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RESEARCH PAPER

Characterization of liquid smoke from pyrolysis of plastic waste pet and other cooking oil packaging as an alternative fuel

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Abstract: Characterization of liquid smoke from the pyrolysis of PET and OTHER plastic packaging waste as an alternative fuel has been carried out. The pyrolysis method produces liquid smoke from PET and OTHER plastic waste at high temperatures. Pyrolysis of PET-type cooking oil packaging plastic waste produces 77.70% liquid smoke, while OTHER type of plastic packaging plastic waste pyrolysis produces approximately 71.65% liquid smoke. The physical properties of liquid smoke resulting from pyrolysis from PET and OTHER plastic cooking oil packaging waste cannot be used directly as fuel oil because some of these physical properties need to meet the SNI fuel quality standards. Identification with GC-MS that liquid smoke from PET-type plastic waste consists of 50 chemical compounds and liquid smoke from OTHER type plastic waste consists of 49 chemical compounds, composed of chemical derivatives of alkanes, alkenes, cycloalkanes, cycloalkenes, and alcohols.

Keywords: liquid smoke; pyrolysis; packaging; cooking oil; PET

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INTRODUCTION

Plastic is the most choice in the industrial world to be used as a container for packaging products. Regarding price, product packaging made of plastic is relatively cheaper and easy to obtain compared to other packaging types, such as cans and glass bottles. Plastic packaging is the best alternative because the material is easy to obtain, cheap, practical, and can be designed according to the desired market goals [1,2]. The cooking oil industry is a sector that uses plastic as a packaging container to ensure quality and hygiene. According to data from the Indonesian Palm Oil Association, domestic demand for cooking oil in 2020 is 17.35 million tons, an increase of 3.6 percent compared to the previous year, which was 16.75 million tons. Along with the great demand for cooking oil, especially palm cooking oil, plastic packaging is also increasing. Plastic packaging for cooking oil is single-use packaging, meaning that after being used, the plastic packaging for cooking oil cannot be used anymore and is disposed of as plastic waste [3].

Cooking oil plastic waste continues to grow every day. If it is not handled properly, it will cause serious environmental problems and harm the soil, water, and living things. Destroying plastic waste by burning is less effective and risky because burning plastic waste produces pollutants from exhaust gas emissions (CO2, CO, NOx, and SOx) and several other polluting particulates. Processing methods are needed to process plastic waste. The acceleration of handling plastic waste must be equal to adding plastic waste itself [4-7].

One form of processing plastic waste to produce energy is processing plastic waste into liquid fuel. One method used to convert plastic waste into liquid fuel, which can be further processed into fuel oil, is the same as gasoline fuel. The advantages of applying the pyrolysis method include having a high conversion ratio and the product having a high energy content as well. The percentage of fuel oil produced from plastic pyrolysis is quite a lot, namely eighty to ninety percent [8,9].

The fuel produced from the pyrolysis process of plastic has advantages compared to fossil fuels; namely, it does not contain sulfur because there is no sulfur in the raw material for plastic. There is sulfur due to burning fuel from plastic pyrolysis, and the amount is less than sulfur in diesel fuel. Fossil fuels contain sulfur, so when combustion occurs, they form SO2, which pollutes the air [10,11]. This research focuses on converting PET and OTHER cooking oil packaging plastic waste into liquid fuel.

MATERIALS AND METHODS

Research Materials

The samples used in this study were PET and OTHER plastic waste packaging for cooking oil. Samples were collected from the final waste disposal site (TPA) in Sumompo Village, Manado City. Cooking oil packaging waste is washed thoroughly and then dried in the sun,

Equipment

A set of pyrolysis equipment, condenser, Erlemeyer glass, separating funnel, measuring cup, analytical balance, tongs, standard, knife, pipette, thermometer, and electric heater. Oswald-Fenske Viscometer (Fisher), Analytical Balance (Metler-Tolledo), Picno Meter (Pyrex), Digital Bomb Calorimeter (IKA C2000), and GC-MS Tool.

Pyrolysis

The research steps for the pyrolysis of plastic waste follow the research procedures carried out by previous researchers [5-7]. Pyrolysis of 200 g of PET-type plastic waste samples was then put into a 500 mL pyrolysis flask. After all the samples have been filled in the flask, the flask is closed tightly until no leaks are found in the flask cover or the tool joints. Pyrolysis of PET plastic waste can begin. The pyrolysis process begins by observing changes in pyrolysis temperature and the physical changes that occur, namely, plastic waste begins to melt, melt, evaporate, and liquid smoke begins to drip. The pyrolysis process was stopped when no pyrolysate dripped into the Erlenmeyer. Pyrolyzate or liquid smoke from the pyrolysis process of PET-type plastic waste is stored in an Erlenmeyer. The resulting liquid smoke is weighed to determine the percentage of liquid smoke obtained. Pyrolysis of OTHER cooking oil packaging plastic waste is carried out in the same way as PET cooking oil packaging plastic waste pyrolysis. The pyrolysis process of PET and OTHER plastic waste was repeated three times each.

Characterization of Liquid Smoke

The next step is to analyze the physical properties of PET and OTHER plastic waste liquid smoke, including calorific value, density, viscosity, flash point, and boiling point. In addition to analyzing the physical properties, the identification of chemical compounds contained in liquid smoke of PET and OTHER types was also carried out using a combination of gas chromatography and mass spectroscopy (GC-MS) tools.

RESULTS AND DISCUSSION

During the pyrolysis process, the researchers observed sequential physical changes: pyrolysis starting at 110 - 130^{o}C, a physical change occurred, namely PET and OTHER plastic waste from solid form slowly turned to melt, accompanied by air bubbles in the plastic samples being pyrolyzed. At a temperature of around 150 - 180^{o}C, the sample starts to melt and boil, accompanied by white smoke with a pungent odor. At a temperature of around 180 - 200^{o}C, liquid smoke is dripping into the Erlenmeyer container bottle. At a temperature of around 240 - 280^{o}C, it can be seen that the speed of dripping liquid smoke starts to normal and looks stable. The pyrolysis process was stopped after no more dripping liquid smoke or pyrolysate, and the pyrolysis time was approximately five hours. The pyrolysis results of PET and OTHER types of plastic waste are presented in Table 1.

The liquid smoke pyrolyzes obtained brown, and the liquid smoke is a mixture of short-chain to long-chain chemical compounds. In addition, the dark brown color of the liquid smoke is predicted to contain tar. Pyrolysate of PET-type plastic waste produces liquid smoke with a percentage of approximately 77.70%, and liquid smoke pyrolysate of OTHER plastic waste of approximately 71.65%. The difference in the percentage of the two types of PET and OTHER liquid smoke can be caused by the different compositions of the mixed raw materials of the two types of PET and OTHER plastics. Oil packaging waste and the color of liquid smoke from the results of pyrolysis of PET and OTHER types of plastic waste are shown in Figure 1.

Table 1. Pyrolysis Results of PET and OTHER Types of Plastic Waste

Type of plastic	Sample massg)	Repetition	Pyrolysate Mass (g)	Masspyrolysate average(g)
	200	1	150.20	
PET	200	2	160.00	155.43
	200	3	156.10	
	200	1	142.00	
OTHER	200	2	140.80	143.30
	200	3	145.20	

a) Sample PET b) Sample OTHER

c. Liquid Smoke PET

d. Liquid Smoke OTHER

Figure 1. PET (a) and OTHER (b) Liquid Smoke of PET (c) and OTHER (d)

Physical Properties of Liquid Smoke from PET and OTHER Plastic Waste

a. density

The density values of PET and OTHER plastic waste liquid smoke are 0.7879 g/mL and 0.7852, respectively. The value of the density of liquid smoke from PET and OTHER plastic waste is almost the same as the gasoline quality standard recommended by SNI and also not much different from the results of previous studies, namely 0.76 g/mL [6,7]. The density of gasoline fuel oil is between the kerosene density, 0.78 – 0.81 g/mL. There is a slight difference in the density value of the liquid smoke of PET and OTHER types of plastic waste which can be caused because the two liquid smoke are predicted to contain unequal amounts of chemical compounds [12,13].

b. viscosity

The viscosity test results of PET-type plastic waste liquid smoke with OTHER are 1.514 cP and 1.376 cP, respectively. The viscosity value of PET and OTHER plastic waste liquid smoke is higher than the viscosity value of gasoline fuel recommended by SNI, namely 0.7 cP. The high viscosity value of liquid smoke from PET and OTHER plastic waste is largely determined by the density value, meaning that the greater the density of the liquid, the greater the viscosity. Fuel oil has larger long-chain chemical structure bonds, and the greater the viscosity. Fuel with high viscosity will be difficult to flow and affect the engine [14,15]. If the viscosity is too high, it will be easier to pump fuel into the combustion chamber and affecting the quality of automation, which is difficult to occur.

Boiling point

The boiling point values of liquid smoke from PET and OTHER plastic waste are 144.6 ^{o}C and 178.2 ^{o}C, respectively. Based on SNI 06-3506-1994, the final allowed fuel boiling point is 205 ^{o}C maximum. The boiling point of liquid smoke from PET and OTHER plastic waste is below the maximum limit of repeated quality standards. Based on this boiling point value, liquid smoke from PET and OTHER plastic waste can be classified as gasoline or kerosene fuel [16].

c. Flash point

The results of the flash point test for liquid smoke from PET and OTHER plastic waste were 28.00 ^{o}C and 27.50 ^{o}C, respectively. The

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flash point of gasoline circulating in the market is 57 ^{o}C. The flash point of PET and OTHER plastic waste liquid smoke shows a number below the flash point of gasoline circulating on the market. Increasing the composition of short-chain hydrocarbon compounds results in lower flash points and higher boiling points [16]. Based on the flash point value, liquid smoke from PET and OTHER plastic waste is classified into gasoline or kerosene as fuel.

d. calorific value

The results of testing the calorific value of PET and OTHER plastic waste liquid smoke were 10,890 cal/g and 10,891 cal./g, respectively. Both PET and OTHER types of plastic waste calorific values can meet the standard calorific value of gasoline based on data from Pertamina, which states that the calorific value of gasoline is a minimum of 10,160 cal/g and a maximum of 11,000 cal/g. Fuel with a low calorific value indicates that the composition of short-chain hydrocarbons is small or vice versa. The calorific value of fuel indicates the value of the calorific energy resulting from a combustion process per unit mass of fuel. Based on the calorific value of liquid smoke, PET and OTHER plastic waste can be classified into gasoline or kerosene as fuel. Gas Chromatography-Mass Spectroscopy (GC-MS) Liquid Smoke PER and OTHER AnalysisThe results of the GC-MS analysis show that the GC chromatogram of liquid smoke from PET plastic waste is presented in Figure 2.

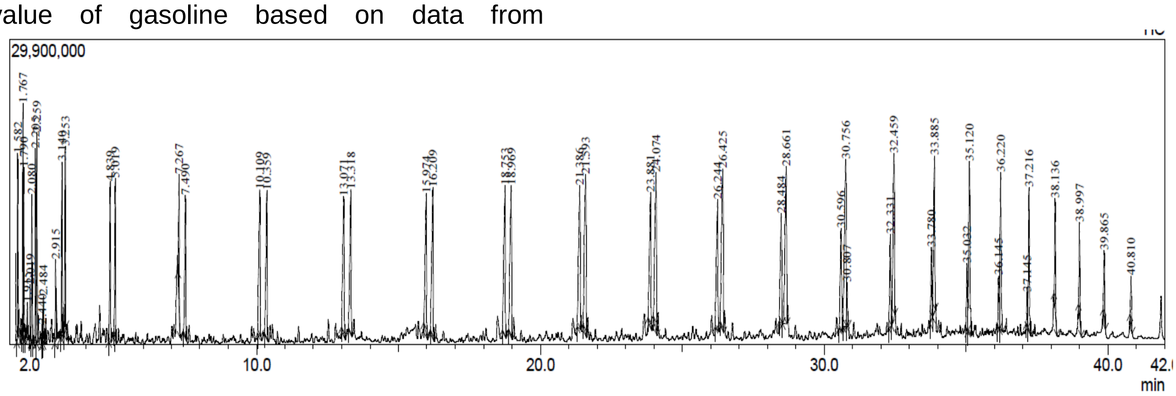

Figure 2 GC chromatogram of PET plastic waste liquid smoke.

The Chromatogram of liquid smoke gas of PET plastic waste shows 50 peaks. It means that the liquid smoke of PET plastic waste consists of 50 chemical compounds.

The results of the GC-MS analysis show that the GC chromatogram of OTHER plastic waste liquid smoke is presented in Figure 3.

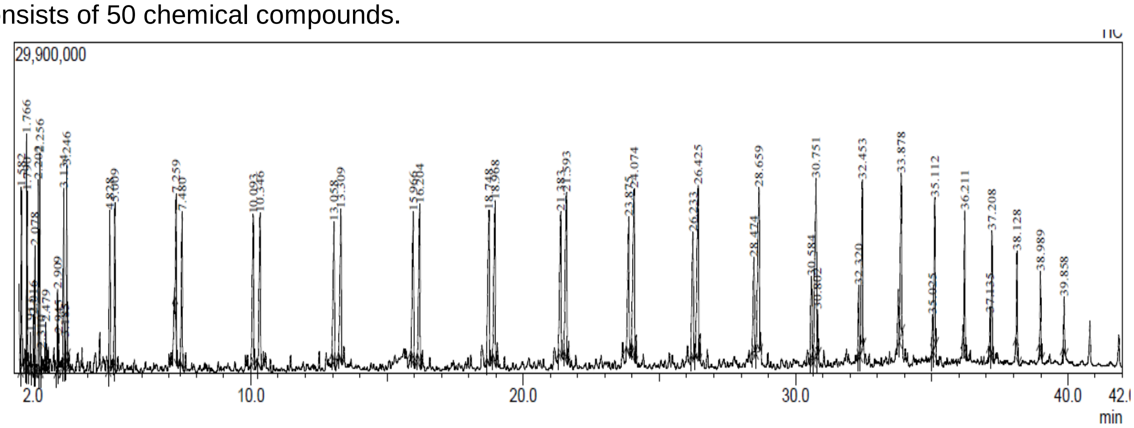

Figure 3 GC chromatogram of liquid smoke from OTHER plastic waste.

The gas chromatogram of liquid smoke from OTHER plastic waste shows 49 peaks. It means liquid smoke from PET plastic waste consists of 49 chemical compounds. Based on data from the mass spectrum, PET and OTHER plastic waste liquid smoke consist of a mixture of hydrocarbon derivatives: alkanes, alkenes, cycloalkenes, benzene, and alcohols.

CONCLUSION

1. Pyrolysis of 200 g of PET-type plastic waste produces 77.70% liquid smoke, and pyrolysis of 200 g of OTHER-type plastic waste produces approximately 71.65%.
2. The physical properties of liquid smoke resulting from pyrolysis from PET and

ORTHER plastic waste cannot be used directly as fuel oil because some of these physical properties need to meet the SNI fuel quality standards.
3. Identification with GC-MS that liquid smoke from PET and OTHER plastic waste consists of 50 and 49 chemical compounds, respectively.
4. Liquid smoke from the pyrolysis results of PET and OTHER types of plastic waste are both composed of derivatives of hydrocarbon compounds, alkanes, alkenes, cycloalkanes, cycloalkenes, and alcohols.

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