Potentials of waste cooking oil from vacuum fryer as biodiesel

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Abstract: Renewable energy is necessary because of its potential in providing a steady supply of power without depleting natural resources. Analyzing the potential of converting waste cooking oil (WCO) from vacuum fryer into biodiesel is presented in this study as fuel source for daily use. Filtration of WCO was done before the process of biodiesel production with the use of granulated activated charcoal. This was done to remove the particles in the WCO. The conversion of WCO into biodiesel undergone the process of transesterification using sodium hydroxide (NaOH) as catalyst. Three-factor three-level complete factorial design was used in the study. The levels of catalyst concentration were 0.8 g, 1.0 g, and 1.2 g mixed with 250 mL of filtered WCO and 65 mL of methanol. On the other hand, the levels of reaction time were 30 min, 60 min, and 90 min while the level of agitation speed were set at 400 rpm, 600 rpm, and 800 rpm. Results showed that the combination of 0.8 g catalyst, 90 min reaction time, and 800 rpm agitation speed has the highest biodiesel yield of 262.3 mL. Statistical analysis showed that catalyst concentration is the only parameter that is significant. This sample was sent to a private laboratory for chemical analysis using ASTM D874 (sulfated ash), ASTM D445 (kinematic viscosity at 40ºC), and ASTM D2709 (water and sediment in middle distillate fuel). Results of the chemical analysis showed that the sample was beyond maximum limit of the three methods used in testing, thus, was not suitable for engine used but can be used as fuel source for cooking.

Keywords: biodiesel, waste cooking oil, transesterification

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1 Introduction

Biodiesel is one of the derived fuels made from renewable resources. This fuel has become more attractive recently because of its environmental benefits. Most of the people who convert vegetable oils into biodiesel obtain their sources from restaurants since it is free and must be properly recycled. Also, production of biodiesel helps aid an expensive fuel market and its by-products can be used for many other things. However, according to Erchamo et al. (2021), given that petrol biodiesel is existing, there is a main problem that is currently facing by biodiesel commercialization and its market competitiveness. It is the production cost and the expensiveness of the raw materials, if not from restaurants and other sources for free, used in the production of biodiesel.

In making biodiesel, there are four primary ways which include the direct use and blending,

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microemulsions, thermal cracking or pyrolysis, and transesterification. In this study, transesterification is to be used to convert waste cooking oil (WCO) into biodiesel. Transesterification is a process in which triacyl glycerides from a variety of feedstock such as nonedible oil seeds, vegetable biodiesel in the presence of alcohol such as methanol or ethanol (Yusup and Rashidi, 2021).

With the challenges in fuel production and consumption, biodiesel is a good choice as an alternative to petrol diesel. In this study, the main focus of biodiesel conversion is the WCO from vacuum fryer used in Food Innovation Center (FIC) MIMAROPA. Turning these stocked oils into biodiesel is a way to avoid disposal into drainages which can harm the environment. The transesterification process was conducted with the use of methanol as the alcohol due to its reactivity and high equilibrium conversion. Commercially available sodium hydroxide (NaOH) or lye catalyst was used in this study.

The general objective of this study is to analyze the potential of WCO from vacuum fryer as biodiesel.

Specifically, the study aims to:

Evaluate the effect of NaOH catalyst concentration, agitation speed, and reaction time in terms of biodiesel yield;

Determine the significant difference between the catalyst concentration, agitation speed, and reaction time in biodiesel yield;

Measure the flammability of biodiesel produced in terms of its burning temperature and time;

Analyze the chemical components of biodiesel produced in the process of transesterification using ASTM D874 (sulfated ash), ASTM D445 (kinematic viscosity at 40^{o}C), and ASTM D2709 (water and sediment in middle distillate fuel).

2 Materials and methods

2.1 Conceptual Framework

The study incorporates the issues-input-process-output-impact approach in the conceptual framework as presented in Figure 1. The issues that are trying to solve by this study is the proper disposal of WCO produced using the vacuum fryer of the Food Innovation Center MIMAROPA. For the oil filtration process, the input was activated charcoal (AC) and WCO from vacuum fryer which resulted to a filtered WCO. For the transesterification process, the input was the filtered WCO, methanol, and NaOH which then resulted to an output of biodiesel. The biodiesel produced from filtered WCO undergone a chemical analysis to determine its fuel properties. The result of analysis showed the results of ASTM D874 (sulfated ash), ASTM D445 (kinematic viscosity at 40^{o}C), and ASTM D2709 (water and sediment in middle distillate fuel) as an output. The impact of this study was the conversion of WCO into something useful such as biodiesel. The potentials of other byproducts of transesterification process can also be explored such as soap and wax.

2.2 WCO sample preparation

WCO was collected from FIC MIMAROPA. As part of the pretreatment process, the oil was filtered to remove food particles and other impurities, using a commercially available AC made from coco shells. Before the filtration, the AC was heated at 90° for 30 minutes. After the oil was filtered, it is now ready to proceed for the transesterification process. Presented in Figure 2 are the unfiltered WCO from vacuum fryer.

2.3 Transesterification of WCO

The transesterification process was carried out using available laboratory equipment. The oil was preheated at 60^{o}C using a heat pan magnetic stirrer until it reached the said temperature to remove the water content present in the oil. Simultaneously, the catalyst was weighed and dissolved in the required amount of methanol. The preheated oil and methanol with dissolved catalyst mixture was combined. Methanol was chosen in comparison to ethanol and butanol because it gives higher biodiesel yield (Hossain et al., 2010). The transesterification process was performed to obtain the maximum yield of biodiesel by varying the amount of catalyst, reaction time, and agitation speed.

To determine and optimize the effect of catalyst concentration, reaction time, and agitation speed, different experimental runs were conducted. All trials had a constant volume of filtered WCO of 250 mL. To determine the effect of catalyst, reaction time, and agitation speed, each run had three levels of values needed for each factor. The parameters like reaction temperature and amount of alcohol were kept constant at 60°C and 65 mL, respectively.

Reaction temperature was set at 60°C because according to the result of the study of Naik et al. (2015), the biodiesel yield is greater than at 60°C compared to 50°C and 70°C. The NaOH catalyst had three different amounts used: 0.8 g, 1.0 g, and 1.2 g. These concentrations were also based on the result of the study of Naik et al. (2015). NaOH was chosen as the catalyst because of its property to dissolve in methanol quickly.

For the reaction time, 30, 60, and 90 minutes was used and agitation speed of 400, 600, and 800 rpm using heat pan magnetic stirrer. The values for the reaction time were based on the study of Coniwanti et al. (2019) wherein a 60 minute reaction time is the optimum value. Each had three trials for the accuracy of the results. The values considered in the agitation speed were based on the result of the study conducted by Tesfay et al. (2019).

Two layers were formed during the transesterification process. The setups were allowed to stand for 24 hours for the layers to settle completely. The glycerol accumulated at the bottom layer and the biodiesel on the top layer. Presented in Figure 3 is the process block diagram of biodiesel production used in this study.

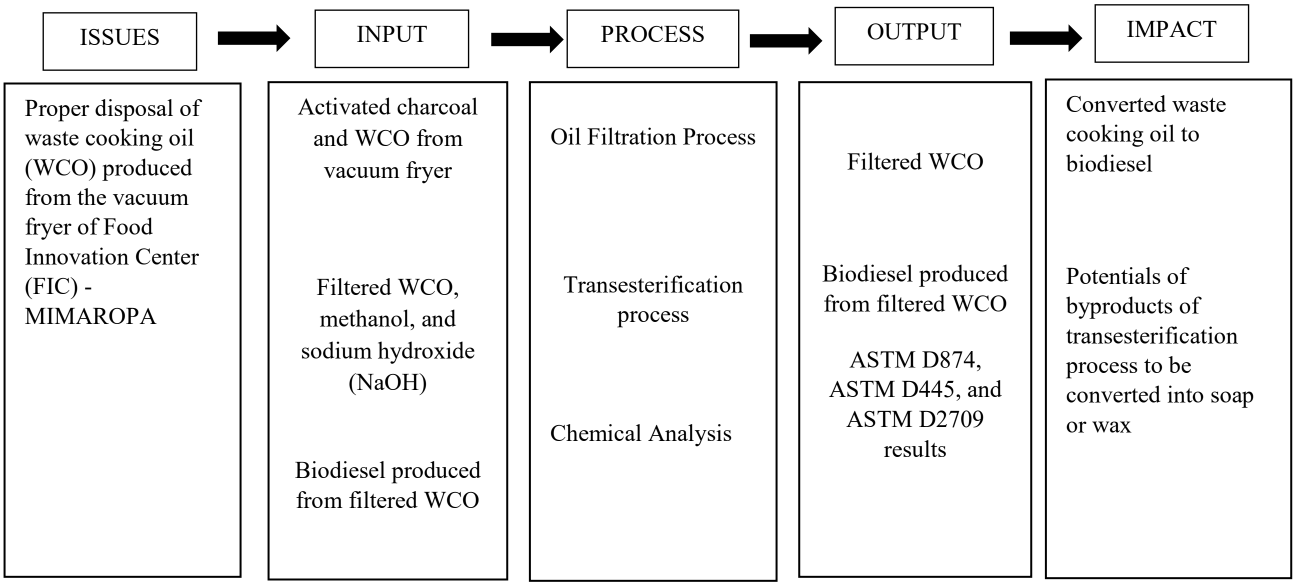


Figure 1 Conceptual framework of the study

Figure 2 The waste cooking oil from vacuum fryer before filtering

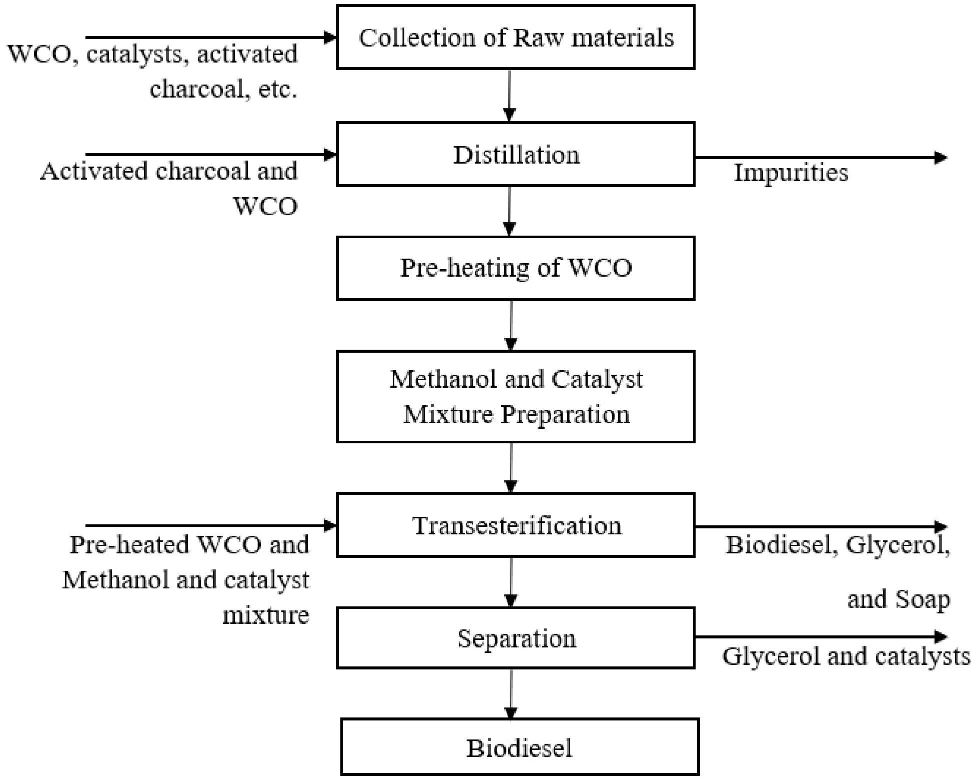


Figure 3 The process block diagram of biodiesel production

2.4 Data gathering

Experiments on converting the WCO into biodiesel were performed. To gather the data in every test of the performance of the catalyst with three levels of reaction time and agitation speed, the biodiesel produced was recorded by volume. The flammability of the produced biodiesel was also recorded in terms of its burning temperature and time it took until the fire ended.

For the testing of the chemical components of the biodiesel produced in this study, the sample with the highest yield was sent to the Oil, Gas, and Chemicals Laboratory Testing, SGS Philippines, Inc. The target test methods for this liquid fuel are ASTM D 874, 445, and 2709 (ASTM.ORG, 2023).

The experimental design of the study was laid out in a three factorial experiment involving three levels of catalyst concentration (0.8, 1.0, and 1.2 g), reaction time (30, 60, and 90 min) and agitation speed (400, 600, and 800 rpm). The data was evaluated using the Mean, Standard deviation, and One-way ANOVA. The data obtained from the experiments and tests are analyzed and interpreted for the results of the study.

3 Results and discussion

3.1 Pre-testing

Prior to the final testing, the researchers conducted pre-testing procedures. During the filtration process, fine AC was changed into granulated due to the discoloration of oil after filtration using fine AC. AC is one of the most common and effective adsorbents for the purification process. In fact, the process of adsorption using AC has been confirmed to be competitive with several other methods of removing pollutants both in terms of adsorption capacity, sustainability, cost, and selection of bio-solvent and other residual wastes as adsorbents. The AC is found to be useful in removing many contaminants from both potable water and wastewater because of its high surface area (Boopathy and Karthikeyan, 2013).

Initially, there were two commercially available catalysts used in the study, the NaOH and calcium oxide (CaO). The researchers adapted the values of the parameters from the related studies and it served as the standards. These values include 3.5 g of catalyst, 120 minutes of reaction time, 600 rpm of agitation speed, 250 mL of filtered WCO, 65 mL of methanol, and 60°C of reaction temperature. In the conduct of the transesterification process using the above-mentioned parameters with NaOH as catalyst, there is no biodiesel produced; instead, the product solidifies. On the other hand, with CaO as catalyst and using the same values as in with the use of the first catalyst, it did not dissolve in the methanol and therefore, making the process incomplete and produced no biodiesel nor solidified. Upon consultation, the two catalysts were reduced into one, rejecting the CaO since it is insoluble in methanol and made no biodiesel at all. Since the standard values that were adapted from the related studies did not produced biodiesel, the lower limit value of catalyst concentrations was used. Using the combination of the first run which is 2.5 g of catalyst, 90 minutes reaction time, 600 rpm agitation speed, and the rest of values being constant, there were no biodiesel produced.

Another amount of catalyst concentration was proposed and was lower than 2.5 g. The experiment was conducted using new values including 1 g of catalyst, 60 minutes reaction time, and 600 rpm agitation speed. In this case, there is biodiesel produced.

3.2 WCO filtration

Thirty-three grams of granulated AC was used in the process of filtration with a 250 mL amount of WCO. After the AC was preheated in the oven at 90°C, filtration process was conducted. Figure 4 shows the filtered WCO using AC and the impurities from WCO collected by the AC filter.

(a) filtered waste cooking oil (b) the impurities from WCO

Figure 4 The filtered waste cooking oil and the impurities from WCO collected in the activated charcoal filter

3.3 Biodiesel production

Twenty-seven test runs of different combinations were conducted to produce biodiesel. Each test run has its own combination of parameter values (catalyst concentration, reaction time, and agitation speed) with the amount of filtered WCO, amount of methanol, and reaction temperature being constant throughout the whole experiment. The amount of filtered WCO was 250 mL, the amount of methanol was 65 mL, and the reaction temperature was 60°C. Summarized in Table 1 are the biodiesel yield per combination.

Table 1 Biodiesel yield from waste cooking oil at different parameters

Run	Catalyst concentration (g)	Reaction time (min)	Agitation speed (rpm)	Replicate 1 (mL)	Replicate 2 (mL)	Replicate 3 (mL)	Average yield (mL)
1	0.8	30	400	0	0	0	0
2	0.8	30	600	0	0	0	0
3	0.8	30	800	0	0	0	0
4	0.8	60	400	0	0	0	0
5	0.8	60	600	0	0	0	0
6	0.8	60	800	0	0	0	0
7	0.8	90	400	0	0	0	0
8	0.8	90	600	0	0	0	0
9	0.8	90	800	263.5	261.5	262.0	262.3

Run	Catalyst concentration (g)	Reaction time (min)	Agitation speed (rpm)	Replicate 1 (mL)	Replicate 2 (mL)	Replicate 3 (mL)	Average yield (mL)
10	1.0	30	400	0	0	0	0
11	1.0	30	600	0	0	0	0
12	1.0	30	800	0	0	0	0
13	1.0	60	400	260.0	256.0	258.0	258.0
14	1.0	60	600	250.0	263.0	261.0	261.0
15	1.0	60	800	256.5	260.0	262.0	259.5
16	1.0	90	400	261.5	260.0	261.0	260.8
17	1.0	90	600	255.0	261.0	259.5	258.5
18	1.0	90	800	0	0	0	0
19	1.2	30	400	258.5	255.0	249.5	254.3
20	1.2	30	600	248.0	257.5	250.0	251.8
21	1.2	30	800	254.0	258.5	259.0	257.2
22	1.2	60	400	257.0	260.0	248.0	255.0
23	1.2	60	600	245.0	256.0	256.5	252.5
24	1.2	60	800	250.0	260.0	250.0	253.3
25	1.2	90	400	252.0	261.0	246.5	253.2
26	1.2	90	600	249.0	256.5	251.0	252.2
27	1.2	90	800	245.0	256.0	255.0	252.0

However, not all those 27 runs produced biodiesel, some solidified. Three replications of each run were done to ensure the validity of the results. The results showed that the combinations of 0.8 g catalyst, 90 min reaction time and 800 rpm agitation speed produced the highest biodiesel yield at an average volume of 262.3 mL. Presented in Figure 5 are the three replications conducted using the combinations of 0.8 g catalyst, 90 min reaction time and 800 rpm agitation speed.


(a) replication 1 (b) replication 2 (c) replication 3

Figure 5 Biodiesel produced from replication 1, 2, 3 of the 0.8 g catalyst, 90 min reaction time and 800 rpm agitation speed combinations

Figure 6 shows the total yield of produced biodiesel increased with the catalyst concentration obtaining the highest yield with catalyst concentration of 0.8 g. Based on the result, the highest total yield of produced biodiesel using 0.8 g of catalyst is 787.0 mL. Whereas, using 1.0 g and 1.2 g produced the highest total yield of 782.5 mL and 771.5 mL, respectively.

Figure 7 shows the total biodiesel yield as a function of reaction time in terms of minutes. It revealed that 90 minutes of reaction time had the highest biodiesel yield in total. On the other hand, the reaction time of 30 minutes produced the least yield of biodiesel.

Figure 8 shows the total biodiesel yield as a function of agitation speed in terms of rpm. It can be seen in the graph that 800 rpm agitation speed produced the highest biodiesel yield as compared to 400 and 600 rpm which produced a lower amount of biodiesel. It revealed that the standard agitation speed of 600 rpm did not produce the highest biodiesel yield even though it was proven in the related studies included in this study.

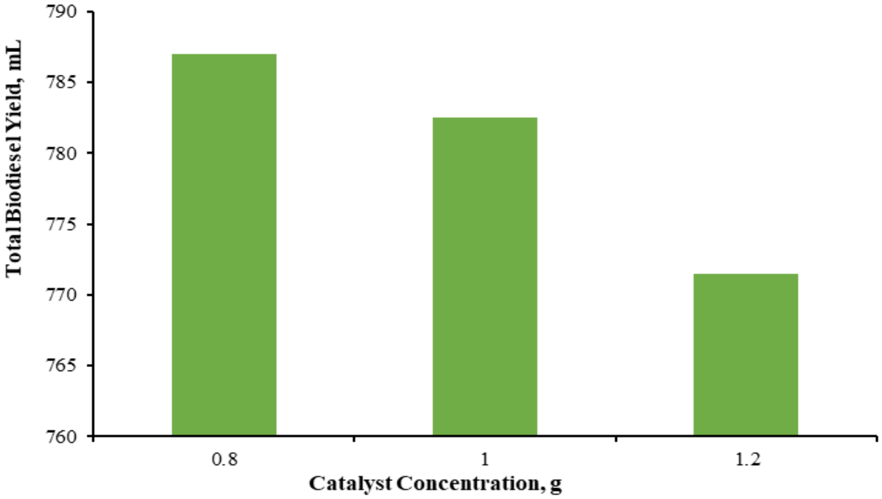


Figure 6 Total yield of biodiesel as function of catalyst concentration

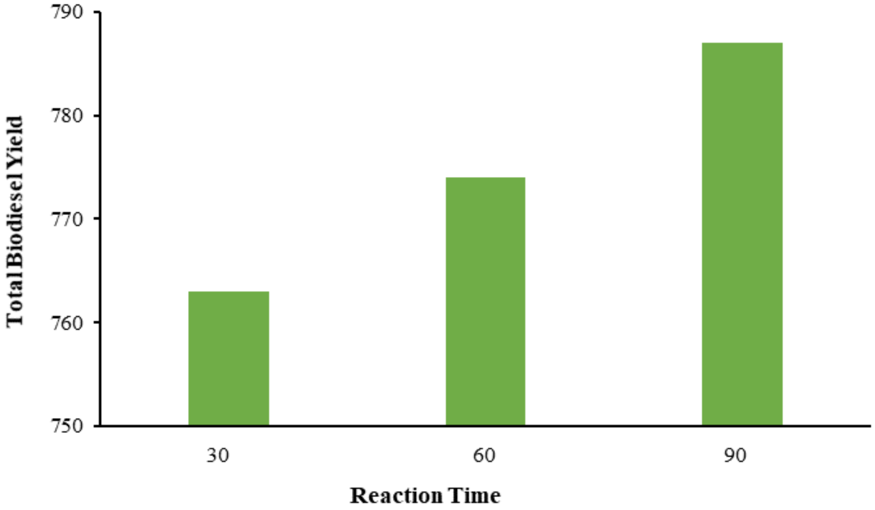


Figure 7 Total biodiesel yield as function of reaction time

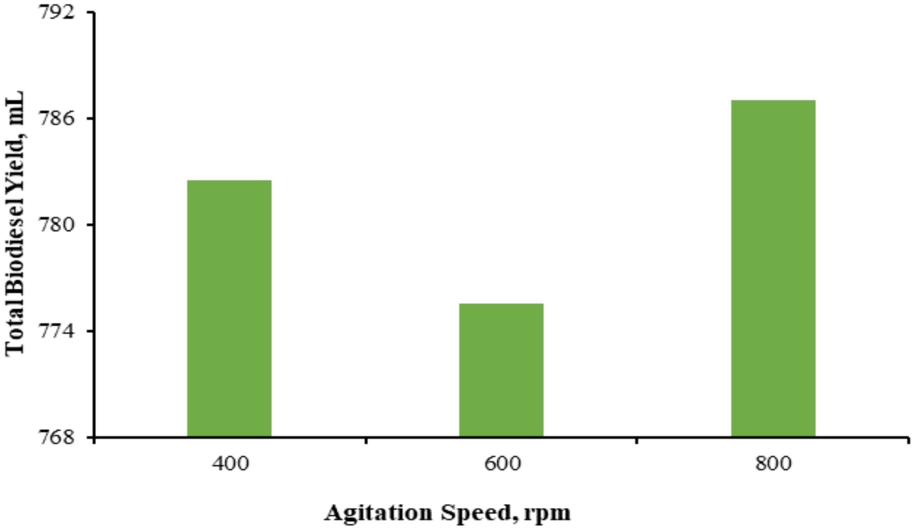
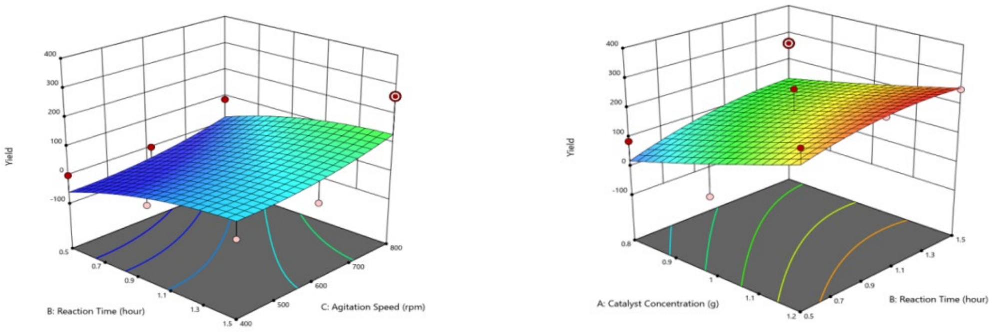
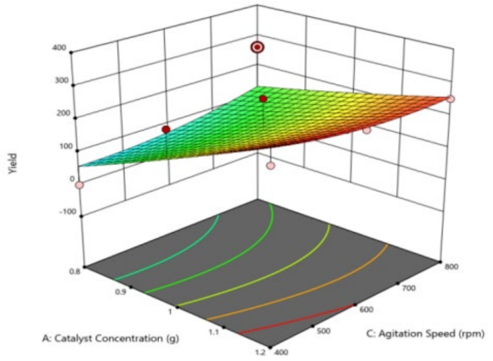


Figure 8 Total biodiesel yield as a function of agitation speed

Illustrated in Figure 9 are the interactions between the parameters with respect to biodiesel yield. Figure 9a represents the interaction between reaction time, h, and agitation speed, rpm, with respect to yield, mL. On the other hand, Figure 9b shows the interaction between catalyst concentration, g, and reaction time, h, with respect to yield, mL, while Figure 9c illustrates the interaction between catalyst concentration, g, and agitation speed, rpm, with respect to yield, mL.



(a) reaction time and agitation speed (b) catalyst concentration and reaction time



(c) catalyst concentration and agitation speed

Figure 9 Response surface graph of interactions between the parameters with respect to biodiesel yield

Table 2 shows the analysis of variance of the NaOH catalyst concentration, agitation speed, and reaction time in the biodiesel yield produced from filtered WCO. Reaction time and agitation speed appeared to be insignificant, indicating that these parameters had no significant effect on the biodiesel yield obtained from the filtered WCO. Meanwhile, catalyst concentration was found to be significant, as its p values were less than the alpha value of 0.01. This indicated that the catalyst concentration did indeed have a significant effect on the biodiesel yield.

Table 2 Analysis of variance for the catalyst concentration, reaction time, and agitation speed

Source of Variation	SS	df	MS	F	p
Catalyst Concentration (grams)					
Between Groups	1866321.5	2	933160.75	13.492*	0.000
Within Groups	1659945.5	24	69164.396		
Total	3526267	26			
Reaction time (minutes)					
Between Groups	319149.556	2	159574.778	1.194^{ns}	0.32
Within Groups	3207117.44	24	133629.894		
Total	3526267	26			
Agitation speed (rpm)					
Between Groups	33386.889	2	16693.444	0.115^{ns}	0.892
Within Groups	3492880.11	24	145536.671		
Total	3526267	26			

Note: **p*<0.01, significant@ 1% alpha level; ns *p*>0.01, not significant@ 1% alpha level.

3.4 Flammability of biodiesels produced

Table 3 summarizes the flammability characteristics of biodiesel sample, filtered WCO, and pure methanol in terms of flame temperature and burning time. A cotton ball was submerged in the same amount of fluid and was subjected to flame test. For the biodiesel sample, it yielded an average flame temperature range from 277.4°C to 416.1°C with a burning time ranging from 7.1 minutes to 10.5 minutes. The filtered WCO does not ignite, thus, no reading of flame temperature and burning time of only around 0.1 minutes due to ignition of the cotton. Methanol, on the other hand, gained an average temperature of 473.0°C, close to its auto ignition temperature (AIT) recorded for stoichiometric concentrations which is 470°C, and has a burning time of 3 minutes and 42 seconds.

Table 3 Flammability characteristics of biodiesels, filtered WCO, and pure methanol

Item	Average flame temperature (°C)	Burning time (min)
Biodiesel run 9 (0.8 g catalyst, 90 min reaction time, 800 rpm agitation speed)	416.1	10.5
Biodiesel run 13 (1.0 g catalyst, 60 min reaction time, 400 rpm agitation speed)	316.7	7.3
Biodiesel run 15 (1.0 g catalyst, 60 min reaction time, 800 rpm agitation speed)	321.2	7.1
Biodiesel run 16 (1.0 g catalyst, 90 min reaction time, 400 rpm agitation speed)	277.4	8.1
Biodiesel run 17 (1.0 g catalyst, 90 min reaction time, 600 rpm agitation speed)	345.9	8.1
Biodiesel run 19 (1.2 g catalyst, 30 min reaction time, 400 rpm agitation speed)	311.1	8.1
Biodiesel run 20 (1.2 g catalyst, 30 min reaction time, 600 rpm agitation speed)	344.4	7.5
Biodiesel run 21 (1.2 g catalyst, 30 min reaction time, 800 rpm agitation speed)	367.9	7.4
Biodiesel run 22 (1.2 g catalyst, 60 min reaction time, 400 rpm agitation speed)	363.1	8.3
Biodiesel run 23 (1.2 g catalyst, 60 min reaction time, 600 rpm agitation speed)	373.9	10.4
Biodiesel run 24 (1.2 g catalyst, 60 min reaction time, 800 rpm agitation speed)	335.8	7.6
Biodiesel run 25 (1.2 g catalyst, 90 min reaction time, 400 rpm agitation speed)	371.8	7.9
Biodiesel run 26 (1.2 g catalyst, 90 min reaction time, 600 rpm agitation speed)	408.4	8.6
Biodiesel run 27 (1.2 g catalyst, 90 min reaction time, 800 rpm agitation speed)	398.4	8.2
Filtered WCO	no record	0.1
Pure Methanol	473.0	3.7

(a) biodiesel produced (0.8 g catalyst, 90 min reaction time, 800 rpm agitation speed) (b) filtered WCO (c) pure methanol

Figure 10 Actual flame comparison of biodiesel sample, filtered WCO, and pure methanol

Figure 10 shows the actual flame comparison of biodiesel sample, filtered WCO, and pure methanol. Biodiesel has a brighter yellow-orange flame and a higher flame height compared to filtered WCO and pure methanol. On the other hand, methanol had almost an invisible flame, light in color, and shows very minimal smoke. This clean combustion with slightly bluish, low-emissivity methanol flames rendered small flames nearly invisible (especially during the day), making them a particularly threatening hazard. The filtered WCO, when ignited, produced little to no flame.

3.5 Chemical analysis and fuel properties

The sample with the highest yield (0.8 g catalyst, 90 min reaction time, 800 rpm agitation speed), was sent to SGS Philippines Inc. for the analysis of fuel properties of biodiesel in accordance with ASTM Standards. The results of the following test methods: ASTM D874, ASTM D445, and ASTM D2709 were recorded. It showed the measurements of the results of the three (3) different test methods in comparison to the standard limits. Test result for ASTM D874 obtained 0.04% which is 0.02% higher than that of 0.020% standard limit. ASTM D445, the test for kinematic viscosity at 40°C acquired 8.941 mm^2 s^{-1} which is 2.941 mm^2 s^{-1} greater than the standard limit, which ranges between 1.9-6.0 mm^2 s^{-1}. Lastly, results for the ASTM D2709 attained a total of 0.30% which is 0.25% higher than the maximum limit of 0.050%. Presented in Table 4 is the summary of the result of the chemical analysis of produced biodiesel from the filtered WCO.

Table 4 Fuel property and chemical analysis of produced biodiesel (0.8 g catalyst, 90 min reaction time, 800 rpm agitation speed) from filtered WCO

Property	Method	Standard limits	Result
Sulfated Ash	ASTM D874	0.020% mass (max)	0.04% (m m^{-1})
Kinematic viscosity (@40 deg. Celsius)	ASTM D445	1.9-6.0 mm^2 s^{-1}	8.941 mm^2 s^{-1}
Water and sediment in middle distillate fuel	ASTM D2709	0.050% mass (max)	0.30% (v/v)

High concentration of sulfated ash content will block the diesel particulate filters, and it can cause the engine to lose power and not function properly and may cause deposits to form on internal engine parts, which can damage the engine. Also, high kinematic viscosity value indicates that fuel tends to be viscous when heated at 40°C may cause a serious problem. The greater density and kinematic viscosity of biodiesel compared to diesel fuel hinders the equivalent distribution during injection into the cylinder, necessitating higher fuel injection pressures and resulting in a poorer discharge and incomplete combustion. Additionally, a high water and sediment content is prone to clogging of the fuel management facilities and issues with the fuel system of a burner or engine. A buildup of sediment in storage containers and on filter screens can prevent oil from flowing from the tank to the combustor. In the presence of detergent, water in middle distillate fuels can cause emulsions or a hazy appearance, as well as corrosion of vessels and equipment.

The high numerical results indicate that the biodiesel sample is of poor quality because it did not meet the specified limits. From the researchers' standpoint, the absence of a purification process is the main reason why the tested biodiesel inhibited low-quality characteristics. The sample sent to the testing center is known to be "crude" biodiesel, meaning that it did not undergo a washing process.

In the absence of a purification process, this indicates that a higher biodiesel yield does not necessarily equate to a higher quality product. Biodiesel derived from WCO feedstock can apparently be utilized directly as fuel if its chemical and fuel properties meet a predetermined standard. Nevertheless, the current oil's numerical value slightly exceeded the standard limits;

thus, the biodiesel produced is restricted to be used as a blended engine fuel. However, this does not mean that the produced biodiesel was completely useless. Rather, it can still be used as a cooking fuel source.

Kapilan et al. (2008) evaluated biodiesel as a substitute for petroleum in a wick burner. According to the findings of the research, the biodiesel-fueled wick furnace produced a flame as stable as kerosene. The thermal efficiency of the wick stove is 51.82% with kerosene and 52.33% with biodiesel. This led to the conclusion that the biodiesel operation is more effective than the petroleum operation. Based on the results of the experiments, biodiesel can be used in place of kerosene in wick burners without any modifications to the design.

4 Conclusion

Based on the findings, conclusions were drawn by the researchers. First, it has been determined that WCO from vacuum fryer which was obtained at FIC-MIMAROPA is suitable to be used as a feedstock for the synthesis of biodiesel. This has been done effectively by employing a methanol reactant and homogeneous catalyst (NaOH) during the transesterification process. AC was proven to be an effective adsorbent material for filtering solid impurities and improving the clearness of the unfiltered WCO.

The effect of the three parameters: catalyst concentration, reaction time, and agitation speed, has also been evaluated in this study. It was found out that among the three, catalyst concentration gave the most significant effect in the yield of the biodiesel. The maximum biodiesel yield was obtained in the combination with 0.8 grams, 90 min reaction time, 800 rpm agitation speed. The rest of the combinations having 0.8 g produced no biodiesel. From this, it can be observed that the only decrement input (0.8 g) which produced biodiesel consistently from the three replicates, had a maximum input required in terms of agitation speed and reaction time (90 min and 800 rpm). On the other hand, all the combinations with 1.2 grams of catalyst obtained a successful transesterification reaction regardless of a minimum of maximum reaction time and agitation speed input.

This means that using a 1.2 grams catalyst, whether one uses a much lower time and a much lower speed, there is an assurance that there will be a biodiesel product. This is advantageous in an economic standpoint in which biodiesel producers can apply, since a lower reaction time and lower agitation speed technically results in a lower electricity consumption perhaps, a lower electricity cost. This claim was supported by Sartomo et al. (2020) as the experimental data show that the higher the mixing speed, the higher the electric current needed. Thus, electricity consumption is also higher.

In terms of flammability, all biodiesel samples showed a longer burn time and temperature ranges above 300 degrees Celsius. The average burn time recorded for all the biodiesel samples ranges from 7 minutes to 10.5 minutes, while methanol and WCO obtained 3.71 and 0.1 minutes, respectively. Lastly, the sample with the highest yield was sent to SGS Philippines Inc.- Oil, Gas, and Chemicals for testing in accordance with ASTM standards: ASTM D874, ASTM D445 and ASTM D2709. Nonetheless, the laboratory tests revealed values that were marginally above the established limits which means, its direct use as an engine fuel is restricted. Rather, it can be used as a cooking fuel source, or improved by a purification process to ensure a better and cleaner biodiesel that meets the ASTM Standard.

Recommendation

The proponents of this study believe that this work is part of a bigger picture for biodiesel research. In line with this, the following recommendations were made:

Filtration using AC is recommended.

The researchers strongly suggest purifying biodiesel samples after separating them from glycerol. This purification process ensures a better quality and cleaner biodiesel sample that could meet the predetermined standards.

Glycerol must be separated from the biodiesel immediately after 24 hours. Letting these layers sit for an extended period of time reduces biodiesel yield because it still causes biodiesel to solidify.

The researchers suggest using powdered NaOH instead of flakes. Powdered NaOH dissolves faster than flakes, making it a great advantage during manual stirring.

Future researchers should use only laboratory-grade catalysts.

This study used a homogeneous catalyst (NaOH); for future studies that may involve biodiesel production from vacuum fryer of FIC MIMAROPA, future researchers can use a heterogeneous catalyst to differentiate and evaluate its effect in biodiesel production.

There should be uniformity in the WCO feedstock samples to be used. This is done to guarantee the accuracy of the final product.

When aiming for chemical analysis tests, it is better to send all the biodiesel samples, regardless of their quantity.

In terms of test methods, it’s better to use all the methods indicated under ASTM D6751.

Aside from FIC MIMAROPA, future researchers can also use oil from other processing centers in the province as a feedstock for biodiesel production.

The study is open for further improvement and utilization of processes. This can be used as a basis and reference for future studies to be conducted.

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