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Effect of nitrogen gas flowing continuously into the pyrolysis reactor for simultaneous production of charcoal and liquid smoke

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Abstract. Biomass waste such as sawdust or red fruit seed waste can be processed into charcoal (carbonized charcoal) and liquid smoke simultaneously by the pyrolysis method. The charcoal process using the pyrolysis method will be more perfect if the reactor is designed in such a way that oxygen from the air is not free to enter the reactor. The small amount of oxygen that is present and enters the reactor can be minimized by flowing inert nitrogen gas into the reactor continuously during pyrolysis. In this study, the effect of flowing nitrogen gas into the pyrolysis reactor was observed with a gas flow rate of 1 liter/minute using raw materials from wood sawdust biomass waste with a pyrolysis time of 2 hours and a pyrolysis temperature of 400 oC. The results showed that the quality of charcoal products was relatively better. The yield of liquid smoke was higher than the results of pyrolysis with nitrogen gas flow compared to without nitrogen gas flow. The calorific value of charcoal without and with nitrogen gas flow is 6828 cal/gram and 7109 cal/gram, respectively, the fixed carbon value is 68.37% and 70.40% respectively, and the yield of liquid smoke is 38.87% and 40.35%, respectively.

1. Introduction

In general, pyrolysis is defined as the process of degradation of macromolecular and complex carbon compounds into simpler compounds to form carbonized charcoal, through heating without or with minimal oxygen. In the pyrolysis reactor of biomass waste simultaneously, besides producing solid carbonized charcoal (charcoal), it also produces liquid and gas products in the form of mixed smoke as a result of degradation of cellulose and lignin macromolecular compounds to form CO_2, methane, water vapour and phenolic compounds. Other which is condensed to produce liquid smoke (liquid smoke). If the heating rate is small enough below 50ºC / minute with a pyrolysis temperature range of 400-600ºC, it is called slow pyrolysis [1, 2]. The pyrolysis method commonly used by the general public is referred to as conventional pyrolysis, including the slow pyrolysis category with a pyrolysis temperature of 300-700 ºC [2, 3].

Through the pyrolysis process, the non-carbon content in materials such as water and volatile matter will be drastically reduced so that the total value of fixed carbon in charcoal products increases, so the calorific value of charcoal from pyrolysis increases mass unity. Charcoal products which are carbon-dense so that they are heat dense are more effective as fuel than the raw material itself. Charcoal products minimal oxygen. In the pyrolysis reactor of biomass waste simultaneously, besides producing solid carbonized charcoal (charcoal), it also produces liquid and gas products in the form of mixed smoke as a result of degradation of cellulose and lignin macromolecular compounds to form CO_2, methane, water vapour and phenolic compounds. Other which is condensed to produce liquid smoke (liquid smoke). If the heating rate is small enough below 50ºC / minute with a pyrolysis temperature range of 400-600ºC, it is called slow pyrolysis [1, 2]. The pyrolysis method commonly used by the general public is referred to as conventional pyrolysis, including the slow pyrolysis category with a pyrolysis temperature of 300-700 ºC [2, 3].

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can be made into briquettes as an alternative solid fuel both in households and in industry. They can also be used as activated charcoal for absorbent purposes, for example for water purification processes or waste treatment [2, 3].

Liquid smoke products are an alternative to conventional meat preservation products. Liquid smoke has an antioxidant effect, produces an inhibitory effect on the growth of the bacteria *Escherichia coli, Salmonella choleraesuis, Staphylococcus aureus and Listeria monocytogenes*. The use of liquid smoke in meat preservation reduces processing time by about 43%, thereby significantly reducing the cost of the meat production process. Processing of meat preservation with liquid smoke will be safer, more economical, and uniform for the processed products and of higher quality [4, 5]

Aladin et al. [4] innovated to design a biomass waste pyrolysis reactor that produces charcoal and liquid smoke products simultaneously. This simultaneous pyrolysis reactor is designed in such a way that nitrogen gas can flow into the reactor effectively. The continuous flow of inert nitrogen gas into the pyrolysis reactor is intended to expel oxygen gas in the reactor and oxygen entering through the condenser pipe during the pyrolysis process. The less oxygen gas in the reactor, the higher the quality of the charcoal product. The less oxygen gas in the reactor, the more perfect the pyrolysis process occurs so that, the higher the yield of liquid smoke products [5].

Indonesia is an area that has an extensive forest area with a variety of woods that thrive. One type of wood that is widely used as a construction material for boat building is bitti wood (*Vitex cofassus*). In the process of processing bitti wood into boats, it produces sawdust waste, as can be found in the typical Bugis boat manufacturing industry in the Bulukumba area (South Sulawesi) [6, 7]. The sawdust waste is only wasted into the environment without being used. The sawdust of bitti wood, with the main content of carbon compounds in the form of cellulose and lignin, can be processed by the pyrolysis method to produce two types of products simultaneously, namely charcoal and liquid smoke [6, 8].

In this article, we discuss the results of research on the effect of a continuous flow of nitrogen gas into a pyrolysis reactor with a gas flow rate of 1 liter/minute using raw materials from biomass waste of bitti wood sawdust

2. Research methods

2.1 Research Apparatus and Materials

The main tool in this study is a set of pyrolysis tools, consisting of a pyrolysis reactor for tar and liquid smoke, a condenser, a circulating water pump, a high-pressure stove with LPG gas and a thermocouple (Figure 1).

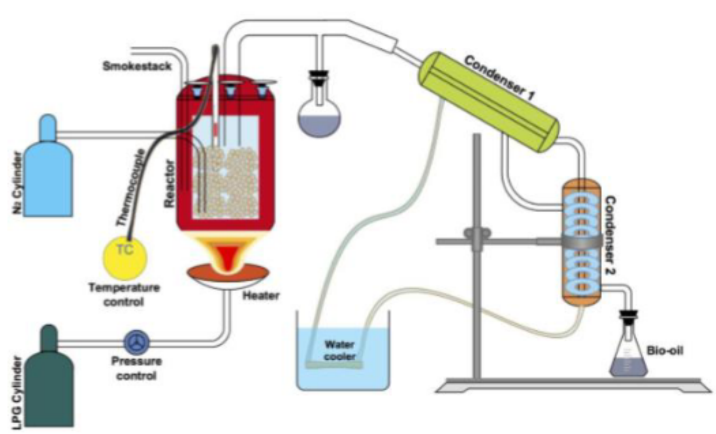
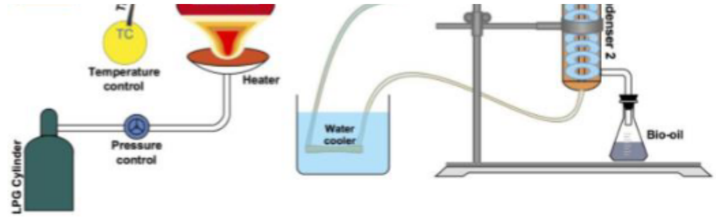


Figure 1. Pyrolysis Apparatus [1]

The main ingredients in this research are nitrogen gas and biomass waste of beet wood sawdust obtained from the phinisi boat-building industry in Bulukumba, South Sulawesi.



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2.2 Research path

This pyrolysis uses optimum procedures and conditions that have been obtained in previous studies with conditioning adjustments as needed [2, 9, 10]. 1 kg of dried sawdust biomass waste material is put into the pyrolysis reactor with the composition of the material in the reactor chamber, not more than 3/4. The cover of the reactor is tightly closed; nitrogen gas flowed into the reactor at a rate of 5 liters/minute until it is a bit excessively full (at a pressure of 1 atm). The flow rate is reduced to 1 liter/minute during the pyrolysis process. Cooling water (maximum temperature 20°C) is circulated through the condenser. The gas stove is turned on, and heating starts until it reaches the target temperature of 400°C. Pyrolysis is allowed to continue for 2 hours from the time the target temperature is reached. The gas and liquid-vapour resulting from pyrolysis flow through a condenser so that it melts to form grade 3 liquid smoke. The reactor lid is opened after being idled to a temperature below 50 °C, and the charcoal product is removed from the reactor and then weighed and stored in a closed container. The liquid smoke product is weighed by mass and measured in volume, then stored in a tightly closed bottle container. For charcoal product samples, proximate analysis and measurement of heating value were carried out, liquid smoke samples were analyzed for their chemical components and measured their specific gravity.
The above pyrolysis procedure is repeated without using nitrogen gas.

3. Results and discussion

The product obtained from pyrolysis charcoal using either nitrogen gas or without nitrogen gas, with the characteristics as presented in Table 1.

Table 1. Characteristics of the raw material for sawdust and charcoal as a result of the proceeds

N2 gas (liter/minute)	**yield (%)**		**proximate analysis charcoal (%)**				**calorific value charcoal (cal/g)**
	Charcoal	Liquid smoke	Moisture	Ash	Volatile matter	Fixed carbon	
-	-	-	9.65	10.23	29.78	50.34	4892
0	45.13	38.87	0.68	17.33	13.62	68.37	6828
1	42.85	40.35	0.31	19.44	9.85	70.4	7109

Table 1 shows there is a significant difference in the quality of charcoal from pyrolysis by flowing nitrogen gas continuously 1 liter/minute compared to without flowing nitrogen gas into the reactor during the pyrolysis process. This difference in quality is shown in the relatively higher fixed carbon composition in the product of charcoal resulting from pyrolysis by flowing nitrogen gas, which is 70.40% compared to without flowing nitrogen gas, which is only 68.37% (Figure 2).

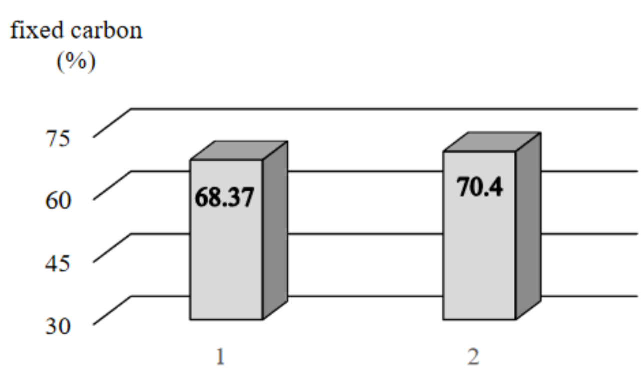
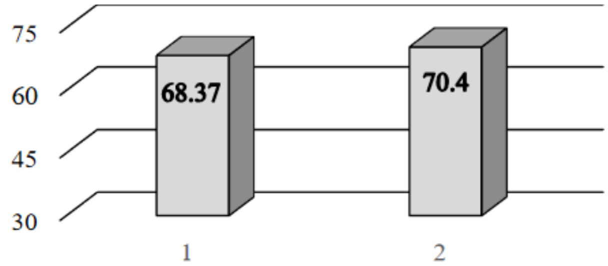


Figure 2. Comparison of fixed carbon charcoal resulting from pyrolysis without the addition of nitrogen gas (1) and with the addition of nitrogen gas (2)



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The second difference in quality is shown in the relatively higher calorific value of charcoal products from pyrolysis by flowing nitrogen gas, which is 7109 cal / g compared to without flowing nitrogen gas, which is only 6828 cal/g (Figure 3).

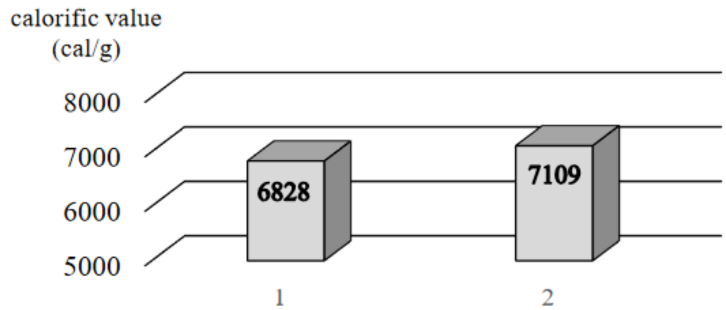

Figure 3. Comparison of the calor value of pyrolysis charcoal without the addition of nitrogen gas (1) and with the addition of nitrogen gas (2)

The phenomenon above can be explained by continuously flowing nitrogen gas into the reactor during the pyrolysis process, causing the expulsion of oxygen gas in the reactor and blocking the possibility of oxygen gas entering the reactor through the condenser pipe, so there is no more oxygen gas in the reactor, because the empty space in the reactor has been fully filled with nitrogen gas, which is inert. The less oxygen gas is in a pyrolysis process; the less likely the combustion reaction will occur; on the contrary, the more perfect the pyrolysis process is. This phenomenon can be seen from the proximate analysis of pyrolysis charcoal, the water content decreased drastically as well as volatile matter, so that fixed carbon increased (Figure 2), resulting in an increase in the caloric value (Figure 1).

Based on Table 1 data, although quantitatively the yield of charcoal from pyrolysis by flowing nitrogen gas is lower (42.85%) than without flowing nitrogen gas (45.13%) as shown in Figure 4, but qualitatively, the calorific value is higher (Figure 3).

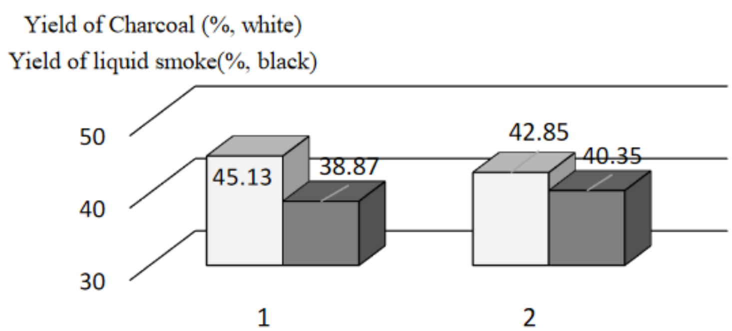

Figure 4. Comparison of yield charcoal and liquid smoke from pyrolysis without the addition of nitrogen gas (1) and with the addition of nitrogen gas (2)

The product of liquid smoke resulting from pyrolysis by flowing nitrogen gas is slightly higher (40.35%) than without flowing nitrogen gas (38.87%) as shown in Figure 4. It is another evidence that the pyrolysis process by flowing nitrogen gas is relatively more completely compared without flowing nitrogen gas continuously into the reactor.

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4. Conclusion

From the results of the pyrolysis research of waste biomass sawdust bitti wood with a pyrolysis time of 2 hours and a pyrolysis temperature of 400ºC, it can be concluded that the product quality of charcoal resulting from pyrolysis by flowing nitrogen gas continuously 1 liter/minute is relatively higher than without flowing nitrogen gas into the reactor. Fixed carbon composition to 70.40% (increase 3%), calorific value to 7109 cal/g (increase 4%). The quantity of the product of liquid smoke resulting from pyrolysis by flowing nitrogen gas continuously 1 liter/minute is relatively higher than without flowing nitrogen gas into the reactor. The yield of liquid smoke became 40.35% (an increase of 4%).

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