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Development of a Low-Cost and Sustainable Biodiesel Reactor Using Waste Cooking Oil

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ABSTRACT

This study developed and evaluated a low-cost biodiesel batch reactor with an integrated washing system for processing waste cooking oil into biodiesel. The reactor was fabricated from locally available materials and designed to perform transesterification and water washing in the same vessel to reduce equipment requirements and simplify purification. Two catalyst systems, KOH and NaOH, were tested using identical volumes of waste cooking oil and methanol. The resulting biodiesel samples were analyzed for kinematic viscosity, specific gravity, and pour point following ASTM methods, and preliminary engine observations were conducted on a 12 HP diesel engine using different biodiesel blends. The KOH mixture produced slightly more biodiesel than the NaOH mixture, and both samples met the standard limits for viscosity and pour point. Specific gravity values were slightly below the ASTM range but remained close to acceptable limits for small-scale applications. Engine observations provided initial insights into smoke characteristics and fuel behavior, although the tests were qualitative and conducted without load. The cost comparison showed that the fabricated reactor was significantly more affordable than commercially available units, while offering a larger working capacity and built-in washing capability. The findings demonstrate the technical feasibility of producing biodiesel from waste cooking oil using an affordable, locally fabricated reactor and highlight its potential value for community-level fuel production. Further studies with controlled reaction conditions, replicated trials, and standardized engine testing are recommended to strengthen performance evaluation.

Keywords: *renewable energy source, low-cost biodiesel generator, waste cooking oil, UN Sustainable Development Goals*

INTRODUCTION

Energy demand is increasing at an unprecedented rate in today's high-growth countries. Although the Philippines has several renewable energy sources, such as hydropower, geothermal power, solar power, wind power, and biomass, that may support future electricity generation demands, it still faces challenges in meeting its long-term needs (German et al., 2023). This makes the consideration of practical and sustainable alternatives that can be locally produced and safely applied in community settings especially relevant. One such alternative is the recycling of waste cooking oil (WCO) for biodiesel production.

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Households, food stores, and fast-food restaurants produce cooking oil waste. It consists primarily of glycerol esters of fatty acids (Alias et al., 2018). The Philippines produces substantial volumes of WCO, estimated at around 60,000 tons per year in major cities alone (Lin, n.d.), yet much of it is improperly disposed of. Previous studies and reports have shown that used grease is often poured directly into drains, where it solidifies, clogs pipelines, and contributes to flooding (Fabunan, 2015). When WCO enters waterways, it can coat river and ocean surfaces, reducing oxygen availability and harming aquatic life (Sharma, 2019). Long-term consumption of repeatedly heated oil also poses serious health risks, including cardiovascular disease and metabolic disorders (Jaarin et al., 2018). These environmental and health concerns reinforce the need for safe and beneficial uses of WCO.

One recommended strategy is to repurpose WCO as raw material for biodiesel production, since it possesses physicochemical properties suitable for transesterification (Cordero-Ravelo & Schallenberg-Rodríguez, 2018). Biodiesel is a renewable and biodegradable fuel made from vegetable oils, animal fats, or recycled grease through transesterification, a process in which triglycerides react with a short-chain alcohol in the presence of a catalyst to produce fatty acid methyl esters (biodiesel) and glycerin (Demir et al., 2020). After the reaction, washing becomes a critical step to remove unreacted catalysts, soaps, and impurities that may affect fuel quality (Atadashi et al., 2015).

Among reactor systems, batch reactors remain widely used for small-scale biodiesel production due to their simplicity, controllability, and suitability for various feedstocks (Usha et al., 2021). However, many existing reactors are commercially manufactured and costly, limiting accessibility for local communities, research institutions, and small entrepreneurs. In addition, most systems require a separate washing vessel, which increases equipment costs, handling time, and the risk of contamination or product loss.

Although numerous studies have examined biodiesel production from WCO, little work has examined low-cost, locally fabricated reactor systems that integrate both transesterification and washing within a single unit. Such a design could simplify the process, reduce material handling, and make small-scale biodiesel production more accessible and affordable. To address this need, the present study develops and evaluates a biodiesel batch reactor made from locally available materials and equipped with an integrated washing component. This approach aims to demonstrate a feasible, practical, and community-based method for converting waste cooking oil into biodiesel.

Objectives of the study

This study aims to design and fabricate a low-cost biodiesel batch reactor with an integrated washing system using locally available materials. Specifically, it seeks

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to: (1) evaluate the feasibility of producing biodiesel from waste cooking oil using alkaline catalysts under controlled conditions; (2) assess the basic fuel properties of the produced biodiesel relative to established standards; (3) document preliminary engine behavior when using different biodiesel blends and (4) compare the developed reactor with commercially available reactors in terms of cost, structural configuration, and fabrication features.

METHODOLOGY

Research Design. The study used an experimental research design that involved collecting and preparing waste cooking oil, designing and fabricating a low-cost biodiesel reactor, producing biodiesel through transesterification, integrating washing, testing fuel properties, and conducting preliminary engine observations. The experiment was conducted in Vigan City, where waste cooking oil was sourced from various food establishments. All fabrication activities used low-cost and locally available materials.

Reactor Design and Fabrication. The biodiesel reactor was constructed using a repurposed freon tank supported by a steel frame. The reactor had a height of 1.10 meters with a ground clearance of 0.80 meters. Openings were installed for the inlet, electric heater, mixer, internal washing line, methanol vapor outlet, and glycerin drain. All joints and fittings were sealed to prevent leakage. The reactor was equipped with a temperature controller for heating and a motorized mixer for agitation during the transesterification and washing processes.

Experimental Mixtures. Two experiments were conducted. Experiment 1 used 34.3 grams of KOH dissolved in 0.7 liters of methanol with 3.5 liters of waste cooking oil. Experiment 2 used 30.8 grams of NaOH dissolved in 0.7 liters of methanol with 3.5 liters of waste cooking oil. The catalyst amounts were determined by titrating the waste cooking oil.

Table 1

Composite of mixture used for experiment 1 for biodiesel production using KOH catalyst

Experiment 1 components	Amount
KOH (g)	34.3
Methanol (L)	0.7
Waste cooking oil (L)	3.5

Table 1 shows that the total volume of Experiment 1 is 4.2 L. Experiment 1 consists of 3.5 L of WCO and 34.3 g of KOH dissolved in 0.7 L of methanol.

Table 2 shows that the total volume of Experiment 2 is also 4.2 L, consisting of 3.5 L of WCO and 30.8 g of NaOH dissolved in 0.7 L of methanol.

Table 2
Composite of mixture used for experiment 2 for biodiesel production using NaOH catalyst

Experiment 2 components	Amount
NaOH (g)	30.8
Methanol (L)	0.7
Waste cooking oil (L)	3.5

Biodiesel Production and Washing

The strained waste cooking oil was placed into the reactor. The methanol and catalyst mixture was added, and the contents were heated to about 60 C while continuously mixed for at least one hour. After the reaction, the mixture was allowed to settle so that glycerin could separate at the bottom. The glycerin layer was drained.

Washing was performed in the same reactor using the built-in washing component. Clean water was introduced through the internal washing line, gently mixed, allowed to settle, and then drained. This washing cycle was repeated until the wash water appeared clearer.

Fuel Property Testing

Biodiesel samples produced from both experiments were brought to DOST ITDI for testing. The parameters evaluated were kinematic viscosity at 40 C, specific gravity at 15 C, and pour point. These tests followed ASTM standards.

Engine Observation Test

A 12 HP Kama diesel engine was used to observe fuel behavior for different biodiesel blends. The blends tested were B20, B50, B100, and pure diesel. The engine was operated at idle for 1 hour for each fuel type. Smoke color, engine response, and fuel consumption were observed. Because the engine was not loaded and manual adjustments were needed, the results were considered preliminary.

Data Gathering Instruments

The study used various tools and materials to construct the reactor and conduct the procedures. These included angle bars, nuts and bolts, a heater, a mixer, a water filter, a hose, ball valves, a cross tee, a submersible pump, a temperature controller, a speed controller, electrical wires, an epoxy sealant, a grinder, and a welding machine.

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Data Gathering procedure

1. Collection of waste cooking oil

Waste cooking oil was collected from multiple food establishments in Vigan City and combined into a single container for use in the experiments.

Figure 1

Collection of waste cooking oil at a stall in Vigan City, Ilocos Sur. (a). filling the container with WCO (b). collection of WCO at Nanang Sion Vigan (c). filling the container with WCO at Pagburnayan Food Corner.

Figure 1 shows the collection of waste cooking oil (WCO) from various stalls in Vigan City, including from the famous Nanang Sion of Viga, with their staff, and the collection of WCO at Paburnayan Food Center. WCO was collected from 10 stalls, totaling 10 liters, comprising 90% coconut oil and 10% vegetable oil.

2. Straining and Pre-treatment

The collected WCO was strained using fabric cloth to remove solid residues before transesterification.

(a) *(b)*

Figure 2

Straining the collected waste cooking oil. (a). straining the WCO using fabric cloth (b). strained solid residues from the WCO

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Figure 2 illustrates the pre-treatment process of the collected WCO to ensure that the WCO is free from any other substances or solid residues before the transesterification process or turning the WCO to biodiesel from the straining process using fabric clothing (a) and showing the strained residue from the WCO in Figure 4 (b).

3. Titration Test

A titration test was conducted to determine the correct amount of catalyst needed. The test involved mixing isopropyl alcohol, WCO, phenol red indicator, and titration solution until a color change occurred.

(a) *(b)* *(c)*

Figure 3

Performing a titration test. (a). Adding 10 ml of isopropyl alcohol and 1 ml of WCO to the titration cup (b). Adding 2-3 drops of phenol red (c). Addition of the measured titration solution to the titration cup

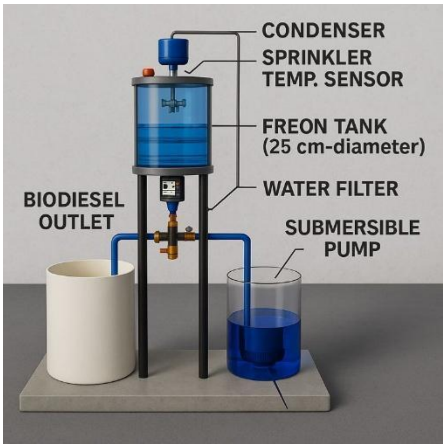
Figure 3 shows the titration test used to determine the amount of catalyst (KOH and NaOH) required for the transesterification process. The test used disposable plastic cups for the containers for the different testing solutions: isopropyl alcohol, WCO, and the titration solution. It also uses a 10 ml syringe to accurately add the amount of each solution for the titration test (a), followed by the addition of 2-3 drops of phenol red to form the solution (b) and the addition of the measured titration solution to the titration cup until a color change is achieved and calculate the catalyst needed for the transesterification process.

4. Reactor Construction

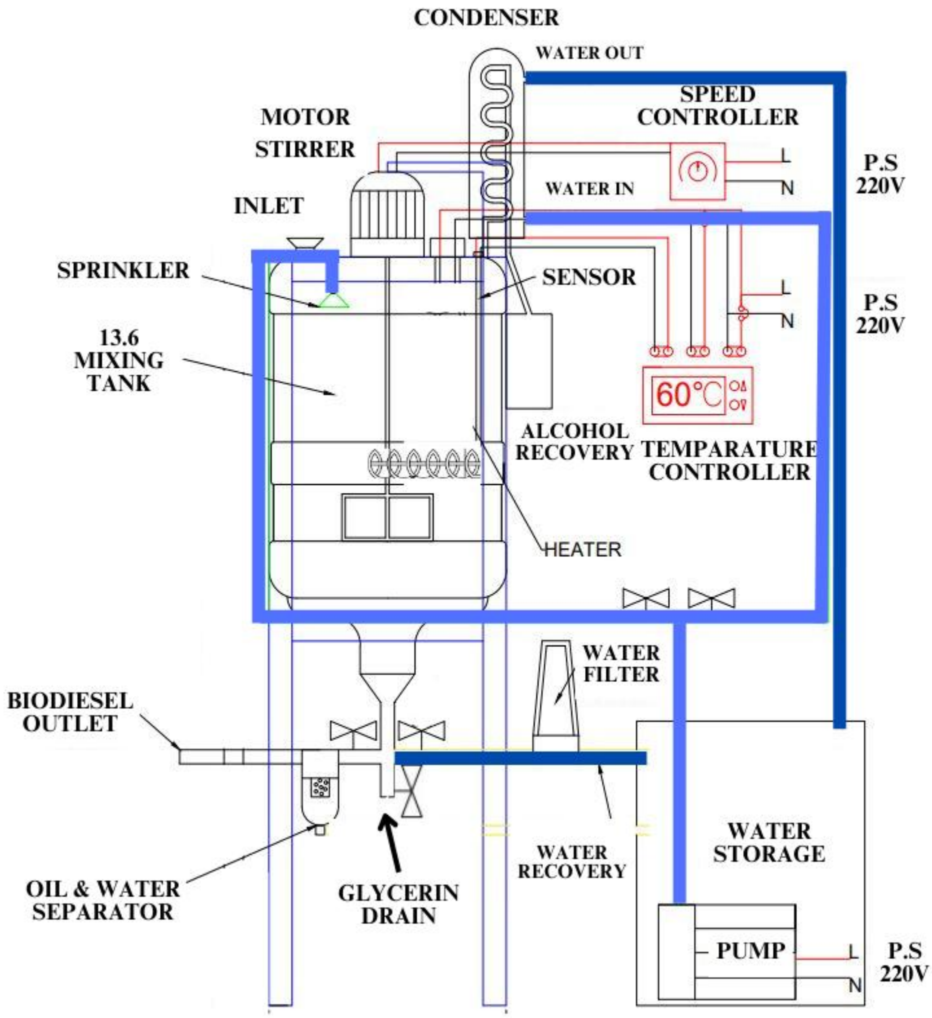
The biodiesel reactor was assembled using a repurposed freon tank mounted on a welded steel frame. The fabrication involved constructing the frame, preparing and modifying the tank, painting the components for corrosion protection, and installing the heater, mixer, and valves. The main steps in the construction process are shown in Figure 4.

(a) (b) (c) (d)

Figure 4
Construction of the innovative biodiesel reactor. (a). Frame making (b). Preparation of the freon tank (c). Painting the tank and the frame (d). Assembling the innovative biodiesel reactor



(a)
Figure 5
Innovative biodiesel Reactor with built-in washing component (a). .3d design (b). diagram



(b)

Figure 5 shows the 3D design (a) to provide the major parts visualization of the biodiesel reactor and a schematic diagram (b) for the detailed parts in 2D of the innovative reactor. Figure 3 shows the actual construction process of the innovative reactor using low-cost materials from the fabrication of the frame (a), preparation of the freon tank ready for installation (b), painting of the freon tank and the frame for corrosion protection (c), and the assembled innovative reactor with a built-in washing component for biodiesel.

The reactor used a 0.75 kW electric heater and a small gear motor with a mixing speed of about 400 rpm, which was sufficient to keep the reaction mixture well agitated without splashing. The working volume of the tank was approximately 13.6 L.

5. Transesterification Process

The waste cooking oil was heated and mixed with the methanol-catalyst solution. The mixture was maintained at around 60 C for one hour. Glycerin separation followed.

(a) *(b)* *(c)*

Figure 6

Transesterification process. (a). Filling the reactor with WCO (b). Adding the mixture of methanol and catalyst (c). Continuous mixing and heating for 1 hr.

Figure 6 shows the transesterification process in which the WCO is filled to the biodiesel reactor (a), then adding the mixture of the calculated amount of catalyst and methanol to the reactor (b), followed by continuous mixing and heating at 60 °C for at least 1 hour, which starts the reaction.

6. 3/27 Conversion Test

A 3/27 test was performed by mixing 3 mL of biodiesel with 27 mL of isopropyl alcohol to check for unreacted glycerides.

(a) *(b)*

Figure 7

Performing 3/27 biodiesel conversion test. (a). Mixing of 3ml of biodiesel and 27 ml of isopropyl alcohol (b). Test the cup after mixing the biodiesel and ethyl alcohol

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Figure 7 shows the mixing of 3ml of biodiesel and 27 ml of isopropyl alcohol (a) and the test cup after mixing the biodiesel and isopropyl alcohol (b). The 3/27 biodiesel conversion test was intended to observe whether the chemical reaction worked as expected. The test showed no biodiesel fell out at the bottom, indicating the reaction went well.

7. Washing of Produced Biodiesel

The integrated water-washing system was used to purify the biodiesel within the same reactor. The process involved adding water, gentle mixing, settling, and draining.

During washing, clean water equal to about 50 percent of the biodiesel volume was added for each cycle. The mixture was gently agitated for about three minutes, allowed to settle for 20 to 30 minutes, and then the wash water was drained. This procedure was repeated three times until the wash water appeared noticeably clearer.

8. Fuel Property Testing

Samples were submitted to the Department of Science and Technology – Industrial Technology Development Institute (DOST–ITDI) for quality analysis.

9. Engine Observation for Fuel Consumption

The biodiesel blends and pure diesel were tested in a 12 HP diesel engine. The remaining fuel after one hour was measured to compute fuel consumption.

(a) *(b)* *(c)*

Figure 8

Fuel consumption and engine performance test. (a). fueling the Kama diesel engine using different biodiesel blends and pure diesel (b). removing the remaining biodiesel and pure diesel to calculate the fuel consumption (c). running the Kama diesel engine using different biodiesel blends and pure diesel

Figure 8 shows the evaluation of fuel consumption and engine efficiency of the produced biodiesel in three different blends and pure diesel using a Kama diesel engine, conducted at Brgy. Lao-ingen, Sto. Domingo, Ilocos Sur. The evaluation starts by fueling the Kama diesel engine with different biodiesel blends and pure diesel (a), then removing the remaining biodiesel and pure diesel to calculate fuel consumption (b), and finally running the Kama diesel engine with different biodiesel blends and pure diesel to evaluate fuel efficiency.

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RESULTS AND DISCUSSION

This study aims to design and fabricate a low-cost biodiesel batch reactor with an integrated washing system using locally available materials. Specifically, it seeks to: (1) evaluate the feasibility of producing biodiesel from waste cooking oil using alkaline catalysts under controlled conditions; (2) assess the basic fuel properties of the produced biodiesel relative to established standards; (3) document preliminary engine behavior when using different biodiesel blends and (4) compare the developed reactor with commercially available reactors in terms of cost, structural configuration, and fabrication features.

1. Biodiesel Production Using KOH and NaOH

Two batches of biodiesel were produced using KOH and NaOH as catalysts. The amounts of oil, methanol, and catalyst were based on titration results to ensure proper transesterification. The mixtures used for each experiment are shown in the tables below.

Table 3
Biodiesel production using KOH and NaOH catalyst

Catalyst used	Volume of WCO (Liters)	Weight of catalyst (grams)	Volume of Methanol (Liters)	Total volume of the mixture (Liters)	Biodiesel produced (Liters)	Glycerin Produced (Liters)
Potassium Hydroxide (KOH)	3.5	34.3	0.7	4.2	3.5	0.7
Sodium Hydroxide (NaOH)	3.5	30.8	0.7	4.2	3.3	0.9

As shown in Table 3, the KOH-catalyzed batch produced about 3.5 L of biodiesel and 0.7 L of glycerin, while the NaOH-catalyzed batch produced about 3.3 L of biodiesel and 0.9 L of glycerin. The main difference between the two mixtures was the amount of catalyst required, as determined by titration results. Experiment 1 required 34.3 g of KOH per 3.5 L of oil, while Experiment 2 required 30.8 g of NaOH for the same amount of oil. Although both batches used the same volume of methanol, the final biodiesel volumes still differed slightly. These differences may be attributed to catalyst behavior, reaction completeness, or small variations during washing and settling.

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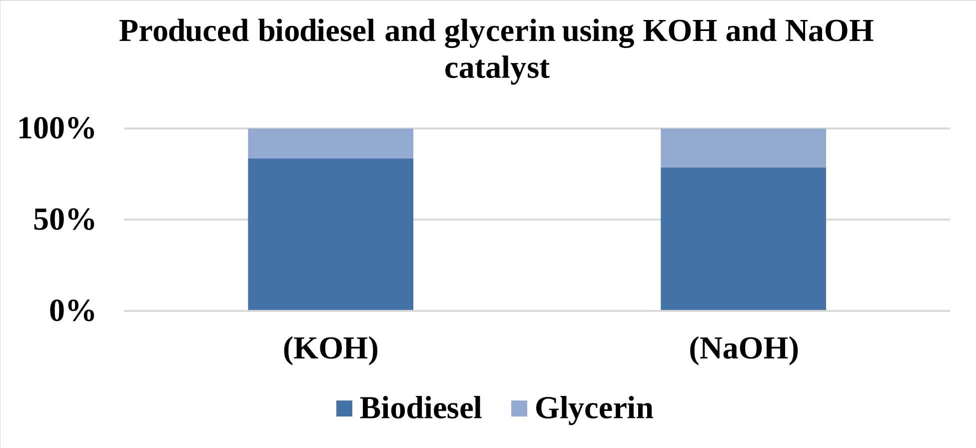

Figure 9
Comparison of two catalysts in the production of biodiesel and glycerin

Figure 9 shows that the KOH batch yielded a higher proportion of biodiesel, accounting for about 83.34 percent of the total mixture, whereas the NaOH batch accounted for about 78.57 percent. The corresponding glycerin values were 16.16 percent for KOH and 21.43 percent for NaOH. These results indicate that the KOH mixture produced slightly more biodiesel and slightly less glycerin under the reaction conditions used in this study. However, these differences should be interpreted as preliminary observations since the experiments were conducted without replicates.

Table 4
Result of the biodiesel quality test using KOH and NaOH as catalyst

Properties	Biodiesel Standard (ASTM D6750)	Test result for Biodiesel (KOH)	Test result for Biodiesel (NaOH)	Test method
Specific Gravity (g/mL) at 15°C	0.86-0.90	0.830	0.830	ASTM D1298
Kinematic Viscosity (mm2/s) at 40°C	1.9-6.0	3.70	4.37	ASTM D445
Pour Point (°C)	-15 to 16	9	9	ASTM D97

Table 4 presents the results of the biodiesel quality tests using KOH and NaOH as catalysts. Two of the three parameters evaluated showed values within the acceptable ranges of the biodiesel standard. The kinematic viscosity at 40 C and the pour point for both samples met the standard limits. The specific gravity values for the two samples were both 0.830, which is slightly below the standard range of 0.86 to 0.90 but still within the acceptable limits.

The biodiesel produced with KOH had a kinematic viscosity of 3.70 mm²/s, while the biodiesel produced with NaOH had a kinematic viscosity of 4.37 mm²/s. Both values fall within the standard range of 1.9 to 6.0 mm²/s. The pour point for both samples was 9 C, which is also within the standard range of minus 15 to 16 C.

Although the specific gravity did not meet the standard range, the measured value of 0.830 suggests that the biodiesel is slightly less dense than the reference standard. Lower-density biodiesel may influence combustion behavior and, in some cases, affect starting performance or reduce power output. However, a more detailed engine evaluation under controlled conditions would be needed to confirm these effects.

3. Basic fuel properties of the produced biodiesel relative to established standards

Table 5 shows the fuel consumption and the record sheet of the produced biodiesel relative to established standards.

Table 5

Fuel consumption record sheet

Fuel type	Total volume (Liters)	Fuel left after one hr. (Liters)	Fuel consumption (Liters per hour)
D100 (100% Diesel)	1	0.80	0.20
B2O (20% Biodiesel + 80% Diesel)	1	0.90	0.10
B50 (50% Biodiesel + 50% Diesel)	1	0.60	0.40
B100 (100% Biodiesel)	1	0.40	0.60

Fuel consumption indicates how much fuel the engine uses during operation. As shown in Table 5, the 12 HP Kama diesel engine operated for one hour using pure diesel, B20, B50, and B100 to observe differences in fuel use. The results show that B100 consumed the most fuel at 0.60 L/h, followed by B50 at 0.40 L/h. Pure diesel consumed 0.20 L/h, while B20 showed the lowest consumption at 0.10 L/h.

While the values suggest that the B20 blend used less fuel during this observation period, these findings should be interpreted with caution. The engine was operated at idle, and the required rpm fluctuated during operation, which can

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influence the amount of fuel consumed. Higher rpm generally leads to higher fuel use. Since the test was performed without a controlled mechanical load and without repeated trials, the results provide only a preliminary indication of consumption differences rather than a conclusive measure of fuel efficiency.

3. Preliminary engine behavior when using different biodiesel blends

Table 6 presents the engine performance test using different biodiesel blends.

From the fuel consumption test conducted on the 12 HP Kama diesel engine, the researchers observed noticeable differences in engine behavior when using the various biodiesel blends and pure diesel. The D100 fuel emitted dark smoke upon starting and during operation. The B20 blend produced lighter smoke, while the B50 and B100 blends produced nearly colorless smoke throughout the one-hour run.

In terms of engine response, D100 and B20 allowed the engine to idle smoothly and start at the usual rpm. In contrast, B50 and B100 required a higher idling rpm to start the engine and maintain operation. These higher blends also showed unstable idling, shifting between low and high rpm during the observation period.

Table 6

Engine performance test

Fuel blend	**Starting- idling RPM**	**Color of Smoke**
D100 (100% Diesel)	Standard idle	Heavy dark smoke
B2O (20% Biodiesel + 80% Diesel)	Standard idle	Light dark smoke
B50 (50% Biodiesel + 50% Diesel)	Nearly half of the accelerator controller	Colorless
B100 (100% Biodiesel)	Half of the accelerator controller	Colorless

Although these patterns were observed, the exact reason for the behavior cannot be confirmed without a more controlled engine test. Factors such as fuel density, ignition quality, and combustion characteristics may contribute to the need for higher throttle input, but further analysis under standardized testing conditions would be required to identify the specific cause.

4. Comparison of the developed reactor with commercially available reactors in terms of cost, structural configuration, and fabrication features.

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Tables 7.1 and 7.2 show the results of the comparison of the developed reactor with commercially available reactors in terms of cost, structural configuration, and fabrication features.

Table 7.1
Innovative biodiesel reactor cost and commercially available biodiesel reactor cost

Biodiesel reactor	Cost (Php)	Total cost (Php)
Innovative biodiesel reactor	Total material cost = 5808 Labor cost = 1250	7508
Commercially available biodiesel reactor cost	36,000	36,000

Table 7.2
Innovative biodiesel reactor specification and commercially available biodiesel specification

Specification	Innovative biodiesel reactor	Commercially available biodiesel reactor
Model		
Price (Php)	7058	36,000
Capacity (L)	13.6	2
Material	Steel, Scrap (Freon tank)	Glass, stainless steel
Washing type	Built in	Separate/none
Reactor type	Batch reactor	Batch reactor

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Based on the comparison of price and specifications, the fabricated biodiesel reactor was significantly more affordable than the commercially available unit. The total cost of constructing the reactor, including labor and materials, was about Php 7,058, while the price of commercially available reactors ranged from Php 36,000 to Php 55,000. The fabricated reactor also had a larger working capacity of 13.6 L, compared to the 2 L capacity of the commercial model examined. Another notable difference is that the fabricated reactor included a built-in water-washing system, whereas the commercial reactor did not. These characteristics indicate that the fabricated reactor offers a more cost-effective option with a higher production volume per batch. However, further performance evaluations under controlled conditions are needed to fully assess the operational advantages of each reactor.

Table 7.3

Patented biodiesel reactor from Espacenet from 2004 up to the present

Patent number Publication date	**Water washing type**	**Patent number Publication date**	**Water washing type**
CN213977602U 2021-08-17	Separated from the mixing tank	CN104031747 2014-09-10	none
CN103877958A 2014-06-25	Separated from the mixing tank	US2014121798A1 2014-05-01	none
CN216837878U 2022-06-28	Separated from the mixing tank	WO2013131161A1 2013-09-12	none
US2011167712A1 2011-07-14	Separated from the mixing tank	BRPI0604251A 2008-05-27	Separate from the mixing tank
TW201239079A 2012-10-01	Separated from the mixing tank	WO2004099115A1 2004-11-18	none
CN105950674A 2016-09-21	Separated from the mixing tank	EP4071226A1 2022-10-12	Separate from the mixing tank
CN100552002C 2009-10-21	Separated from the mixing tank	AU2021104040A4 2022-05-12	Separate from the mixing tank
AU2006100428A4 2006-06-29	Separated from the mixing tank		

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Table 7.3 shows the various patented biodiesel reactor designs identified in Espacenet, the database managed by the European Patent Office, using the filter term “biodiesel reactor with water washing” from 2004 to the present. The reviewed patents generally fall into two categories. In the first category, the reactor and washing unit are separate machines, with water washing performed in a dedicated tank or chamber apart from the main reactor. In the second category, some patents describe reactors without a water-washing component, relying instead on other purification methods or post-processing steps.

The biodiesel batch reactor developed in this study differs from the designs found in the Espacenet search. In this case, the reactor has built-in water washing. The main mixing tank which is used for mixing and washing in the same vessel. This configuration eliminates the need for an additional washing tank and reduces the number of handling steps during purification. Although there are benefits to this integration in small-scale production, to compare overall performance, additional assessment under standardized conditions would be required with patented systems.

CONCLUSIONS

The study demonstrated that waste cooking oil can be converted into biodiesel using a low-cost, locally constructed batch reactor with an integrated washing system. KOH and NaOH were both useful in the production of biodiesel. Under the test conditions, KOH yielded slightly higher results, although more experiments are needed to confirm this. The reactor combined transesterification and washing in a single vessel, providing a low-cost solution for small-scale users. Nevertheless, the research did not compare its performance across business units. The produced biodiesel had standard viscosity and pour point ranges. Its specific gravity was also below the target but within an acceptable range. Preliminary idle-engine test showed that B20 consumed less fuel and that there were significant variations in smoke and idling behavior between blends. However, to arrive at credible performance conclusions, load-based testing is required. A patent examination revealed that the built-in washing appliance is not a common design among the available designs. It needs to be examined formally to determine its novelty. Overall, the findings indicate that it is possible to produce biodiesel on a small scale using this low-cost reactor. Additional controlled and replicated research is suggested.

RECOMMENDATIONS

Future research should retest with KOH as the catalyst to confirm its slightly higher biodiesel yield. The refining, purification, and washing of the product can enhance fuel properties, including the specific gravity, by combining biodiesel with diesel. The performance of the engines should be tested using blends of B20, B50, and B100 under controlled load conditions to determine the optimal ratios for real-world engines. Safety, durability, and quality sealing should be paramount in reactor construction, with cheap, locally available materials. Further growth in the quantity of waste cooking oil collected from households and restaurants will enable an increase in production scale, and the reactor's washing and drying stages will yield a more transparent and consistent fuel output. The steps will build on biodiesel production, enhance engine performance testing, and increase the use of waste cooking oil as a renewable energy source.

REFERENCES

Acena, N. M. Q., & Llanes, N. L. P. (2020). Correlates on academic performance of international students. *UNP Research Journal, 29*(1). https://doi.org/10.69566/ijestm.v29i1.62

Alias, N. I., Javendra, K., & Shahrom, M. Z. (2018). Characterization of waste cooking oil for biodiesel production. *Jurnal Kejuruteraan, 30*(2), 79–83.

Alternative Fuels Data Center. (n.d.). *Biodiesel fuel basics*. https://afdc.energy.gov/fuels/biodiesel_basics.html

Alternative Fuels Data Center. (n.d.). *Biodiesel blends*. https://afdc.energy.gov/fuels/biodiesel_blends.html

Alternative Fuels Data Center. (n.d.). *Biodiesel production and distribution*. https://afdc.energy.gov/fuels/biodiesel_production.html

ASTM International. (2017). *ASTM D1298-12bR17: Standard test method for density, relative density, or API gravity of crude petroleum and liquid petroleum products by hydrometer method*. https://doi.org/10.1520/D1298-12BR17

ASTM International. (2021). *ASTM D445-21e1: Standard test method for kinematic viscosity of transparent and opaque liquids (and calculation of dynamic viscosity)*. https://doi.org/10.1520/D0445-21E01

ASTM International. (2022). *ASTM D97-17bR22: Standard test method for pour point of petroleum products*. https://doi.org/10.1520/D0097-17BR22

Atadashi, I. M., Aroua, M. K., Abdul Aziz, A. R., & Sulaiman, N. M. N. (2015). Production of biodiesel using heterogeneous catalysts: A review. *Egyptian Journal of Petroleum, 24*, 383–396.

Balaria, F. E., Pascual, M. P., Crisostomo, V. S., Reyes, C. J., & Cawagas, G. D. (2021). Disposal of waste cooking oil from restaurants and eateries: A potential environmental hazard. *International Journal of Advanced Engineering, Management and Science, 7*(1), 16–18. https://doi.org/10.22161/ijaems.71.3

Cordero-Ravelo, V., & Schallenberg-Rodríguez, J. (2018). Biodiesel production as a solution to waste cooking oil disposal: Will any type of WCO suffice for a transesterification process? *Journal of Environmental Management, 228*, 117–129. https://doi.org/10.1016/j.jenvman.2018.08.106

Demir, O., et al. (2020). A review of biodiesel sources and production methods. https://dergipark.org.tr/tr/download/article-file/941575

Fabunan, S. S. D. (2015, June 21). Grease and debris cause flooding. *Manila Standard*. https://www.manilastandard.net/news/metro/180576-grease-debris-cause-flooding.html

German, M. A., Paiste, R. P., Rafanan, C. M. D., & Pilien, V. P. (2023). Biogas generation from vegetable waste and horse dung through an improvised anaerobic digester. *The Vector: International Journal of Emerging Science, Technology and Management, 32*(1). https://vector.unp.edu.ph/index.php/1/article/view/307

Jaarin, K., Masbah, N., & Kamisah, Y. (2018). Heated oil and its effect on health. In *Elsevier eBooks* (pp. 315–337). https://doi.org/10.1016/B978-0-12-811442-1.00010-9

Ruhul, A. M., Kalam, M. A., Masjuki, H. H., Fattah, I. R., Reham, S. S., & Rashed, M. M. (2015). State of the art of biodiesel production processes: A review of heterogeneous catalysts. *RSC Advances, 5*(122), 101023–101044. https://doi.org/10.1039/C5RA09862A

Sharma, V. K., Chandna, P., & Bhardwaj, A. (2017). Green supply chain management-related performance indicators in the agro-industry: A review. *Journal of Cleaner Production, 141*, 1194–1208.

Sharma, D. (2019, January 14). Used cooking oil: A hazard to health and the environment. *Times of India Blog*. https://timesofindia.indiatimes.com/readersblog/tatsat/used-cooking-oil-a-hazard-for-health-and-environment-1228/

Usha, V., Jaiyeoba, K., Oyewusi, T., Abbah, C., Oyedokun, J., Okafor, V., & Akubude, V. (2021). Overview of different reactors for biodiesel production.