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Waste Frying Oil as Source of Alternative Energy

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Abstract:*Waste frying oil (WFO) is a potential harmful substance to human health and environment. It can be converted as alternative energy source. Conversion WFO into fatty acid methyl ester (FAME), also known as biodiesel, can be carried out by esterification to minimize free fatty acid (FFA) content, then followed by transesterification. In this process, methanol is added with potassium hydroxide (KOH) acts as catalyst. Variations of KOH percentage and reaction temperature give yields of 98%. Physical and chemical properties of FAME produced meet standard of Pertamina (Indonesian Petroleum Company), especially on density and flash point. However, the viscosity is much higher than expected.*

Keywords: *WFO, FAME, FFA, esterification, transesterification*

I. INTRODUCTION

In Indonesia, the most common oil for cooking is palm oil. According to Ministry of Trading, 4.8 million tonnes palm oil is used in 2012 [1]. Most of the oil is used for frying. After exposed to extreme heat during frying, composition of palm oil becomes harmful for human health [2]. Dumping this waste causes environment pollution. Therefore, waste frying oil must be processed into a useful substance.As human population increase energy demand rising to fulfill necessity of human's life. At the moment, most energy source is fossil fuel that in forms of coal, oil, and gas. Deposit of fossil fuel is limited and unsustainable. The amount of crude oil in the bead of the earth decreasing due to enormous exploration and exploitation for the last 60 years since the end of World War II. According to [3], crude oil will last for 40 years. Therefore, an alternative source of world energy must be immediately determined.In Indonesia, production of crude oil keep decreasing since 2001. Recently, according to [1] the production is less than 1 million barrels perday. With consumption of oil more than that, Indonesia has to import. The problem becomes more complicated as the government must give oil subsidy in order to keep the price affordable. In 2011, the oil subsidy is more than Rp 140 trillions or almost 10% of national budget. This is not healthy in terms of national development program and energy security. Therefore, an alternative energy source to replace fossil fuels, especially gasoline and diesel fuels, must be on top priority.Energy source comes from plants or vegetable is more promising as an alternative. It is more sustainable and more environmentally friendly than fossil fuels. Energy from plants form closed loop while fossil fuels do not , as visualized below.

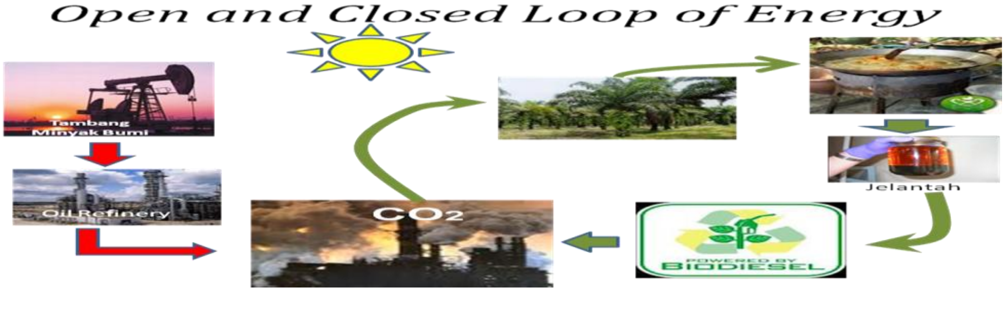


Figure 1. Loop of Energy

Several studies to determine energy source from various plants and seeds have been carried out through out the world. Biodiesel, a fuel that produced from plants or seeds to replace diesel fuel from fossil, already in market since 1990s [4]. It can be produced from plants namely soybean, peanut, sunflower, corn, coconut, palm, and many other type of plants.In Turkey, [4] studying biodiesel production from waste cooking oil with KOH catalyst and achieve a yield of almost 90%. Meanwhile, [5] producing biodiesel from sunflower oil using lypase enzyme with a yield of 97%. In China, [5] study on transesterification of a vegetable oil called eruca sativa gars (ESG) with methanol reach a conversion yield more than 80%. Using rice bran oil (RBO), [6] can reach conversion 98.7%. In the USA, [7] producing biodiesel from soybean oil with conversion yield of 97%. In the same country, [8] using canola oil and corn oil to produce biodiesel with conversion yields achived 95% and 96% respectively.Besides oil from such plants mentioned above, palm oil can also be used as raw material for biodiesel. Palm is the most common plant producing frying oil in Indonesia. It grows almost in all islands from Sumatera (Andalas) to Papua. In 2011, the production of palm oil is almost 20 million tons a year and the national consumption is less than 5 million tons, mostly for frying. Although palm oil can be used to produce biodiesel, it will cause conflict of interest because it is edible. Avoiding that conflict, waste of frying oil (WFO) is more suitable as material for biodiesel production.

WFO comes from oil used for frying, already exposed to extreme heat of more than 250 ^{o}C. The heat decompose frying oil contents, mostly as palmitate in triglyceride, to form palmitic acid as part of free fatty acid (FFA) and several chemical compounds such as aldehydes and peroxides. According to [2], WFO is not edible and harmful to human health even may cause cancer.There are two major contents in WFO, FFA and triglyceride. In order to produce biodiesel, there must be two chemical reactions required, namely esterification and transesterification. Esterification is a reaction converting an acid to form an ester using an alcohol. At this stage, FFA is reacted with methanol to form methyl ester and water. After that transesterification, a reaction converting one type of ester to form another ester. Triglyceride is an ester. Reaction of triglyceride and methanol producing methyl ester and glycerine (glycerol). Methyl esters produced from esterification and transesterification is known as fatty acid methyl ester (FAME), another name of biodiesel.

II. MATERIALS AND METHODS

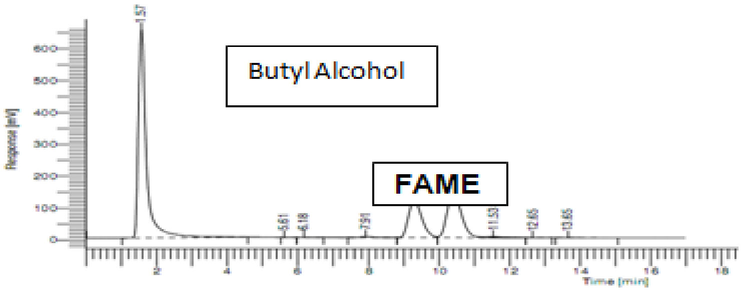
In this research, WFO that originally palm oil was bought from local home industries producing snacks. Methanol used was technical grade and made by Merck Germany. Potassium hydroxide (KOH) and sulphuric acid (H_2SO_4) used as catalyst were technical grade and also made by Merck Germany.WFO was analyzed by titration method using phenolphtalein (PP) as indicator. This step was carried out to determine it's FFA percentage which indicating whether esterification must be performed or not.

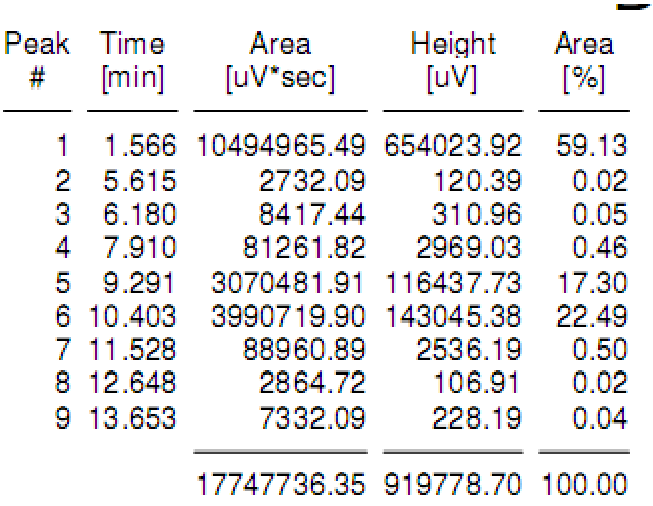
WFO and methanol was mixed and strirred gently to perform esterification of FFA. The product of the reaction was methyl ester and water. The latter was then decanted using a separatory funnel [10] .A solution of 1% KOH in methanol was made by mixing the materials using an electric stirrer. The solution then was electrically heated to 60^{o}C. Simultaneously, already esterified WFO was also heated to 60 ^{o}C. Both solutions were reacted, gently stirred, and heated to 65 ^{o}C. This condition was maintained for 30 minutes. The products of the reaction were methyl ester, glycerol, and unreacted methanol. The methyl ester as clear top product was separated using a separatory funnel [7] [10] .A gas chromatography (GC) at Instrumentation Analysis Laboratory of The State Polytechnic of Malang, was made by Hewlet Packard (HP) with a packing column of OV. Flame ionozation detector (FID) was used to analyze the methyl esters [12]. This step was carried out to determine conversion percentage by comparing with standard FAME provided by Pertamina. Butyl alcohol was added as internal standarad [13] [14] to avoid miscalculation in quntitative analysis.Physical and chemical properties of the methyl ester were determined in terms of density, viscosity, and flash point. The properties were compared to values of Pertamina commercial diesel fuel (petrodiesel) that in Indonesia known as *solar*.

III. Results and Discussion

Titration of WFO using 0.1N KOH showed that the FFA percentage was less than 2.5. Esterification using sulphuric acid as catalyst was not necessarily performed prior to transesterification [9]. Variables used in transesterification were percentage of catalyst KOH and temperature of reaction. The percentage: 0.5, 1.0, and 1.5. The temperature: 55, 57, 60, 63 and 65 ^{o}C [11].

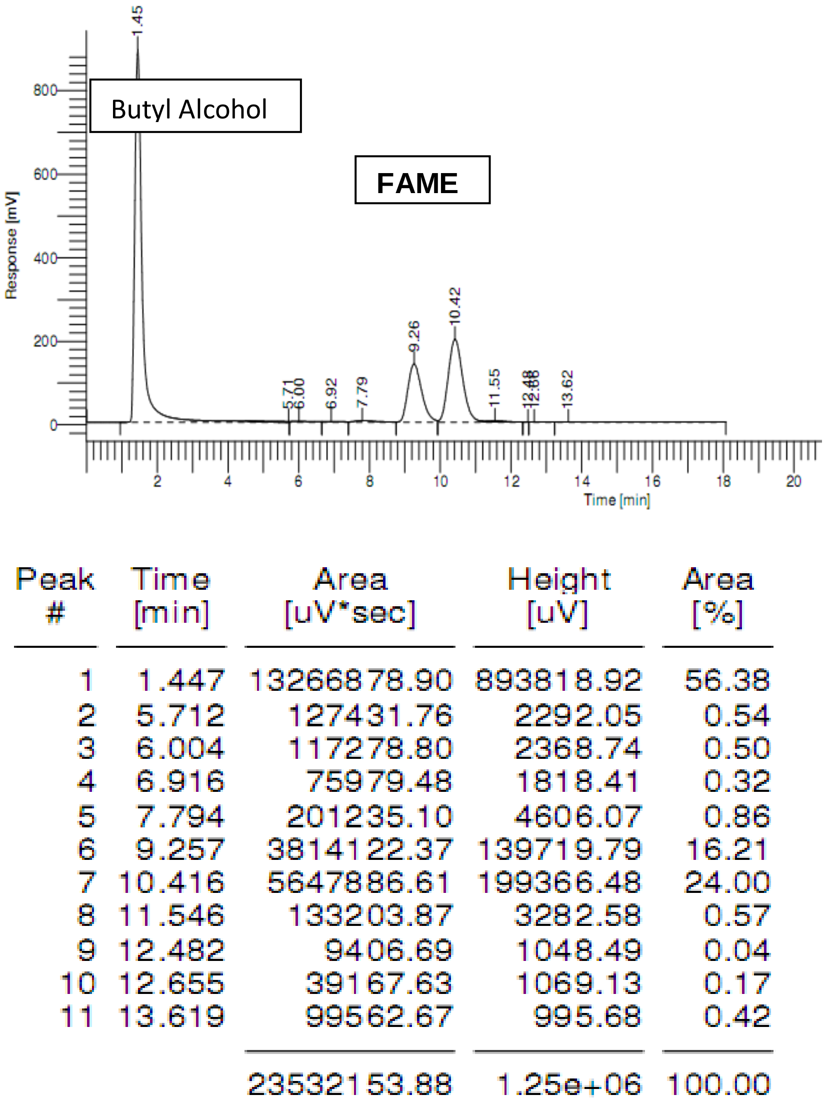
Chromatograms of standard FAME and optimum product were as follow:





Peak #	Time [min]	Area [uV*sec]	Height [uV]	Area [%]
1	1.566	10494965.49	654023.92	59.13
2	5.615	2732.09	120.39	0.02
3	6.180	8417.44	310.96	0.05
4	7.910	81261.82	2969.03	0.46
5	9.291	3070481.91	116437.73	17.30
6	10.403	3990719.90	143045.38	22.49
7	11.528	88960.89	2536.19	0.50
8	12.648	2864.72	106.91	0.02
9	13.653	7332.09	228.19	0.04
		17747736.35	919778.70	100.00

Fig 2 Chromatogram of FAME from Pertamina (Standard)



Peak #	Time [min]	Area [uV*sec]	Height [uV]	Area [%]
1	1.447	13266878.90	893818.92	56.38
2	5.712	127431.76	2292.05	0.54
3	6.004	117278.80	2368.74	0.50
4	6.916	75979.48	1818.41	0.32
5	7.794	201235.10	4606.07	0.86
6	9.257	3814122.37	139719.79	16.21
7	10.416	5647886.61	199366.48	24.00
8	11.546	133203.87	3282.58	0.57
9	12.482	9406.69	1048.49	0.04
10	12.655	39167.63	1069.13	0.17
11	13.619	99562.67	995.68	0.42
		23532153.88	1.25e+06	100.00

Fig 3. Chromatogram of Optimum FAME Produced from WFO

Both chromatograms shows a similarity in terms of retention time. It means FAME produced from WFO contains the same substances as Pertamina standard.

Table 1. Results of The Research

No	%KOH	T (°C)	Yield (%)	ρ (kg/lt)	ν (cSt)	F_T (°C)
1	0.5	55	81	0.88	21	154
2		57	82	0.88	21	153
3		60	84	0.88	20	154
4		63	85	0.87	21	153
5		65	85	0.87	19	155
6	1.0	55	83	0.88	21	156
7		57	84	0.88	20	158
8		60	85	0.87	21	156
9		63	85	0.88	22	160
10		65	86	0.88	22	158
11	1.5	55	86	0.88	20	154
12		57	88	0.86	22	158
13		60	92	0.88	22	160
14		63	96	0.87	21	158
15		65	98	0.88	22	160
Pertamina Diesel Fuel (*Solar*)				0.82-0.86	2.0-4.5	Min 55

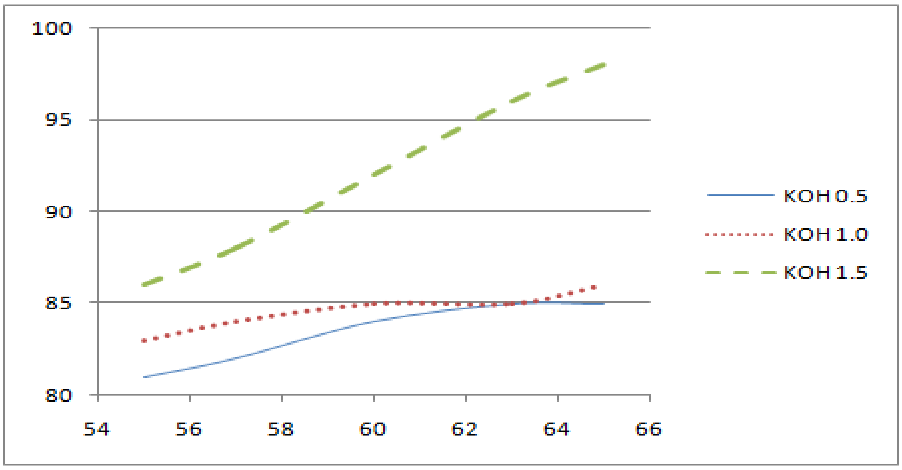


Figure 4. Yield of FAME at Various Temperatures and Catalyst Concentrations

Homogeneous transesterification of WFO using KOH as catalyst showed a yield increase as the catalyst concentration higher. Nevertheless, a high catalyst concentration has a higher risk of sapononification that decerease the yield [10]. Therefore, the catalyst concentration was kept below 1.5% (w/w).Similarly, the higher the process temperature, the higher was the yield. However, it should not reach the boiling point of the methanol to avoid evaporation and loss of the methanol that could decrease the yield. At this experiment, the maximum process temperature was 65 °C [6] and produced a maximum yield.

IV. Conclusion

WFO can be converted into fuel for diesel engine with density and flash point meet those of Pertamina diesel fuel. The only problem is its viscosity. With high viscosity a problem arises on injection process since it cannot form a perfect mist of fuel and air mixture. Optimum point is determined at percentage catalyst KOH of 1.5% and reaction temperature 64 °C giving a maximum yield of 98%.

V. Acknowledgement

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