ANALYSIS OF PALM SHELL MESH VARIATIONS WITH INCREASING PRODUCTIVITY OF LIQUID SMOKE USING AIR-COOLED REFRIGERATION SYSTEMS

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Abstract - Liquid smoke increases in demand by the community and research is being carried out related to its various benefits, and is environmentally friendly. The raw material in making liquid smoke comes from waste, which can directly minimize the amount of waste in the world. The process of condensing the smoke into liquid smoke has been carried out using conventional water so that there is still a lot of smoke from pyrolysis that has not been condensed. Smoke condensation can be done with controlled low-temperature air. The refrigeration system is used in this study to increase the productivity of liquid smoke. The air temperature used in the smoke condensing process is between 10°C - 0°C for 360 minutes, with variations in the size of palm shell raw materials -3+4 mesh, -4+5 mesh, and -5+6 mesh. The best results were obtained in the smoke condensing process with -5+6 mesh, with the results of 23.26% liquid smoke, 5.16% tar, 61% charcoal, and 6.33% gas, with the yield of 56.18% phenol. These results indicate that the condensing process using low-temperature air is more effective for maximally condensing smoke than conventional water.

Keywords - Condensation, Liquid Smoke, Palm Shell, Refrigeration

I. INTRODUCTION

Indonesia is a country with the avast area, the vast area of land in this country is used in many ways to achieve human welfare, one of which is oil palm plantations. Oil palm plantations produce CPO (Crude Palm Oil), and waste reaches 43% (Elisabeth & Ginting, 2003). Indonesian oil palm plantations increased from 10.6 million ha in 2013 to 13.7 million ha in 2020(Shahputra & Zen, 2018). Oil palm with a capacity of 100 thousand tons of fresh fruit bunches (FFB) per year produces around 6 (six) thousand tons of palm shells, 12 (twelve) thousand tons of fibers, and 23 (twenty-three) tons of empty fruit bunches. This waste is very potential if it is developed into products that are useful and provide added value from economic as well as environmentally friendly aspects such as liquid smoke, fuel, briquettes, and others (Fauziati et al., 2018). Palm kernel shell is one type of solid waste byproduct of the palm oil processing industry that currently still causes problems for the environment because this waste is produced in large quantities and is difficult to degrade/decompose naturally in the environment. (Fauziati, 2015). Palm kernel shell contains lignin (29.4%), hemicellulose (27.7%), cellulose (26.6%) (Fauziati et al., 2018). Disposal of large amounts of biomass waste is considered garbage and pollutants is a major problem of environmental management. Biomass waste must be converted into useful products to minimize environmental pollution. One way to use waste is to convert the waste into liquid smoke.

Liquid smoke is a result of condensation or condensation of smoke from combustion, directly or indirectly, from materials that contain lots of lignin, cellulose, and hemicellulose, and other carbon compounds. (Ni'Mah et al., 2019). Liquid smoke is defined as the condensate liquid which has undergone storage to separate tar and certain materials. This technology has many advantages, especially that the main product is charcoal which can be developed into several products of economic value (Abdul Gani Haji, 2006). Liquid smoke is currently gaining popularity as a preservative for various food products and biopesticides to increase agricultural production. Moreover, liquid smoke is used to improve soil quality and neutralize soil acids, kill plant pests, and control plant growth, repel insects, and accelerate growth of roots, stems, tubers, leaves, flowers, and fruit (Kılınç & Çaklı, 2012). Research related to liquid smoke on palm kernel shell raw materials is always carried out as is being done (Omoriyekomwan et al., 2016).

Pyrolysis is a process of decomposition of organic compounds through a heating process with little or no oxygen (Endang et al., 2016).

Pyrolysis can be defined as the thermal decomposition of organic material (in the absence of oxygen) which will cause the formation of volatile compounds. Pyrolysis generally starts at a temperature of 200^0C and lasts at temperatures around 450-500^0C(Sheth & Babu, 2006).

Condensation is the process of changing the phase from gas to liquid. In this condensation process, heat release will occur. In the manufacture of liquid smoke, the condensing process is carried out using water as it is done (Sheth & Babu, 2006), (Faisal et al., 2020), (Ridhuan et al., 2019), (Lisa Ginayati et al., 2015). The condensation process of

smoke into liquid smoke is carried out conventionally using water that is circulated using a continuous pump. In the process of making liquid smoke, there are still many gases that escape the environment because the water temperature continues to increase (Ridhuan et al., 2019).
The size of the palm kernel shell raw material in the production of liquid smoke will be one factor in increasing the yield of liquid smoke. Because the smaller surface area (Ogunkanmi, 2018).
Refrigeration is generally used for the air conditioning process for convenience or for freezing a product.

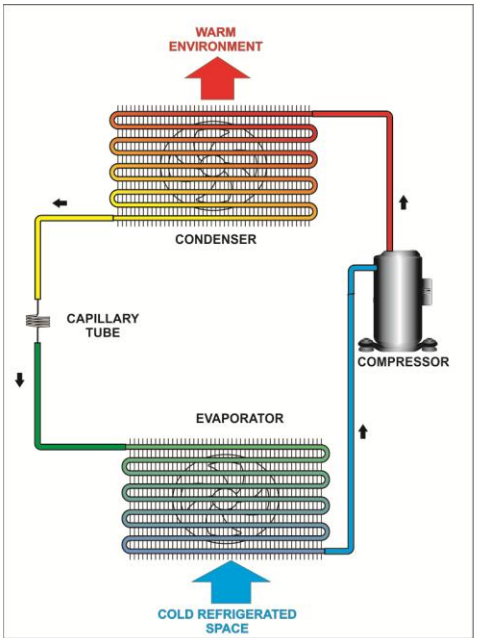

Figure 1. Refrigeration cycle

Figure 1 there is refrigeration cycle consists of 4 main components, namely compressor, condenser, expansion, and evaporator. Also, there are various kinds of safety and control devices to save energy and keep the main components safer(Withman & Johnson, 2009).

The process of making liquid smoke will be carried out with the smoke condensing method using low-temperature air, which combines the refrigeration system so that this study does not use water. Moreover, there will be variations in the size of the palm kernel shells in the liquid smoke production process. Therefore that it can increase the productivity of liquid smoke.

II. MATERIALS AND METHOD

The raw material used in the process of making liquid smoke is palm kernel shell waste which has been varied in size -3 + 4 mesh, -4 + 5 mesh, and -5 + 6 mesh. With the following in Table 1.

Compound	Percentage (%)
Selulosa	11,52
Hemiselulosa	2,68
Lignin	76,22
Kadar Air	12,18
Abu	3,19

Table 1. Palm shell compounds

The palm kernel shell will be subjected to a pyrolysis process at a temperature of 300^0C-400^0C. The smoke from the pyrolysis process will be directed to the smoke condensing place in the form of cold storage at a controlled temperature between 10^0C-0^0C. Cold Storage comes from a refrigeration system that uses a compressor, condenser, capillary tube, and evaporator. With a compressor capacity of ¾ HP. The smoke from the pyrolysis is cooled using cold air from the evaporator and distributed using a fan with a fan speed of 5.4 m / s. The results of this study are the percentage of liquid smoke, tar, charcoal, and gas that escaped.

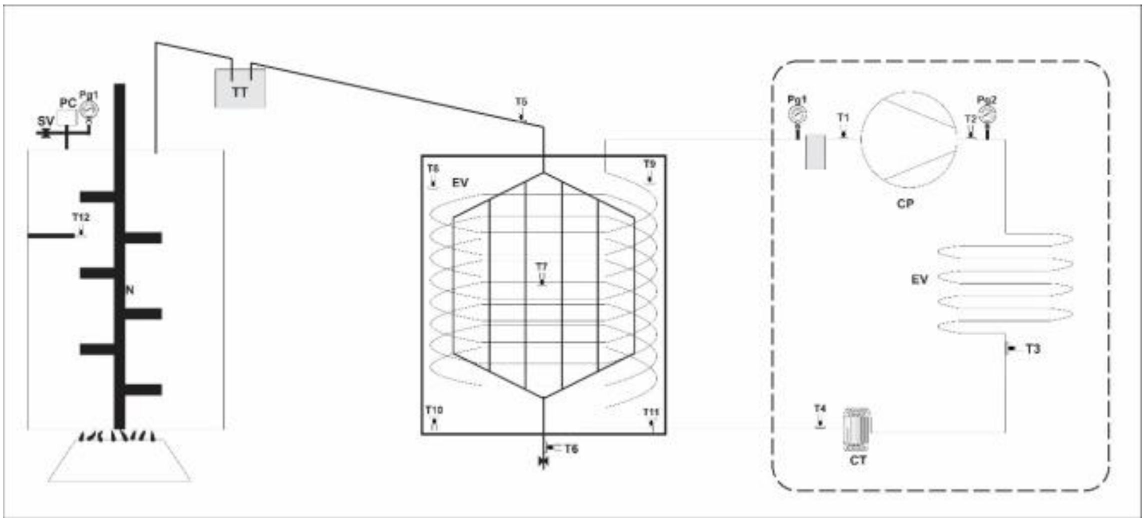

Figure 2. Schematic diagram of a liquid smoke maker with a refrigeration system

Can be seen in Figure 3 above, is a cycle of the process of making liquid smoke using a refrigeration system. The raw material for the palm kernel shells will be carried out by the pyrolysis process using a reactor tube where the main fuel is gas. The pyrolysis smoke will flow into the cooling room, the liquid smoke will be cooled by low-temperature air which is the result of evaporator cooling in the refrigeration system with air temperature control. The result of this temperature variation will produce different charcoal, tar, liquid smoke, and gas.

III. ANALYSIS

The results of the liquid smoke manufacturing process will be carried out by the GCMS lab test and the calculation of the percentage of liquid smoke.

$$m_{shell} = m_{liquid\ smoke} + m_{tar} + m_{charcoal} + m_{gas} \quad (1)$$

$$\text{Percentage of liquid smoke} = \frac{m_{liquid\ smoke}}{m_{shell}} \text{ x } 100\% \quad (2)$$

$$\text{Tar percentage} = \frac{m_{tar}}{m_{shell}} \text{x}100\% \quad (3)$$

$$\text{Charcoal percentage} = \frac{m_{charcoal}}{m_{shell}} \text{x}100\% \quad (4)$$

$$\text{Gas percentage} = \frac{m_{gas}}{m_{shell}} \text{x}100\% \quad (5)$$

IV. RESULTS AND DISCUSSION

Liquid Smoke

Based on the research results, the results are illustrated in the following table:

Massa	-3+4 mesh (gr)	-4+5 mesh (gr)	-5+6 mesh (gr)
Palm shells	10000	10000	10000
Liquid Smoke	2007	2129	2326
Tar	380	413	516
Charcoal	6980	6507	6100
gas	633	951	1058

Table 2. Results of liquid smoke using the palm kernel shell raw material refrigeration system

Table 2 shows the production results of the liquid smoke condensing process, where at -5 + 6 mesh more liquid smoke is produced, while at -3 + 4 mesh the resulting gas is less.

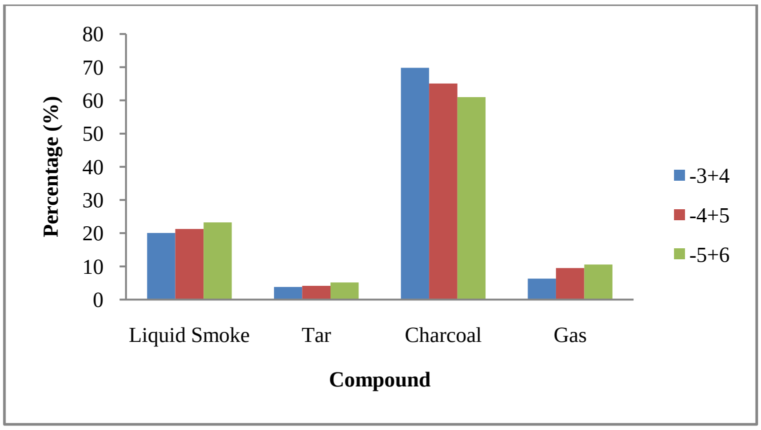

Figure 3. The result of smoke condensation of palm shell raw materials

Figure 3 shows that the percentage for gas that passes into the environment is at least -3 + 4 with a yield of 6.33%, while the maximum yield of liquid smoke is obtained at -5 + 6 mesh of 23.26%.

Based on these data, the manufacture of liquid smoke made from palm kernel shells using the refrigeration system method with low-temperature air obtained different results from each mesh. The maximum yield of liquid smoke is obtained by raw material of palm kernel shells measuring -5 + 6 mesh with a liquid smoke yield of 23.26%.

Chemical Compounds

For each liquid smoke result, a GCMS laboratory test is carried out, and this is carried out on each liquid smoke production starting from the raw material of palm shells -3 + 4 mesh, -4 + 5 mesh, and -5 + 6 mesh.

RT	Senyawa	Area %
2.20	Hydrazine, ethyl	13.88
2.31	3-Methyl-6-(methylthio)hexa-1,5-dien-3-ol	0.51
2.47	Butanoic acid, 2-amino-, (S)	0.21
2.59	Ethanol, 2-nitro-, propionate (ester)	1.61
3.11	Pyridine	0.28
3.29	Butanoic acid	0.47
3.96	Furfural	9.83
4.21	3-Furanmethanol	0.46
4.34	2-Propanone, 1-(acetyloxy)-	0.27
4.95	2-Cyclopenten-1-one, 2-methyl-	0.58
5.01	Ethanone, 1-(2-furanyl)-	0.8
5.11	Anisole	0.27
5.81	2-Furancarboxaldehyde, 5-methyl-	0.3
6.08	Phenol	55.08
6.60	Butyric acid hydrazide	1.22
7.69	Phenol, 3-methyl-	2.16
7.89	Acetic acid, phenyl ester	0.54
8.24	p-Cresol	1.58
8.76	Phenol, 2-methoxy-	5.36
8.95	5-Amino-1-benzoyl-1H-pyrazole-3,4-dicarbonitri	0.17
10.06	Phenol, 3-ethyl-	0.21
10.30	Phenol, 3,4-dimethyl-	0.39
10.70	Phenol, 3,4-dimethyl-	0.28
10.94	Creosol	0.16
11.17	Creosol	1.27
11.29	Catechol	0.18
12.21	4-Methoxybenzene-1,2-diol	0.17
12.42	Phenol, 4-ethyl-2-methoxy-	0.67
13.21	Phenol, 2,6-dimethoxy-	0.91
14.09	Phenol, 4-methoxy-3-(methoxymethyl)-	0.16

Table 3.GCMS laboratory test results of liquid smoke palm shell raw material -3+4 mesh

Table 3 explains based on the results of GCMS laboratory tests on liquid smoke made from palm kernel shells -3 + 4 mesh, the value of phenol is 55.08%, this value is high when compared to the liquid smoke research conducted by (Desi Ardilla et al., 2015) which researched liquid smoke with phenol yield 37,962%.

RT	Senyawa	Area %
2.23	Formic acid hydrazide	17.00
2.61	Ethanol, 2-nitro-, propionate (ester)	1.26
3.11	Pyridine	0.27
3.3	Propanedioic acid, propyl-	0.34
3.96	Furfural	3.60
4.21	3-Furanmethanol	0.25
4.33	2-Propanone, 1-(acetyloxy)-	0.26
4.94	2-Cyclopenten-1-one, 2-methyl-	0.23
5	Ethanone, 1-(2-furanyl)-	0.58
5.81	2-Furancarboxaldehyde, 5-methyl-	0.21
6.08	Phenol	56.59
6.52	Pyridine, 3-methoxy-	0.46

6.6	Butyric acid hydrazide	0.79
7.04	1,2-Cyclopentanedione, 3-methyl-	0.37
7.68	Phenol, 3-methyl-	2.40
7.88	Acetic acid, phenyl ester	0.29
8.22	p-Cresol	2.53
8.75	Phenol, 2-methoxy-	4.20
10.04	Phenol, 3-ethyl-	0.20
10.28	Phenol, 2,3-dimethyl	0.45
10.69	Phenol, 3,4-dimethyl-	0.44
11.16	Creosol	1.32
11.26	Catechol	0.66
12.19	1,2-Benzenediol, 3-methoxy-	0.39
12.41	Phenol, 4-ethyl-2-methoxy-	0.77
13.2	Phenol, 2,6-dimethoxy-	2.56
14.08	1,2,4-Trimethoxybenzene	0.62
14.15	Methylparaben	0.33
14.77	5-tert-Butylpyrogallol	0.31
14.84	1-(4-methylthiophenyl)-2-propanone	0.30

Table 4. GCMS laboratory test results of liquid smoke palm shell raw material -4+5 mesh

Table 4 explains based on the results of GCMS, laboratory tests on liquid smoke made from palm kernel shell -4 + 5 mesh yielded a phenol value of 56.59%, the phenol value increased due to the reduced size of the palm shell raw material so that the phenol compound was easily broken down compared to palm shell -3 + 4 mesh.

RT	Senyawa	Area %
2.19	Hydrazine, ethyl-	12.73
2.31	Butanoic acid, 2-ethyl-, 1,2,3-propanetriyl ester	0.29
2.47	Butanoic acid, 2-amino-, (S)-	0.21
2.59	Ethanol, 2-nitro-, propionate (ester)	1.43
3.12	Hexane, 3,3,4,4-tetrafluoro-	0.24
3.28	Propanedioic acid, propyl-	0.41
3.97	Furfural	8.3
4.21	3-Furanmethanol	0.48
4.34	2-Propanone, 1-(acetyloxy)-	0.28
4.94	2-Cyclopenten-1-one, 2-methyl	0.59
5	Ethanone, 1-(2-furanyl)-	0.71
5.81	2-Furancarboxaldehyde, 5-methyl-	0.24
6.06	Phenol	56.18
6.6	1,5-Heptadiene-3,4-diol	1.08
7.05	2-Cyclopenten-1-one, 2-hydroxy-3-methyl-	0.19
7.68	Phenol, 3-methyl	2.53
7.88	Acetic acid, phenyl ester	0.49
8.23	Phenol, 3-methyl-	1.99
8.76	Phenol, 2-methoxy- 9	5.94
10.04	Phenol, 3-ethyl-	0.23
10.28	Phenol, 2,3-dimethyl-	0.45
10.69	Phenol, 2,3-dimethyl-	0.33
10.93	Phenol, 2-methoxy-3-methyl-	0.19

Table 5. GCMS laboratory test results of liquid smoke palm shell raw material -5+6 mesh

Table 5 explains based on the results of GCMS laboratory tests on liquid smoke made from palm kernel shell -5 + 6 mesh, the value of phenol was 56.18%. This phenol value is slightly lower than the raw material for palm kernel shells -4 + 5, this is due to the possibility that the size of the raw material is too small so that the phenol compounds can pass into the air. The amount of gas released into the environment can be minimal compared to other studies which in gas escaping as much as 22.9%(Oh et al., 2016), and gas escaped as much as 19% with the same raw material, namely palm kernel shells (Priatni et al., 2018). While the phenol content in this liquid smoke is higher by an average of 56.18% compared to research using conventional cooling 13.49%(Chang et al., 2016), phenol value also reached 28.3% with 16% gas(Nayaggy & Putra, 2019). Other studies on palm kernel shells have also been carried out by using the pyrolysis method using a microwave and conventional condensing with 34.91% phenol and 37.69% passed gas (An et al., 2020)

V. CONCLUSION

Based on the results of this study, it is found that in increasing the productivity of liquid smoke, the condensation process can use a refrigeration system with controlled low-temperature air fluids as an effort to save energy. Within 6 hours (360 minutes) of the pyrolysis process of 1000 grams of palm kernel shells for each experiment, with variations of -3 + 4 mesh, -4 + 5 mesh, and -5 + 6 mesh, the average yield of liquid smoke was 2154 gr (21.54%).), gas escapes an average of 8.81%, phenol average of 55.95%. The maximum results were obtained in the palm shell experiment -5 + 6 mesh with 23.26% liquid smoke, 5.16% tar, 61% charcoal, and 10.56% escaped gas with 56.18% phenol content. The condensing process of liquid smoke using controlled low-temperature air between 10-0^0C can minimize the gas escaping to the environment.

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