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Production of Phenol From Liquid Smoke Resulted by the Pyrolysis of Cashew Nut Shells

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Abstract. Cashew nut shell is a waste from cashew nut industry. It contains liquid known as Cashew Nut Shell Liquid (CNSL) which has similar molecule structure with synthetic phenol. Phenol is a material for phenolic resin in preparation of varnish. The aims of this research are to determine the optimum temperature of pyrolysis for producing phenol liquid smoke and knowing the chemical composition of liquid smoke. This research used pyrolysis method at various pyrolysis temperatures were 200, 300, 400 and 500°C, respectively. The gas from the pyrolysis process was then condensed by the condenser until liquid was obtained. The liquid was deposited for 1 week in a separating funnel and then separated to obtain liquid smoke and residue. The volatile compounds of liquid smoke from a cashew nut shell were analyzed using gas chromatography and mass spectrometry (GC-MS). The results showed that the optimum pyrolysis temperature was at 400°C with a yield of 53.4% liquid smoke and the chemical composition of liquid smoke percentage: phenol (36,6%), carbonyl (7,1%), acid (18,8%) respectively. Phenol from liquid smoke resulted by the pyrolysis of cashew nut shells is an alternative material potential for substituting or replacing synthetic phenol from petroleum derivatives.

Keywords: Cashew nut shells, pyrolysis, liquid smoke, phenol

1. Introduction

Cashew nut shells become a waste in the cashew nut processing industry in abundant amount but its utilization is not yet optimal. It is generally used as a fuel which can cause environmental pollution [1]. The abundant potential of cashew nut shell can be used as a profitable commodity with appropriate processing alternatives to be products with quite high economic value [2].

Cashew nut shells contain Cashew Nut Shell Liquid (CNSL). The main component of CNSL are 94% cardanol which has chemical structure similar to synthetic phenol, so it is possible to substitute or replace synthetic phenol compounds from petroleum derivatives [2]. Petroleum is a non-renewable natural resource and its reserves are depleted [3], so it is necessary to find alternatives such as the utilization of cashew nut shells. The advantages of phenol from CNSL smoke and its derivative products have high biodegradability, so it is considered an environmentally friendly product and a renewable resource where the availability of raw materials is assured.

CNSL smoke is a potential alternative material to be used as a substitute for phenol in the production of varnish [4]. This liquid smoke is obtained from the pyrolysis through the heating process at a certain temperature from organic materials at an inert atmosphere (without the presence of oxygen). The pyrolysis method is an environmentally friendly alternative technology that can convert biomass waste such as cashew nut shells to produce useful products such as liquid smoke, gas and solid. Pyrolysis is thermal destruction of biomass in the absence of air/oxygen [5,11].



Phenol is the raw material of phenolic resin in the production of varnish. Varnish is a homogeneous mixture of one or more types (synthetic or natural resin) with drying oil, drying agent and solvent. Varnish serves as a surface coating both for protective or decorative purposes [4]. Varnish does not contain pigment so it is a transparent surface coating [6]. The final result of the varnish is a transparent film layer showing the texture of the coated material [7]. In this study, researchers used the cashew nut shell waste as a source of phenol to be used as a raw material in the production of varnish.

2. Experimental Method

The main ingredients used in this research were cashew nut shells obtained from Oempu Village, Tongkuno District, Muna Regency, South East Sulawesi. Cashew nut shells that have been cleaned were sun dried for a few days to remove the moisture content and inserted into the Pyrolysis Reactor. The main tool used to produce liquid smoke was a pyrolysis reactor equipped with a thermocouple, a tar reservoir, a condenser and a container of liquid. The reactor was then heated until it reached the required temperature and time, while the temperature was kept constant. Cashew nut shells that have been cleaned were dried and put as much as 2000 g into the reactor. The reactor was heated until it reached the required temperature (200°C), while the temperature was allowed to remain constant. The smoke produced in the condensation become liquid. The obtained liquid was entered into the separation funnel for 7 days to be separated from the residue by using filter paper. The same procedure was carried out at three temperature levels were 300, 400 and 500°C. The char yield collected in the reactor was weighed at the end of experiment. The volatile compounds of liquid smoke were analyzed using gas chromatography and mass spectrometry (GC-MS). The gas yield was then calculated by the difference [8].

3. Results and Discussion

3.1. Effect of pyrolysis temperature on liquid smoke and char yields

The pyrolysis process of cashew nut shells was carried out in the pyrolysis temperature variations of 200, 300, 400 and 500°C. Pyrolysis generated liquid and char. The gas yield was obtained not from observation, but from the calculation. To clarify the observed effects of pyrolysis temperature on liquid smoke and char yields was presented in Figure 1.

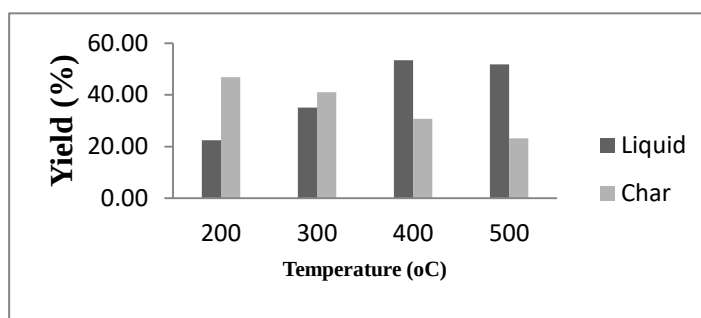


Figure 1. Effect of pyrolysis temperature on liquid smoke and char yield

Figure 1 shows that in general the increase of pyrolysis temperature is in line with increasing yield of liquid smoke but at a temperature of 500°C begins to show a decrease in the yield of liquid smoke. The yields of char decreased from 46.81 wt.% to 23.20 wt.% as the final pyrolysis temperature was increased from 200 to 600 °C. The pyrolysis temperature is one of the most important parameters affecting the pyrolysis products. The liquid yield increased from 24.1wt.% at 200 °C to a maximum of 53.4 wt.% at 400 °C, and then decreased to 51.8 wt.% at 500 °C. This is probably due to at the temperature of 400°C, the components of the cashew nut shells are experiencing an optimum decomposition reaction resulting in more decomposed volatile compounds and the increase in liquid

smoke at that temperature reaches its peak. The result of this research is better when compared with research with liquid product is equal to 52,1 at temperature 500 °C [8]. Over these temperatures, however, it is possible that greater secondary decomposition occurs so that more non-condensable gases (eg hydrogen, methane, carbon monoxide, etc.) are produced. At a temperature of 400°C, it is possible that the decomposition reaction of the cashew nut shell components reaches the optimum level, resulting in more long chain hydrocarbons being split into short chain hydrocarbons that produce smoke that is condensed into liquid. At the temperatures of between 400°C and 500 ° C, there is only secondary decomposition reaction causing the gas yield to rise as the pyrolytic temperature increases while and the yield of solid and liquid of pyrolysis decreases.

This is in accordance with previous research [5] which conducted a study at temperatures of 550, 700 and 850°C stating that rising pyrolytic temperatures resulted in increasing pyrolytic gas yields, while yields of solid and liquid of pyrolysis were decreased. This is likely because the temperature in the cooling water system was increased with the increasing pyrolytic temperature, so the smoke produced for liquid smoke production was not optimally condensed. The condensation process will take place optimally when the water in the cooling system is continuously flown so that the temperature in the cooling system does not increase. Therefore, the yield of the liquid smoke produced in the process of pyrolysis highly depends on the temperature of the pyrolysis and the condensation system used, the higher the temperature the higher the yield of the resulting liquid smoke, but if the temperature is too high (> 400°C) and the time is too long, the resulting liquid smoke will get lower. These results of this study were accompanied to the literature [5,8]

The yields of this pyrolysis study were larger by 53.4% when compared to the pyrolysis of dregs of sago and bark of sago plant stems by [9] were 33.7377 and 44.1445% respectively. This was probably caused by the raw materials used. Each material had different chemical composition. Besides, the pyrolytic temperature, coolant system and the mass of the feedstock also greatly affected the liquid smoke yield.

3.2. Characterization of Liquid Smoke Chemical Properties

Analytical results of *Gas Chromatography Mass Spectrometry* (GC-MS) of liquid smoke can be seen on Table 1.

Table 1. The effect of temperature on the chemical properties of liquid smoke

Temperature (°C)	Total Phenol (%)	Total Carbonyl (%)	Total Acid (%)
200	33.7	-	8.3
300	34.5	6.2	13.9
400	36.6	7.1	18.8
500	35.0	18.8	19.0

Table 2 shows that the temperature treatment affected the chemical properties of liquid smoke. The highest phenol production was at 400°C with total phenol was 36.6%. The degradation of lignin to be phenol happened in 2 stages were at a temperature of the beginning of 300°C which caused the breaking of phenol rings from lignin and at temperature of more than 300°C which produced polymerization into guaiacol and 2 methoxy phenols, as well as other compounds such as methanol, acetone and acetic acid [10]. According to [4], lignin decomposition will produce phenolic compounds. Phenol is also produced from CNSL contained in the cashew nut shells. Cashew nut shells contain 16.42% lignin [4] and CNSL containing 30-35% as a natural phenol [2].

This is probably one of the causes of high phenol contained in the liquid smoke of cashew nut shells. and the chemical composition of liquid smoke percentage: phenol (36,6%), carbonyl (7,1%), acid (18.8%) respectively. The phenol yields of this study were larger when accompanied to the literature [12,13]. This study showed that the phenol from pyrolysis liquid smoke from cashew nut shell is a potential alternative material to be used as a phenolic compound or a substitute for phenol which has been obtained from petroleum for the manufacture of varnish.

4. Conclusions

From this study, it can be concluded that:

- 4.1. The maximum liquid yield of 53,4 wt% was obtained at the final pyrolysis temperature of 400 °C and composition of liquid smoke percentage: phenol (36,6%), carbonyl (7,1%), acid (18.8%) respectively.
- 4.2. Phenol from liquid smoke resulted by pyrolysis of the cashew nut shells is a potential alternative material for use as a phenolic compound or a substitute for phenol which has been obtained from petroleum for the manufacture of varnish.

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