IOP Conf. Series: Materials Science and Engineering **309** (2018) 012073 doi:10.1088/1757-899X/309/1/012073

Liquid smoke characteristics from the pyrolysis of oil palm fronds

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Abstract. This study was conducted as means to characterize the pyrolysis of oil palm fronds into more economical products. In particular, this study was focused on pyrolysis of oil palm fronds, which could generate products such as liquid smoke, tar and char. Four characteristics of liquid smoke were examined in this study, namely the yield of liquid smoke, phenolic content, total acid content and pH. These characteristics were examined in a temperature of 150 ^{o}C, 200 ^{o}C and 250 ^{o}C with processing time of 60 minutes, 90 minutes and 120 minutes. This study revealed that the highest yield of liquid smoke was equal to 43.47% at a temperature of 150 ^{0}C for approximately 2 hours, while the highest level of phenolic was obtained at a temperature of 250 ^{o}C for approximately 1 hour. Moreover, the highest total acid content obtained was 11.23% at a temperature of 150 ^{0}C with a time of 1 hour. In addition, all operating conditions has produced liquid smoke with an average pH value of 3.

1. Introduction

Oil palm plantations in Indonesia have begun to grow rapidly since the early 80s. Approximately, 23.5 million tonnes of crude palm oil was produced in 2012 [1]. Currently, oil palm has become one of the plantation commodities that play a very important role in stimulating the economy in Indonesia, such as increasing foreign exchange, employment, and improving the living standards of people in the region. In addition, producing Crude Palm Oil (CPO) as the main commodity, the palm oil plantation also produces several types of potential wasted, namely Oil Palm Frond (OPF). The plantations will produce 22 stems per tree every year, and each stem has a weight about 2.2 kg. So that in 1 ha of oil palm plantations will generate 6.3 tonnes oil palm fronds each year [2]. Oil Palm Fronds (OPF) is one of the organic waste produced from oil palm plantations that are processed by burning or just throwing away [4]. The moisture content reaching 75 %, OPF is considered as a category of wet by-product. The large amount of waste generated in these oil palm plantations makes palm oil has a great potential to be processed into useful product. It is also driven by the content present in palm oil, which consists of hemicellulose (34.89 %), cellulose (27.14%), and lignin (19.87 %) [3]. In order to produce an economical product, one of the methods that can be used is through pyrolysis of raw materials containing hemicellulose, cellulose, and lignin that would be condensed to become liquid smoke.

Pyrolysis is defined as the thermal degradation process of solids in the absence of oxygen, allowing the occurrence of several thermochemical conversion pathways so the solid becomes permanent gasses, pyrolysis liquid and char [5]. Pyrolysis can be classified as slow pyrolysis and fast pyrolysis [6]. Slow pyrolysis takes place at low temperature with longer time. In general, aimed to produce char. Fast pyrolysis requires the material cutting into small size with special equipment to remove moisture content quickly.

Liquid smoke is a compound that vaporizes simultaneously from a heat reactor through pyrolysis technique (decomposition by heat) and condenses on a cooling system [7]. Liquid smoke has a major component of acidic compounds, phenol derivatives, and carbonyls that act as a flavoring, coloring, antibacterial, and antioxidant [8]. The chemical composition of liquid smoke depends primarily on the type of wood and water content of wood, the influence of both pyrolysis temperature and the duration of smoke generation. The disadvantage of the full strength of liquid smoke is the high content of the

active compounds of flavor and color, which limits their applications when used for specific purposes such as antimicrobial agents [9]. Therefore, the purpose of this study was to determine the effect of temperature, pyrolysis time, and moisture content on the yield and pH of liquid smoke produced.

2. Methodology

The pyrolysis process takes place at the pyrolysis reactor under predefined operating conditions. Oil palm fronds is first dried, then weighed. The pulverized oil palm fronds is introduced into the reactor and pyrolized according to predetermined time and temperature, then condensed. The generated smoke will be condensed by using condensor and accommodated in a storage tank. Liquid smoke is allowed for 2 x 24 hours then filtered with filter paper. The set of equipment in the pyrolysis process is shown in Fig. 1.

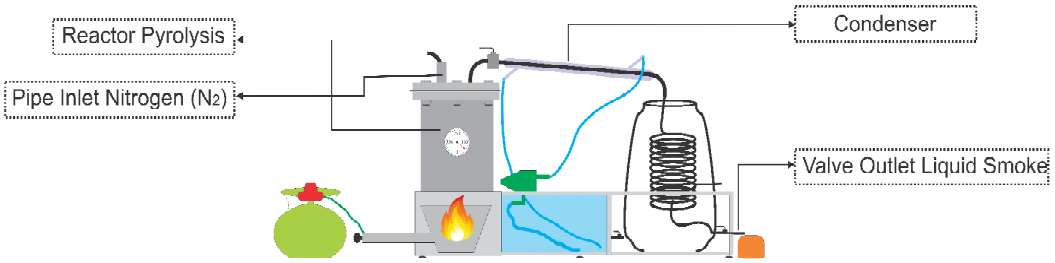

Figure 1. Pyrolysis Reactor

Analyzed parameters to obtain the quality of liquid smoke are total acid, phenol content, pH and yield of liquid smoke.

3. Result

The pyrolysis temperature is allow the breaking of chemical bonds on cellulose, hemicelluloce and lignin compound. Higher pyrolysis temperature leads to more yield of liquid smoke [10]. This is because the oil palm fronds get a sufficient amount of heat to breaking of chemical bonds so that the compound in the palm oil bark increasingly decomposes and condensed into liquid smoke [11]. High temperatures and long periods of time on pyrolysis is led more complete decomposition of raw materials to obtain higher yields of liquid smoke [12]. The highest yield was obtained at pyrolysis temperature of 150 ºC with pyrolysis time for 120 minutes, i.e. 43.47%.

Table 1. Yield of Smoke Liquid

Experiment	Water content (%)	Pyrolysis temperature (^{0}C)	Pyrolysis time (minutes)	Yield of Liquid (%)
1	29.64		60	35.187
2	27.25	150	90	41.646
3	27.96		120	43.470
4	28.34		60	28.133
5	26.64	200	90	30.588
6	23.62		120	38.142
7	21.66		60	29.203
8	21.53	250	90	31.970
9	21.28		120	34.001

Cellulosic pyrolysis will produce acetic acid compounds and carbonyl compounds. The acid compounds formed from the pyrolysis process are organic acid compounds [13] among which are large amounts of acetic acid, propionic, butyric and valeric [14]. Other than that, there are carbonyl compounds present in the liquid smoke including vanillin and syringaldehyde [14]. Hemicellulose pyrolysis will produce furfural, furan, acetic acid and its derivatives [13], thus the acid obtained in

liquid smoke is obtained from the decomposition of hemicellulose and cellulose. The highest total acid was 11.23%, which was obtained at pyrolysis temperature of 150 °C with a pyrolysis time of 60 minutes, as shown in Figure 2.

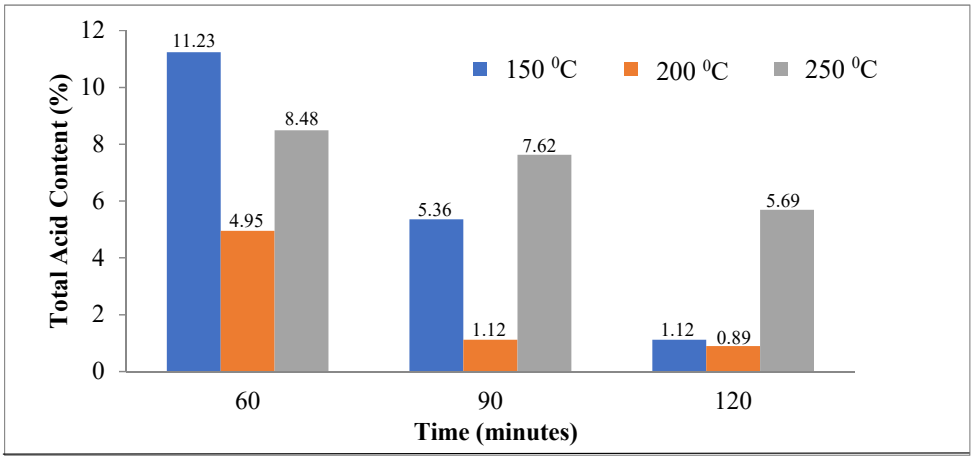

Figure 2. Effect of total acid content against pyrolysis time in various temperatures

Phenol is the result of degradation of a wood component called lignin. The more lignin content in the wood, the greater the phenol content obtained in liquid smoke [15]. The phenol compounds present in wood smoke are generally aromatic hydrocarbons composed of benzene rings with a number of bound hydroxyl groups [14]. The amount and quality of phenol in the liquid smoke depends on the temperature of the pyrolysis and the lignin content of the feedstock [16]. The highest phenol content obtained was 12.28% at pyrolysis temperature of 250 °C and pyrolysis time of 60 minutes.

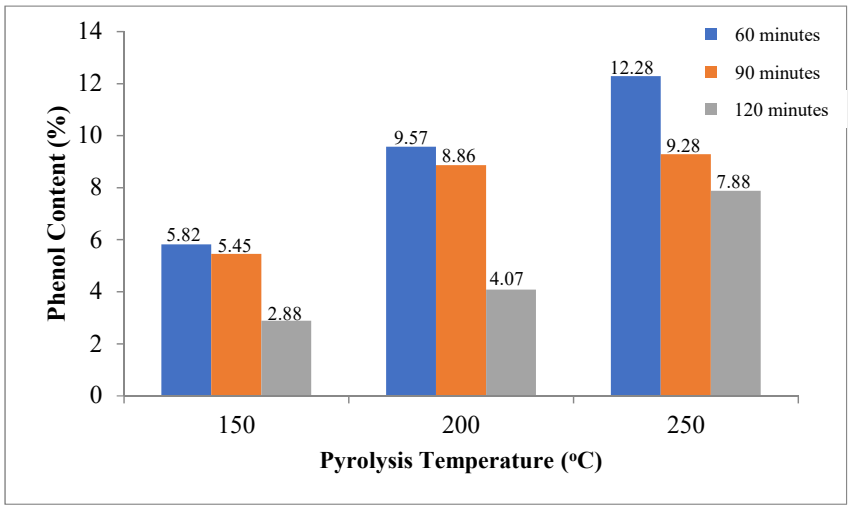

Figure 3. Effect of phenol content against pyrolysis temperature in various times

The quality of the resulting liquid smoke can be determined by measuring the degree of acidity (pH). The pH value indicates the rate of decomposition process of the wood chemical component occured can produce acid and phenol in liquid smoke [17]. The result of measurement of pH of liquid smoke ranged between 3.1 and 3.8. This shows that liquid smoke products are acidic.

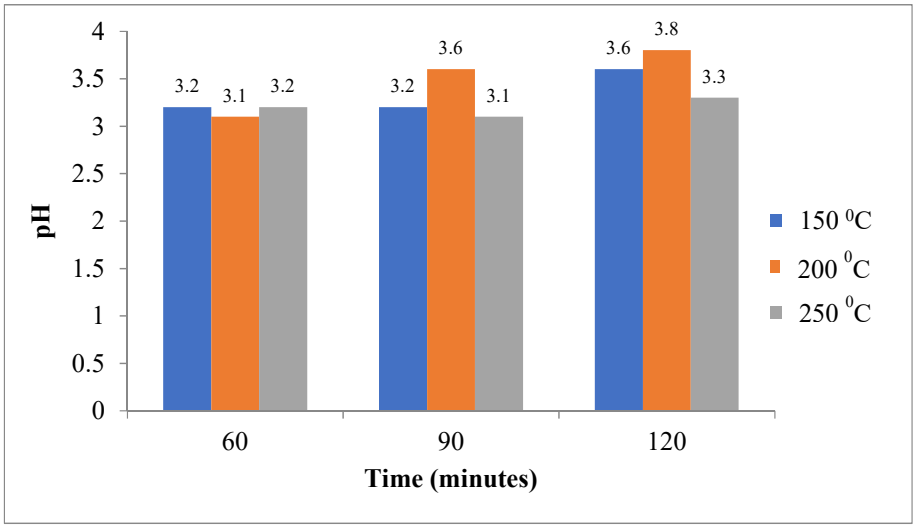

Figure 4. Effect of pH against pyrolysis time in various temperatures

Conclusion

Based on the purpose of this research, it was found that the highest yield of liquid smoke was equal to 43.47% at a temperature 150 ºC in 2 hours, while the highest total acid content obtained was 11.23% at a temperature of 150 ºC in 1 hour. Moreover, the highest phenolics were obtained at a temperature 250 ºC in 1 hour and pH is around 3.1 to 3.8.

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