	57.55	6853
600 + 10% O2	3.81	9.88	28.19	58.12	6923
600 + 25% O2	3.64	10.16	28.3	57.9	7020
900	2.77	15.79	22.4	59.04	6474
900 + 10% O2	2.72	13.97	22.06	61.25	6583
900 + 25% O2	2.84	14.22	20.41	62.52	6606

3.2. Scanning Electron Microscope analysis (SEM)

SEM pictures of char product at temperature of 600 °C and 900 °C is shown in fig.2 and 3. The average pore diameter was found in a range of 2 μm to 10 μm.

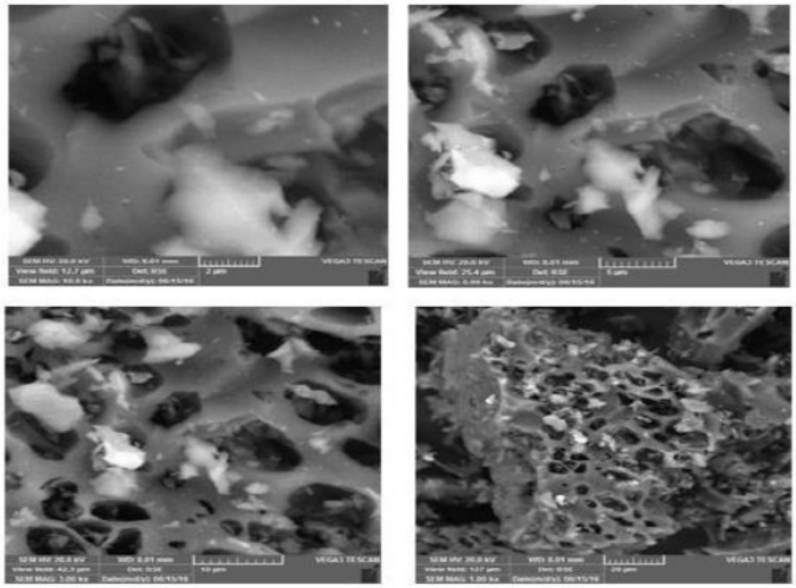

Fig. 2 SEM picture of char produced at 600 °C

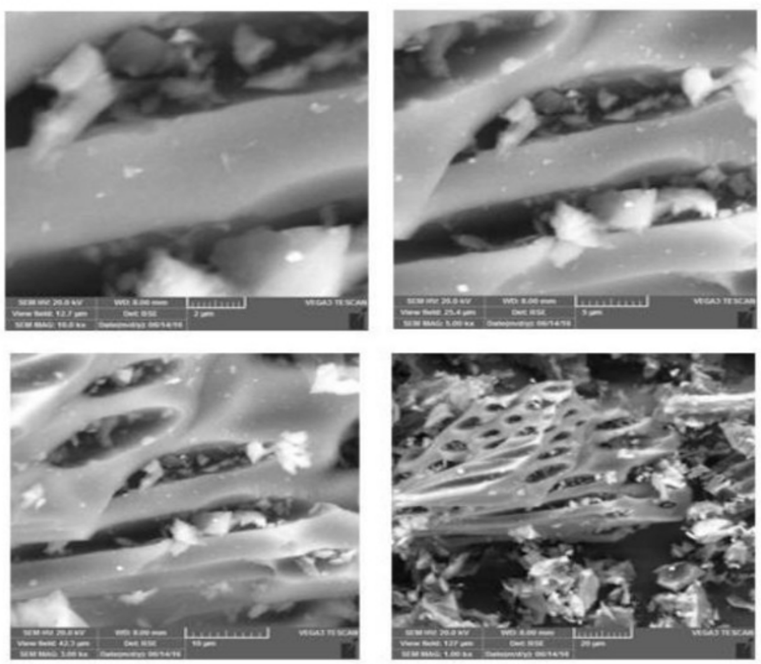

Fig. 3 SEM picture of char produced at 900 °C

3.3. Liquid and Tar product

Oil produced from pyrolysis product then analyzed using viscometer to obtain viscosity. It was found that CNS oil has a viscosity of 0.9528 cP. Tar product from pyrolysis process analyzed using GCMS-QP2010 Ultra Shimadzu. The peak is shown in figure 4. Strong peak was observed at 91° contained Phenol 3-pentadecyl with are of 14.85%. The high level of phenol also reported in the previous study[6].

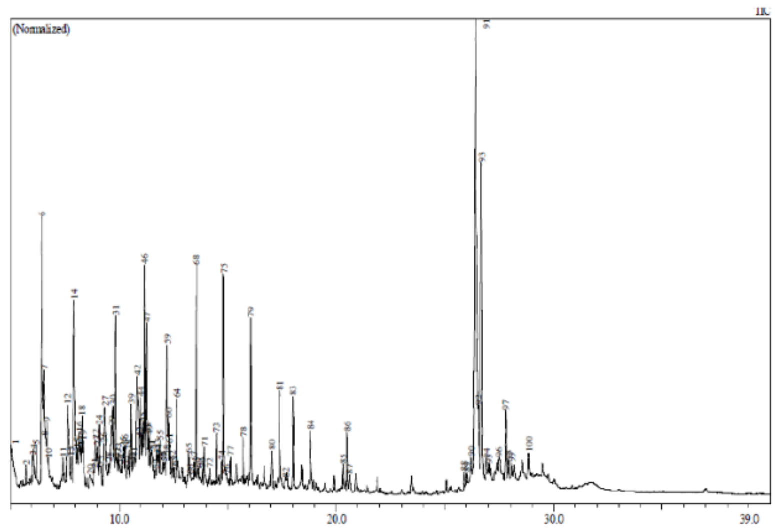

Fig. 4 Gas Chromatography peak of Tar from pyrolysis product

3.4 Gas product

Characterization of gas produced from pyrolysis and gasification of cashew nutshell was conducted using gas chromatograph (GCMS-ASTM D2163). The gas product obtained consist of some hydrocarbons such as methane, ethane, propane, n-butane, iso butane, n-pentane, and iso pentane. These values are presented in table 2.

Table 2. Gas composition of cashew nutshell

Component	Result (%liquid volume)
Methane	22.68
Ethane	22.4
Propane	44.2
n-Butane	2.71
iso butane	6.96
n-pentane	0.26
iso pentane	0.76

4. Conclusion

Cashew nutshell products have been studied using pyrolysis and gasification step. A higher heating value (HHV) of 7020 Kcal/kg in gasification step with addition of 25% of O_2. SEM pictures of char produced at temperature of 600 °C and 900 °C shown at average pore diameter of 2 μm to 10 μm. High phenol composition was detected at tar product, while viscosity of liquid product was observed at 0.9528 cP. Some hydrocarbon detected at gas product from gasification step.

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