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The Potential of Waste Cooking Oil and Oily Food Waste as Alternative Biodiesel Feedstock in Padang Municipality

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Abstract. Indonesia is highly dependent on fossil fuels to support its development. In order to reduce fossil fuel dependency, Indonesian Government sets up policies to promote biodiesel, i.e. a petro-diesel substitute deriving from plant oils. However, current biodiesel production only relies on the use of crude palm oil (CPO). This study has, therefore, been done to know other potential biodiesel feedstock in Padang Municipality, namely, waste cooking oil (WCO) and oily food waste (OFW). The surveyed WCO and OFW generators comprised of households and commercial activities. Direct sampling for waste quantification was carried out based on the Indonesian standard for municipal waste sampling (SNI No. 19-3964-1994), while questionnaire survey was done to know the existing practices in waste handling and people willingness to participate in collecting the wastes. Moreover, WCO and OFW samples were laboratory analysed for its acid value, water content and fatty acid profile. Some good practices were also learned from Kitakyushu City in Japan that has used WCO in biodiesel production. This study shows that WCO and OFW are highly potential for biodiesel feedstock in Padang Municipality, due to the waste availability, their properties to be converted to biodiesel, and willingness of people to collect the waste.
Keywords: Biodiesel, FAME, Padang Municipality, Waste Cooking Oil

1. Introduction

Indonesia is the world’s fourth largest nation with 251 million people [1] that needs large amount of energy source to support the country. However, since 2004 Indonesia has become a net oil importer country that must fulfil some of the demands by importing it. This situation has given additional burden for the government expenditure, particularly when there is an increase in world oil price.

In order to overcome the energy issue, since 2008 the government through the Ministry of Energy and Mineral Resources [2] issued some policies to reduce the dependency on imported fuels. One of the policies is the utilization of biodiesel as an alternative fuel to petro-diesel. Recently, a newer regulation [3] has been issued to accelerate the increase of biodiesel amount used domestically, i.e., the implementation of 20% biodiesel blending with petro-diesel (B20) for transportation sector will be implemented in earlier in 2016, instead of executed in 2025 as planned by the former regulation.

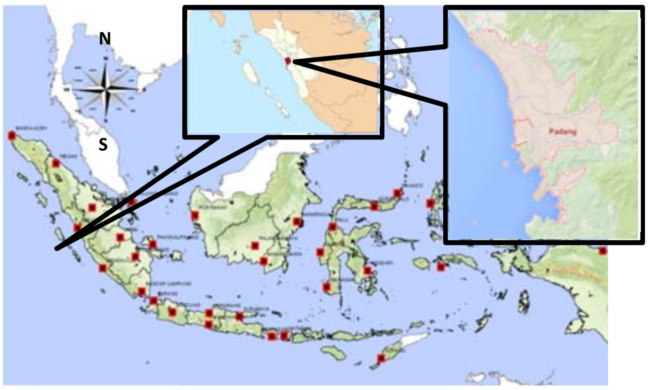
However, at the moment, biodiesel producers in Indonesia only use crude palm oil (CPO) as the main biodiesel feedstock [4], triggering land conversion into oil palm plantations. Moreover, in order to prepare the land conversion, some people often created forest/peatland fires. Both practices not only increased the amount of carbon emission and endangering biodiversity, but also increased the risk of food crisis in Indonesia [5].

Oil and fats consumed in West Sumatera Province are higher than the other provinces in Indonesia, because of its oily-food eating habits [6]. Some of those oil and fats will eventually become wastes that can potentially be converted into biofuel [7]. Therefore, this study was done to know the potential of waste cooking oil (WCO) and oily food waste (OFW) from some households and food selling activities as biodiesel feedstock in Padang Municipality.

2. Methodology

2.1. Location of Study

Padang municipality is located in West Sumatera Province with total population of 999,805 people or 166,076 households in 2014. Moreover, there are 456 food commercial activities (food sellers) that potentially generate WCO and OFW. The location of Padang Municipality in the West Sumatera Province is shown in Figure 1.



INDONESIA **Figure 1.** Location of Study

2.2. Determination of Sample Number

This study comprised of questionnaire survey, collection of WCO and OFW samples, and laboratory analysis of the samples. The questionnaire study was used to know the existing habit on WCO and OFW handling. The direct WCO and OFW sample collection was taken to know the waste amount fluctuation. The laboratory analysis was done to evaluate some important waste parameters. The recapitulation of sample number is shown in Table 1.

Table 1. Recapitulation of Sample Number

No.	Type of Activity	Number of Household or Business Unit	Number of Sample for		
			Questionnaire *	Waste Quantity Analysis**	Waste Quality Analysis***
Households****					
1.	High Income (HI)	54,560	347	8	3
2.	Medium Income (MI)	74,339	473	9	3
3.	Low Income (LI)	37,177	236	5	3
	Total	166,076	1,056	22	9
Food Sellers					
1.	Catering	24	7	7	3
2.	Hotel	68	39	10	3
3.	Restaurant	82	49	9	3
4.	Food Stall	175	104	9	3
5.	Street Vendor	107	97	12	3
	Total	456	296	47	15

*Based on Slovin Equation
** Based on SNI 19-3964-1994 [8]
*** Based on Stratified Random Sampling Method
****HI: > IDR 3.5million/month; MI: IDR 1.5-3.5/month; LI: < IDR 1.5 million/month [9]

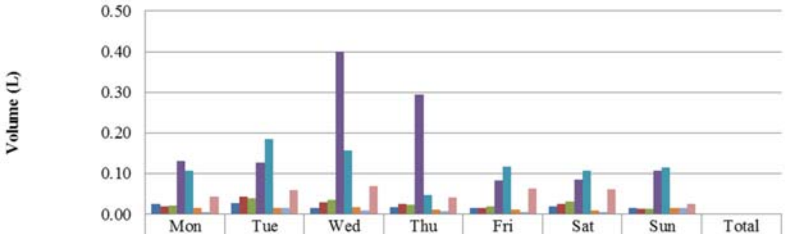
2.3. Laboratory Analysis of Samples

Laboratory analysis was done to know some important parameters related to biodiesel production method and expected biodiesel cold-flow properties. Those parameters are water content, free fatty acid (FFA) content and fatty acid profile. Water content and FFA content were measured by using gravimetric and titration method, respectively. While for fatty acid profile, the measurement was done by using Gas Chromatography-Mass Spectrometry (GC-MS). The determination of possible biodiesel production method was based on the fatty acid contents, i.e., the higher the fatty acid contents, the less possible for using alkali-catalysed methods. While for the cold-flow properties, the fatty acid compositions were used to estimate possible solidification of biodiesel due to low temperatures. The more saturated fatty acids, the most likely it would be frozen at low temperatures.

3. Results and Discussion

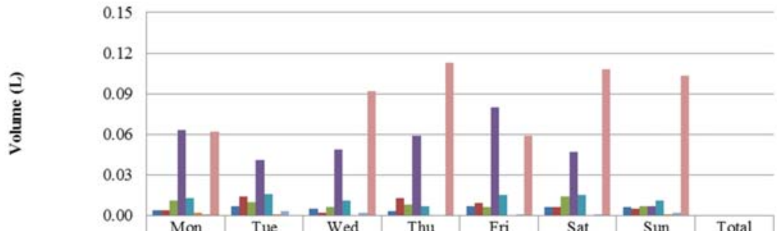
3.1. Estimation of WCO and OFW Quantity

Direct measurement of WCO and OFW generation was done in order to know the amount of those waste coming from both households and food sellers per day during a week period of time. This measurement was also conducted to see the fluctuation of the waste generation. The results of direct WCO and OFW amount generated per day in a week are presented in Figure 2 (a) and (b), respectively.



	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
Low Income	0.025	0.027	0.014	0.016	0.014	0.019	0.015	0.131
Medium Income	0.019	0.042	0.028	0.024	0.014	0.025	0.012	0.163
High Income	0.021	0.039	0.035	0.023	0.019	0.031	0.012	0.179
Catering	0.13	0.127	0.4	0.295	0.082	0.085	0.106	1.225
Hotel	0.106	0.185	0.157	0.046	0.116	0.106	0.115	0.831
Restaurat	0.015	0.015	0.017	0.01	0.01	0.008	0.014	0.089
Food Stall	0.005	0.015	0.009	0.006	0.005	0.004	0.014	0.057
Street Vendor	0.042	0.059	0.068	0.04	0.063	0.06	0.025	0.358

(a) WCO



	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
Low Income	0.004	0.007	0.005	0.003	0.007	0.006	0.006	0.039
Medium Income	0.004	0.014	0.002	0.013	0.009	0.006	0.005	0.053
High Income	0.011	0.01	0.006	0.008	0.006	0.014	0.007	0.063
Catering	0.063	0.041	0.049	0.059	0.08	0.047	0.007	0.347
Hotel	0.013	0.016	0.011	0.007	0.015	0.015	0.011	0.088
Restaurant	0.002	0.001	0	0	0	0	0.001	0.004
Food Stall	0.001	0.003	0.002	0	0.001	0.001	0.002	0.011
Street Vendor	0.062	0	0.092	0.113	0.059	0.108	0.103	0.538

(b) OFW

Figure 2. Average WCO and OFW Amount Generated in a Week

As can be seen from Figure 2 (a), the average amounts of WCO generated from households and food sellers were from 0.131 to 0.179 litres per week and from 0.057 to 1.225 litres per week, correspondingly. The catering generated more WCO compared to other waste generators due most likely to the number of food servings that must be higher for that activity. While for the food stalls that generate the least amount of WCO, it might be due to the WCO re-using habit in preparing foods. Figure 2 (a) also shows the weekly fluctuation of WCO generation from households and food sellers. The highest amount of WCO generation from households was on Tuesday, while for the food seller it happened on Wednesday.
Furthermore, Figure 2 (b) shows the average amounts of OFW generated from households and food sellers, ranging from 0.039 to 0.063 litres per week and from 0.004 to 0.538 litres per week, respectively. From this direct measurement we can see that some of the food sellers almost did not generate any OFW at all, which are directly related to the type of food that they provide for costumers, i.e., non-oily meals. Moreover, from the same figure we can observe that the highest OFW amounts generated by households and food sellers were on Tuesday and Saturday, respectively.
Based on data shown in Figures 2 (a) and (b), waste generation factors for both WCO and OFW were obtained, and shown in Table 2. The factors were then multiplied by the total population of each waste generator as presented in Table 1. Thereby, the estimation of total amount of WCO and OFW per week in the study area could be obtained, and shown in Figure 3.

Table 2. WCO and OFW Generation Factor

No.	Type of Activity	Waste Generation Factor	
		WCO	OFW
Households			
1.	High Income (L/HH/week)	0.131	0.039
2.	Medium Income (L/HH/week)	0.163	0.053
3.	Low Income (L/HH/week)	0.179	0.063
Food Sellers			
1.	Catering (L/BU/week)	1.225	0.347
2.	Hotel (L/BU/week)	0.831	0.088
3.	Restaurant (L/BU/week)	0.089	0.004
4.	Food Stall (L/BU/week)	0.057	0.011
5.	Street Vendor (L/BU/week)	0.358	0.538

*HH = household; BU = business unit

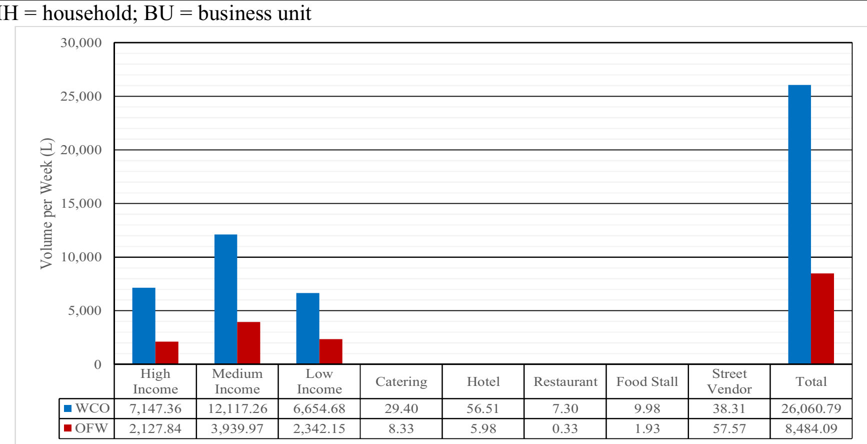


Figure. 3. Estimation of Total WCO and OFW Amounts Generated per Week

From Figure 3, it is estimated that the highest amounts of WCO and OFW come from medium, low, and high income households, respectively. This is most likely due to the population number of those sources. Based on the figure, approximately 26,060.79 and 8,484.09 litres/week of WCO and OFW are generated, correspondingly, in the study area.

3.2. Existing Practice in Using Cooking Oil and Handling the WCO and OFW

Existing WCO handling are shown in Figure 4. Most households (61-75%) directly discharged the waste into the sewer, while the figure is 24-43% for the food sellers. Although at present there is no regulation that bans this waste handling practice in Padang Municipality, however this activity is not acceptable due to the risk of water pollution issues [10][11]. On the other hand, the re-using of WCO showed a contrast figure, i.e., conducted by 20-39% households and practiced by up to 60% food sellers.

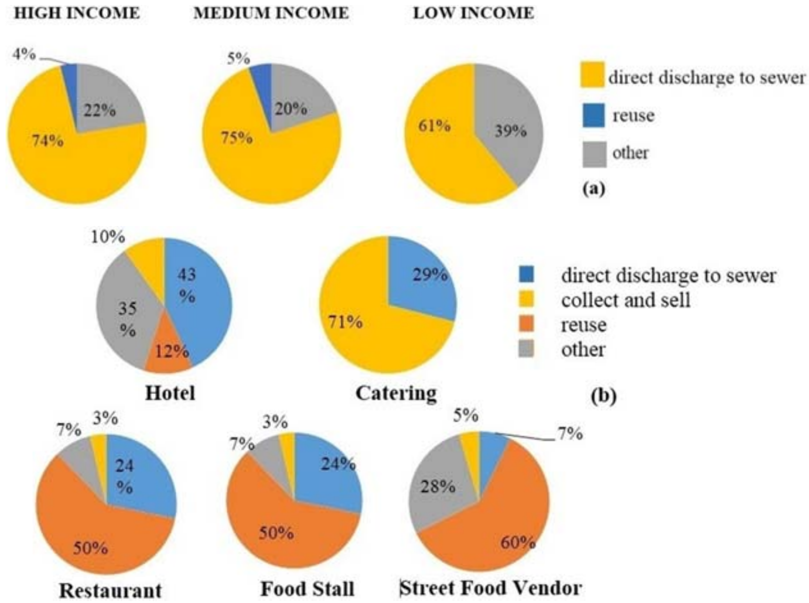


Figure 4. WCO Handling by Respondents (a) Households; (b) Food Sellers

The questionnaire survey further explored current practices in re-using cooking oil, and the results are shown in Figure 5. Based on the figure, most household respondents (51.26%) re-used the cooking oil up to 3 times. On the other hand, almost all food sellers re-used the cooking oil more than once. Around 16% of street food vendors re-use the cooking oil more than 8 times. Re-using cooking oil has been studied by many researchers [12][13][14] with a similar conclusion, i.e., it causes health problems due to the formation of free radicals during the re-heating of the cooking oil.

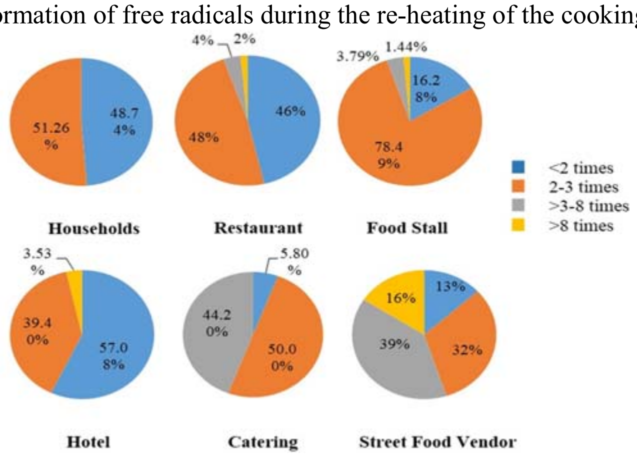


Figure 5. Cooking Oil Re-using Habit among Respondents

3.3. Possible People Participation in Collecting WCO and OFW

The results of questionnaire survey to find out people willingness to collect WCO and OFW are shown in Figure 6, as follow.

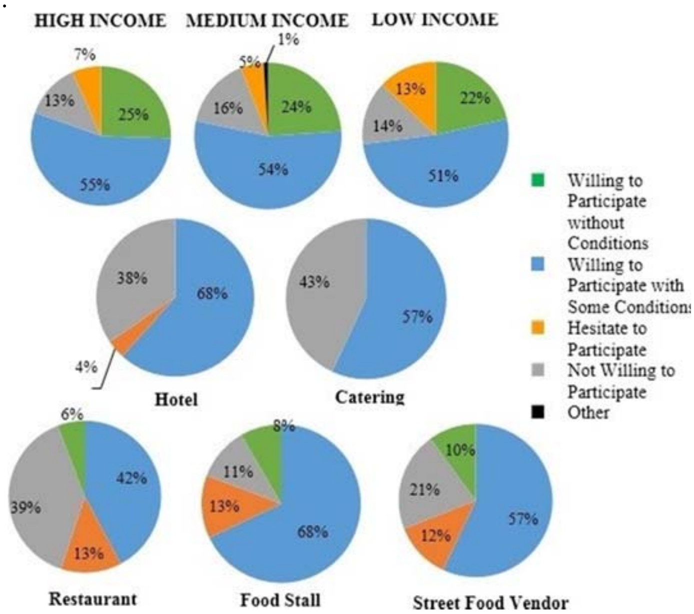


Figure 6. Possible People Participation on Collecting WCO and OFW

Most households (up to 73-80%) are willing to participate in collecting the waste, although some of them (57-68%) required the waste containers to be provided by other parties. As for the food sellers, around 48-76% will join to collect the wastes, but most of them (42-68%) have some conditions that must be fulfilled, e.g., institutions that want to utilize the waste must pay money for their participations. On the other hand, 13-16% household respondents are against the proposed plan, while the number is higher for the food seller respondents (up to 43%). Hesitant respondents for households and food sellers are 5-13% and 4-12%, respectively.

3.4. Evaluation of WCO and OFW Properties

Some important parameters that were evaluated are water content, acid value and fatty acid profile of the wastes. The results of WCO and OFW chemical property evaluation is presented in Figures 7, 8, and 9.

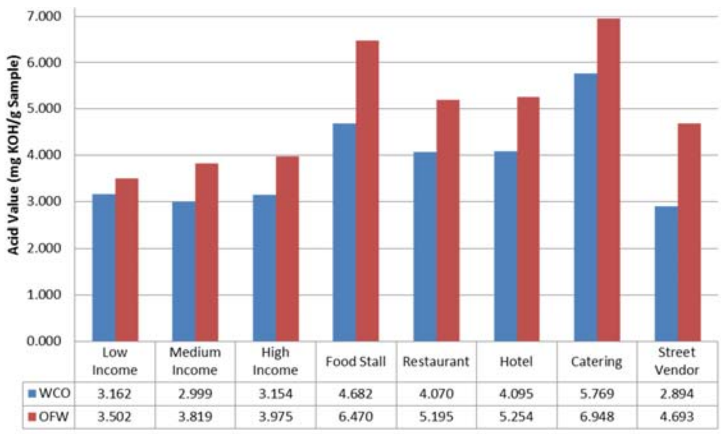


Figure 7. Acid Value of WCO and OFW

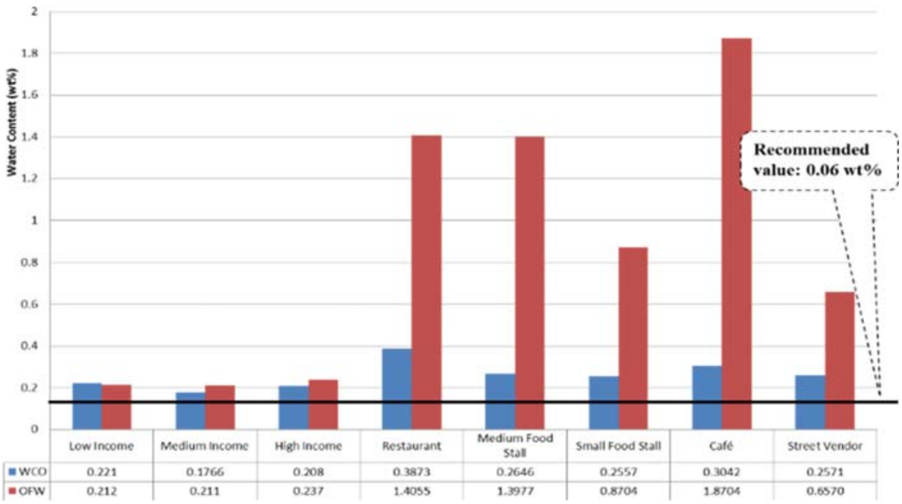


Figure 8. Water Content of WCO and OFW

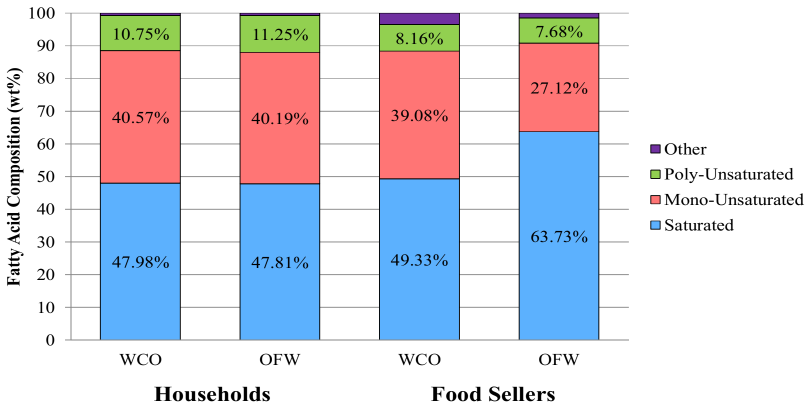


Figure 9. Fatty Acid Profile of WCO and OFW

Figure 7 shows that all samples had higher acid value than the maximum value of 1 mg KOH/g sample, which makes the most popular alkali-catalysed biodiesel production method unsuitable. Another alternative is acid-catalysed method that is continued by the alkali-catalysed method (two step method). However, this method can be disrupted by high water content in feedstock. From Figure 8 we can observe that all water contents are more than the recommended value of 0.06wt% [15]. The high water content in biodiesel feedstock could interfere the acid-catalysed method [16], thus a WCO and OFW dewatering process must be taken into account, either by using dewatering agents or by vacuum heating process, to ensure that the acid-catalysed method can proceed [17].

Lastly, the result of fatty acid profile measurement of WCO and OFW is presented in Figure 9. The fatty acid profile can be used to predict some biodiesel important properties, i.e., cold flow property and oxidation stability. It can be seen that only OFW from food sellers that had more than 50% saturated fatty acid that could cause biodiesel solidification at low temperature [18]. However, this is not an issue since the annual ambient air in Padang is around 25ºC. As for the oxidation stability, the highest amount of poly-unsaturated fatty acid, which is related to low oxidation stability, was found in OFW from households [19]. Nevertheless, this can be overcome by the use of anti-oxidant, if necessary.

3.5. Lessons Learned from Kitakyushu City

Some information has been gathered from stakeholders who are participating in re-utilization of WCO in Kitakyushu City, which can be seen in Table 3, as follows.

Table 3. Compiled Information from Stakeholders in Kitakyushu City

No.	Stakeholder	Action
1.	Government	• Set regulations to prevent direct discharge of WCO. • Educate people. • Allocate spaces for placing WCO collection box. • Policy to use biodiesel for city buses and garbage trucks.
2.	Biodiesel producer	• Provide containers at collection points. • Provide pick up service for WCO generators. • Distribute brochures to educate people. • Convert WCO into biodiesel. • Utilize the biodiesel in company vehicles.
3.	Other stakeholders	• Supermarkets allocate spaces for WCO collection boxes. • Industries located nearby biodiesel producer location use biodiesel for their forklifts.

4. Concluding Remarks

Based on this study, households and food sellers in Padang Municipality produce approximately 26,060.79 and 8,484.09 litres/week WCO and OFW, respectively. At the moment the handlings of the wastes are mostly by direct discharging into the sewer or re-using them in meal preparation. The willingness of both households and food sellers to participate in collecting the wastes to be re-utilized as biodiesel feedstock was quite high, particularly for the households. Based on the evaluation of some chemical properties of WCO and OFW, it can be concluded that it will be necessary to conduct dewatering process before the production of biodiesel starts. Based on information gathered from Kitakyushu stakeholders who are involved in biodiesel production from WCO in Kitakyushu City, some supporting regulations and infrastructures must be prepared to ensure the potential alternative biodiesel feedstock can be used in Padang Municipality.

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