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Research Article

Comparative study of biodiesel production from different waste oil sources for optimum operation conditions and better engine performance

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ABSTRACT

Biodiesel from waste sources can be considered as the cheapest and most viable fuel alternative to depleting mineral diesel. In this work, biodiesel has been produced from different sources of waste oil; grilled chicken waste oil (GCWO) which is animal based source and waste cooking oil (WCO) which is vegetable based using transesterification method. The impact of different variables such as temperature, transesterification ti me, an d am ount of catalyst on the conversion and yield of biodiesel were investigated. Produced biodiesel was characterizes using ASTM standard methods for biodiesel property testing to determine the fuel properties including; kinematic viscosity, specific gravity, flash point, pour point, cloud point and acid number. Engine test has been conducted at increasing speed and constant load to evaluate the engine performance using the produced fuel. The results obtained indicate that the yield and conversion of bio-diesel from grilled chicken waste oil are greater than waste cooking oil. Both produced biodiesel fuel properties are within the standard biodiesel fuel specifications ASTM D6751. The maximum conversion and yield of biodiesel obtained by 97.76% and 94.4% suing GWCO and WCO respectively at optimum operating variables of 600C temperature, 3 h reaction time, and 0.4 wt% potassium hydroxide. Engine test results show similar trends for both biodiesels compared to diesel in term of engine brake power (BP) and brake specific fuel consumption (BSFC) with increasing engine speed. The maximum reduction in BP is found to be about 19% at 2400 rpm and a maximum increase in BSFC of 17% is obtained at 1800 rpm engine speed with both biodiesels compared to diesel fuel. Accordingly, though both biodiesels show comparable engine performance, GWCO presents higher biodiesel yield.

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INTRODUCTION

Energy crises are one of the most challenges facing the world in the near future due to the increasing development in the machining utilization. Industry and transportation sectors are consumed the large share of energy in which internal combustion engine are widely used. These sectors are mainly depend on fossil fuel which represents the main share of world marketing [1]. Fossil fuel is considered as a depleting fuel with limited resources available in a certain regions of the world, its prices increases with time due to the increasing demand. Moreover, this type of fuel is considered as the main source of pollution which contributes directly to the global warming [2]. World fuel demand have been increased continuously due to population growth and modern technology utilization, especially liquid fuel [3]. The large consumption, depletion of fossil fuel, and growing up for different industries lead the governments of different countries in the world to search for an alternative fuel instead of the fossil fuel. Besides that, the fossil fuel can effects on the environment generally and on the human health specially [4,5]. Biodiesel is a natural resource and an appropriate choice for various countries dependent on import, in order to use natural resources in best manner for other basic needs [6]. Biodiesel is the most viable alternative for mineral diesel due to their comparable characteristics [7]. The main advantage of this fuel is the variety of their sources which is available in almost all the regions in the whole world. It can be produced locally from edible or inedible vegetable oils and animals fats.

In all proportions the biodiesel fuel is miscible with Petroleum-diesel. However, sometimes biodiesel blended with petroleum-diesel which denoted as BX like; B5, B20, and B50. The blend B5 indicates that, a blend composes of 5% and 95% percentage of biodiesel and Petroleum-diesel respectively. Biodiesel can demonstrating similar to Petroleum-diesel in terms of Cetane number [8,9]. Cetane number is a property that expresses the quality ignition of the fuel. The other properties exhibited by biodiesel are widely similar to petroleum-diesel which are heat of combustion, cloud and pour points, oxidative stability and viscosity [10,11]. The degradation capacity of biodiesel is many times faster than diesel. Within 28 days, pure biodiesel degrades 85 to 88 percent in water. Biodiesel flash point is much more than that of diesel fuel. Accordingly, blended biodiesel-diesel fuel's flash point increases with increasing the percentage of biodiesel in the blend. Therefore, biodiesel and blends of biodiesel with diesel are safer to handle and storage [12]. The main obstacle facing biodiesel commercialization is the world food security that will affect from the utilization of edible oils as a biodiesel fuel source.

Response Surface Method (RSM) is widely utilized as a statistical technique in different applications [13]. This software is considered as a viable tool to declare relationship between the correlate input parameters and their response for optimum operation conditions through a set of polynomial functions [14]. This technique is adopted successfully in many studies for optimization biodiesel fuel production and engine performance [15–18].

Vegetable oil can be used as an alternative fuel for diesel engines and heating oil burners. In order to run these engines that designed to burn petroleum-diesel fuel, vegetable oil which has high viscosity must be lowered as possible. Many problems will be faced due to higher viscosity such as starter problem, carbon build up on the piston, knocking, damage of the engines, and incomplete combustion [19]. Mono-alkyl esters of fatty acids can be called biodiesel when it derived from vegetable oils or animal fat oils [20,21]. Biodiesel can be manufactured from edible (vegetable or animal) oil, and non-edible (vegetable or animal) oil [22]. The production of biodiesel are the most commonly used (vegetable and non vegetable) oil such as palm, soybean, sunflower, rapeseed canola, cotton seed, animal fat and Jatropha. Waste oil like grilled chicken waste oil (GCWO) which is animal based source and waste cooking oil (WCO) can be preferred as low priced sources and from other sides like an economic, waste management, and also because the rate of edible vegetable oil are higher than that from diesel fuel [23].

The aim of the current study is to investigate biodiesel production from different sources of waste oil using transesterification method. Waste cooking oil and grilled chicken waste oil have been chosen for the biodiesel preparation as they are available in the local restaurant and from domestic use as a waste products which represent a source for biodiesel production that are free of cost. The impact of different variables includes; reaction temperature, reaction time, catalyst type and concentration have been analyzed for optimum production conditions. Engine test has been conducted to assess fuel suitability for operating diesel engine.

METHODOLOGY

In this study two types of locally available waste oil have been investigated; grilled chicken waste oil (GCWO) which is animal based source and waste cooking oil (WCO) which is from sunflower (plants seeds based). The waste oil has been collected from the local restaurants (free from cost) and used in this study. The effects of different parameters such as, reaction temperature, reaction time, catalyst weight % on the biodiesel yield from different sources were investigated. The yield of biodiesel strongly depends on the reaction temperature [24], catalyst concentration [25] and reaction time [26] which can be considered as an important parameter effected the conversion of biodiesel. One of the major common catalysts used in biodiesel production is the potassium hydroxide [27] which has been used in this study.

Transesterification process was carried to produce biodiesel in alkali based batch as shown in figure 1 [28]. The reaction flask setup was made such that, it could process under various operating condition. The process is conducted using potassium hydroxide catalyst at a percentage of 0.3 wt%, 0.45 wt%, 0.6 wt%, 0.75 wt% and 0.9 wt at 0.15 increments. A reaction time of 1, 2 and 3 h and a reaction temperature of 50, 60, 70 and 80 (±1°C) has been considered at 1atm pressure.

The different properties of produced biodiesel were measured in according to the ASTM standard test methods for each property as shown in table 1. The tested properties include kinematic viscosity at 40°C, specific gravity at 15°C, acid value (AV), flash point, cloud and pour point, and calorific value. Each test was repeated in triplicate for high accuracy and reliable results.

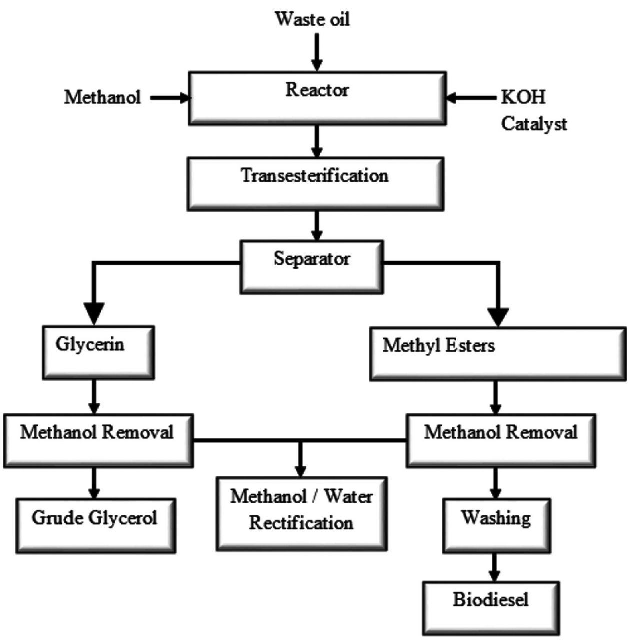

Figure 1. A schematic diagram for experimental set-up.

Response Surface Method (RSM) is a useful statistical technique for optimization in many engineering applications. [13]. This method consists of a set of statistical equations which implemented the linear function or square polynomial function to indicate the interaction among output responses and its input variables to obtain the optimum operation conditions. Costumer defined designs of RSM has been adopted in this study as an optimization technique [17]. Three input variables have been considered in the current study that optimized to obtain the output response. Based on Customer defined design of RSM, the discrete function has been adopted according to the used variables in the current experiments. Adoption of the settings of discrete factor can achieve more convenient experiment to perform with minimal effect on the analysis accuracy [13].

The basic and simple RSM model is based on a linear function and can be presents as in the following equation [16,17]:

$$Y = \beta_o + \sum_i^k \beta_i X_i + \varepsilon \tag{1}$$

In case that the linear model shows any curvature, a model of second order should be implemented as presents in the following equation [16,17]:

$$Y = \beta_o + \sum_i^k \beta_i X_i + \sum_{i<1}^k \beta_{ij} X_i X_j + \varepsilon \tag{2}$$

In the current study, to indicate the point of critical function (optimum), quadratic model has been used as the suitable model for this case and presented in the following equation [16,17]:

$$Y = \beta_o + \sum_i^k \beta_i X_i^2 + \sum_{i<1}^k \sum \beta_{ij} X_i X_j + \varepsilon \tag{3}$$

where k represents the number of input variables (X), β is the constant term and ε is the residual associated to the experiments.

The choice of optimum variables conditions may be implemented for multi response to enhance biodiesel production and improve engine performance. In order to the

Table 1. ASTM standard test methods and specifications

Properties	ASTM D6751 (B100)		EN14214 (B100)		ASTM D7467 (B6-B20)	
	Limits	Method	Limits	Method	Limits	Method
Kinematic viscosity @ 40°C (mm^2/s)	1.9–6.0	D 445	3.5–5	EN 3104/3105	1.9–4.1	D 445
Flash point, closed cup (°C)	93	D 93	101	EN 3679	52	D 93
Cetane No. (min.)	47	D 613	51	EN 5161	40	D 613
Cloud point (°C)	Report[d]	D 2500	Country specific[d]		Report[d]	D 2500
Acid No. (mg KOH/g, max.)	0.50	D 664	0.50	EN 14104	0.3	D 664
Density@ 15°C (kg/m^3)	880	D 1298	860–900	EN 3675	820–858	D 1298/D6890

selected parameters, the approach of desirability function was adopted and performed using Design Expert software.

Reaction temperature and catalyst ratio were considered as influences parameters in this study. All specified candidate set of points based on the implemented technique. The output responses from this optimization include biodiesel yield (%) and conversion (%). The required number of runs for these experiments was set based on the number of considered parameters and level of optimization.

Engine test was conducted to evaluate the different investigated fuel samples using single cylinder Yanmar TF 120 diesel engine. The engine is a 4-stroke water cooled direct injection with a cylinder bore, stroke length and connecting road length of 92 mm, 96 mm and 149.5 mm respectively. The engine maximum output power is 12 kW at 2400 rpm. The test is conducted at increasing speed from 1200 rpm to 2400 rpm with 300 rpm increment and constant 50% engine load. The brake power (BP) calculated based on collected torque and speed using the following equation:

$$BP(kW) = \frac{2\pi NT}{60} \tag{4}$$

where N is the engine speed (rpm), T is the measured engine torque (N.m).

Brake specific fuel consumption (BSFC) is calculated based on mass flow rate of the fuel and the obtained brake power using the following equation:

$$BSFC\left(\frac{kg}{kW}.h\right) = \frac{\dot{m}}{BP} \times 3600 \tag{5}$$

where $\dot{m}$ is the mass flow rate.

Brake thermal efficiency (BTE) is a measured of fuel conversion efficiency and calculated based on calculated brake power, mass flow rate and heating value of the fuel using the following equation:

$$BTE(\%) = \frac{BP}{m \times H\dot{V} \times 103} \times 100\% \tag{6}$$

where HV is the heating value of the fuel (MJ/kg).

Specific fuel consumption was calculated based on the obtained power and the measured fuel flow using fuel flow meter. Figure 2 presents the schematic diagram for engine experimental set-up used in this study.

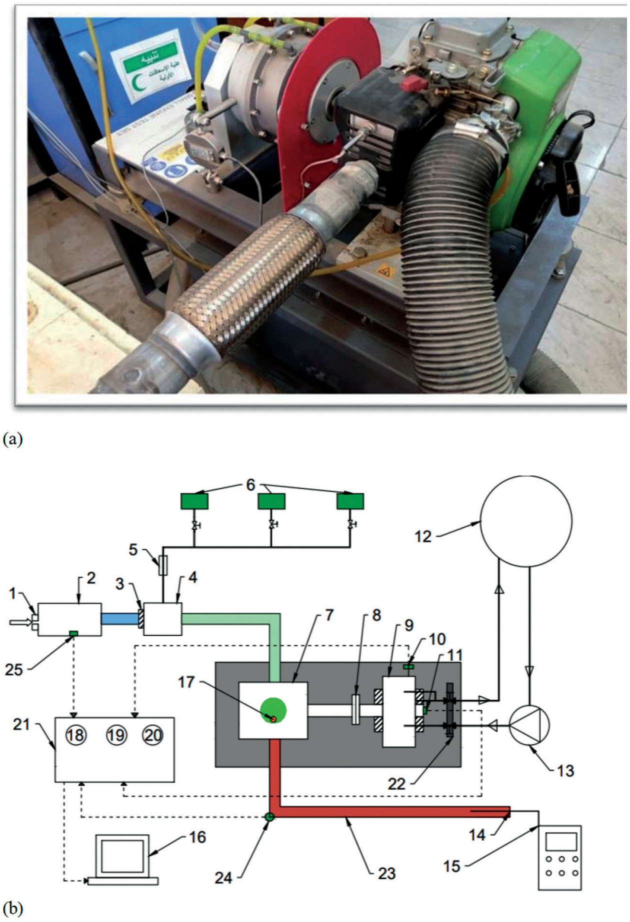

Figure 2. (a) Engine test rig; (b) Schematic diagram for engine experimental set-up.

(1.Air flow meter, 2. Air flow tank, 3. Throttle gate, 4. Carburetor, 5. Fuel flow meter, 6. Fuel tank, 7. Engine, 8. Coupling, 9. Hydraulic meter, 10. Electronic loading cell, 11. Engine speed sensor, 12. Water tank, 13. Water pump, 14. Emission analyzer probe, 15. Exhaust analyzer, 16. PC, 17. Spark plug, 18. Temperature and pressure screen panel, 19. Torque and speed screen panel, 20. Interface VDAS-F, 21. Equipment screen panel, 22. Control valve, 23. Exhaust, 24 and 25. Thermocouple K-type)

RESULTS AND DISCUSSION

In this work, GCWO was collected from chicken grill and WCO was the collected from the waste of frying oil in the restaurants that used cooking oil for frying. base catalysts of potassium hydroxide (KOH) at 0.3 wt%, 0.45 wt%, 0.6 wt% and 0.75 wt% have been studied. Figure 3 presents the optimization results for the impact of reaction temperature on the yield of biodiesel from GCWO at constant atmospheric pressure (1 atm) and different reaction temperatures of 50°C, 60°C, 70°C and 80°C. The figure shows the influence of base catalyst on the yield of biodiesel with increasing ratio of KOH concentrations. According to the results obtained, the maximum yield was achieved from GWO at 0.4 wt% of KOH catalyst. An increasing in base catalyst more than this limit, the transesterification reaction affected and the yield decreased. The maximum biodiesel yield obtained from GWO is found to be 94.935 achieved at a temperature of 60 °C with 0.4% KOH concentration as shown in Figure 4.

Figure 5 presents the optimization results for the impact of reaction temperature on the yield of biodiesel from WCO at constant atmospheric pressure (1 atm) and different reaction temperatures of 50°C, 60°C, 70°C and 80°C. The figure presents the influence of base catalyst on the yield of biodiesel with increasing ratio of KOH concentrations. According to the results obtained, maximum yield was achieved from WCO at 0.4 wt% of KOH catalyst. An increasing in base catalyst more than this limit, the transesterification reaction affected and the yield decreased. This can be explained as the further concentration means mass transfer become very important. The yield of biodiesel production increased gradually with increasing reaction temperature then tends to decrease after a certain maximum value. On the other hand, it presents constant trend of decrease with increasing catalyst concentration. The maximum biodiesel yield obtained from WCO is found to be 93.58 achieved at a temperature of 59.9°C with 0.35% KOH concentration as shown in figure 6.

Figure 7 presents the optimization results for the impact of reaction temperature on the biodiesel conversion from GCWO at constant atmospheric pressure (1 atm) and different reaction temperatures of 50°C, 60°C, 70°C and 80°C. The Figure presents the influence of base catalyst on the biodiesel conversion with increasing ratio of KOH concentrations. According to the results obtained, maximum conversion was achieved at 0.4 wt% of KOH catalyst. An increasing in base catalyst more than this limit, the transesterification reaction affected and the conversion decreased. The maximum biodiesel conversion is found to be 97.54 achieved at a temperature of 60.1°C with 0.4% KOH concentration as shown in figure 8.

Figure 9 presents the optimization results for the impact of reaction temperature on the biodiesel conversion from WCO at constant atmospheric pressure (1 atm) and different reaction temperatures of 50°C, 60°C, 70°C and 80°C. The figure presents the influence of base catalyst on the biodiesel conversion with increasing ratio of KOH concentrations. According to the results obtained, maximum conversion was achieved from WCO at 0.4 wt% of KOH catalyst. An increasing in base catalyst more than this limit, the transesterification reaction affected and the conversion decreased. This can be explained as the further concentration means mass transfer become very important. The conversion of biodiesel increased gradually with increasing

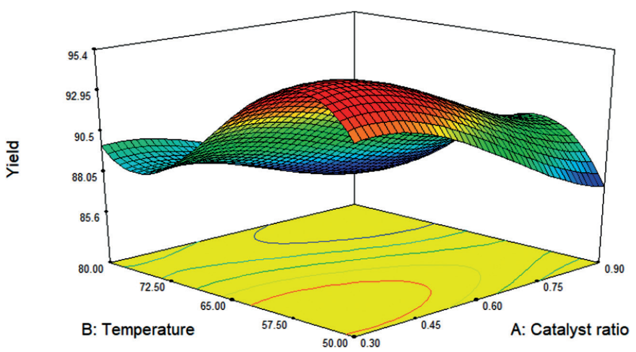

Figure 3. Optimization of biodiesel yield with KOH catalyst.

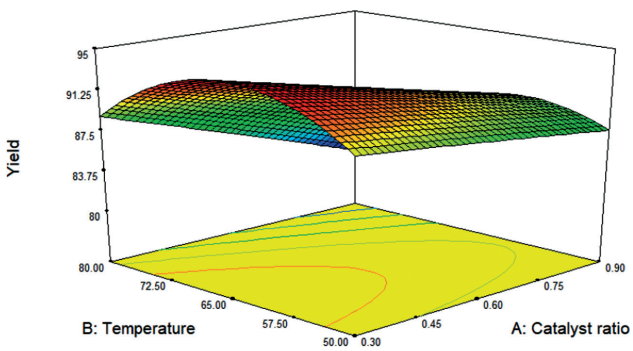

Figure 4. Optimum biodiesel yield conditions from GCWO.

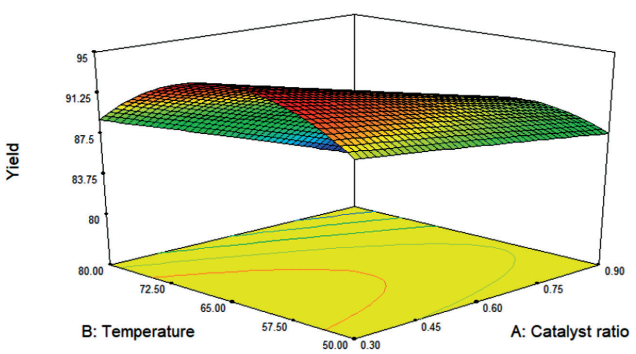

Figure 5. Optimization of biodiesel yield from WCO.

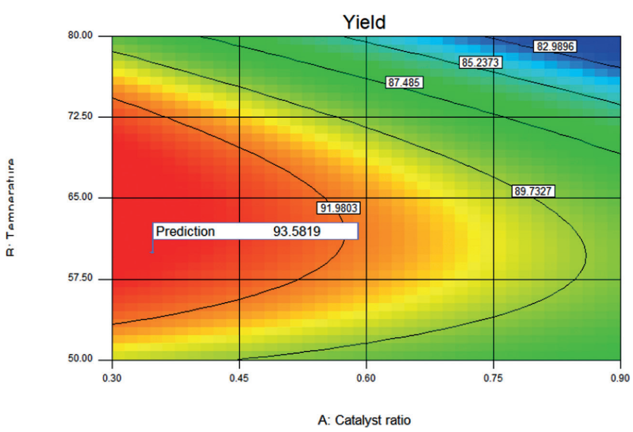

Figure 6. Optimum biodiesel yield conditions from WCO.

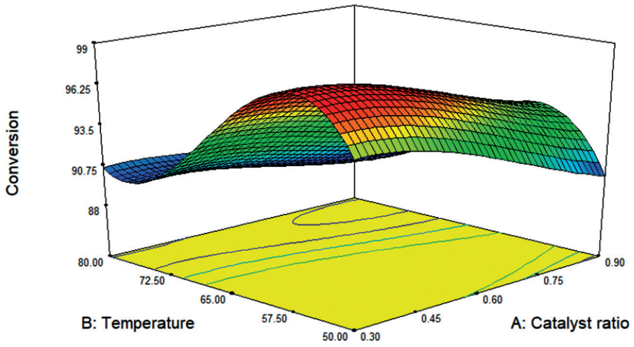

Figure 7. Optimization of biodiesel conversion with GCWO.

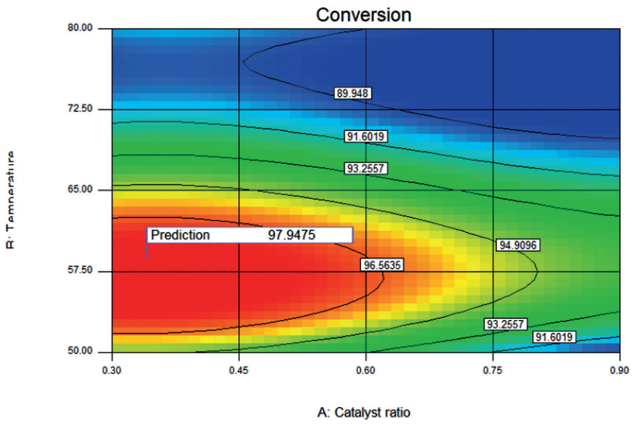

Figure 8. Optimum biodiesel conversion conditions with GCWO.

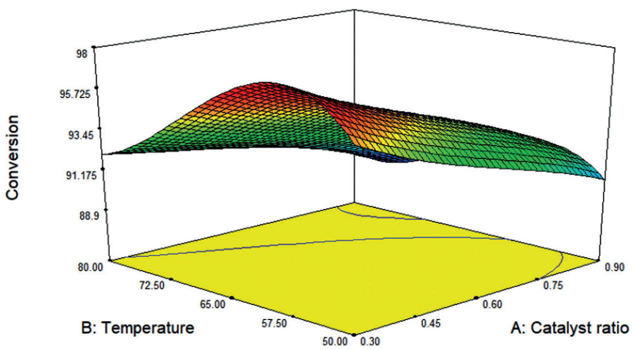

Figure 9. Optimization of biodiesel conversion with WCO.

reaction temperature then tends to decrease after a certain maximum value. On the other hand, it presents constant trend of decrease with increasing catalyst concentration. The maximum biodiesel conversion is found to be 97.21 achieved at a temperature of 59.9^{0}C with 0.35% NaOH concentration as shown in figure 10.

From the study results it can be seen that the yield and conversion of bio-diesel from grilled chicken waste oil,

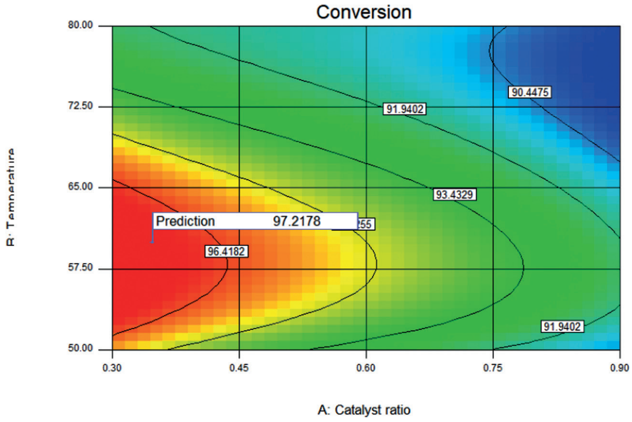

Figure 10. Optimum biodiesel conversion conditions with WCO.

Table 2. Measured properties of investigated fuel samples

Properties	Diesel	GCWOB	WCOB
Kinematic viscosity at 40°C (mm^2/s)	2.8	4.3	4.915
Density at 15°C (kg/m^3)	847	876	884
Heating value (MJ/kg)	43.28	39.9	37.2
Cetane number	50	53	49
Flash point (°C)	75	177	178°C
Acid value (mg KOH/g)	0.16	0.27	0.42

greater than waste cooking oil. Optimum operating conditions obtained are 60^{0}C, 3hr, and 0.4 wt% for reaction temperature, reaction time and KOH catalyst respectively. The higher yield and conversion were at low temperature, but methyl ester conversion was good at increased temperature. It must be taking into account that highest reaction temperature more than the boiling point for CH_3OH can effect mainly on the yield and conversion of biodiesel and also causing evaporation of alcohol (CH_3OH).

To ensure that the biodiesel produced meets the ASTM D6751 standard limits, analysis for checking its properties were conducted as presents in Table 2. It is obvious that produced biodiesel meets the standard specifications listed in Table 1. However, though the same production procedures adopted, investigated biodiesel samples reveals varying properties due to their different original source. Kinematic viscosity is an essential parameter controlling fuel droplets size and fuel spry penetration; in turn fuel spray formation affects the mixture combustion progress and efficiency. High viscosity leads to large fuel droplets and improper spry formation, on the other hand, very low viscosity may results in fuel leakage through the fuel system lines connections. The results in table 2 show that both biodiesels have kinematic viscosity values higher than that

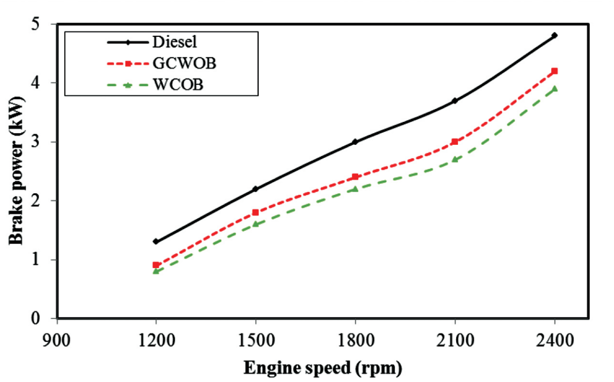

Figure 11. Variation of Engine BP with increasing engine speed.

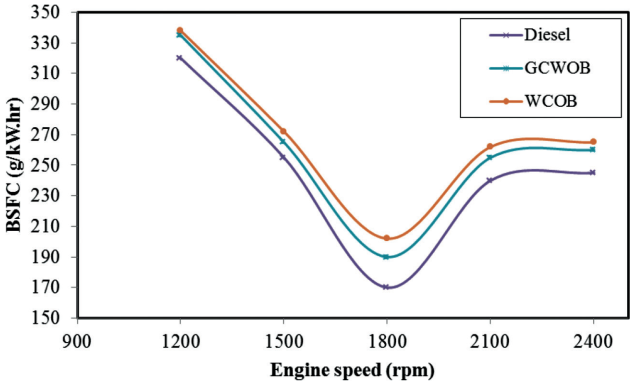

Figure 12. Variation of Engine BSFC with increasing engine speed.

of diesel. However, these values are within the biodiesel fuel standard limits shown in table 1 with lower value for GCWOB compared to WCOB. Fuel density is an important indicator to compare the amount of fuel consumed using different fuel samples as the fuel system handling fuel based on volume bases. Different fuel samples show comparable density value closed to that of diesel fuel. Though ASTM standard didn't include certain limits for heating value, it can be considered as the main indicator for the engine output power. The results show that both biodiesels have heating values lower than that of diesel with lower value for WCOB compared to GCWOB. Both fuels meet the requirement of cetane number value mentioned in ASTM D6751 with better value for GCWOB which is higher than that of diesel fuel. This indicates better ignition quality and smooth engine operation with GCWOB. The high flash point of biodiesel fuel indicates safe storage and handling compared to diesel. Through WCO has higher acid value compared to diesel and GCWOB, it is still meet the ASTM D6751 standard.

Figures 11 and 12 shows the engine test results for brake power (BP) and brake specific fuel consumption (BSFC) respectively, at constant half engine load. During the whole engine speed, the obtained engine BP with both biodiesels found to be lower that of diesel fuel. However, better engine BP obtained with GCWOB compared to WCOB during the whole engine speed. The reduction in BP at 1800 rpm found to be about 20 with GCWOB and 26.6 with WCOB compared to diesel which can be attributed to the lower calorific value and higher viscosity of biodiesel fuel compared to diesel fuel as shown in Table 2 [29]. On the other hand, higher BP by about 8.3% obtained with GCWOB compared to WCOB. Moreover, both biodiesels reveals higher BSFC during the whole engine speed. The maximum increase is found to be 11.7% and 18.8 with GCWOB and WCOB respectively at 1800 rpm engine speed which can be attributed to the lower heating value and higher density of biodiesel fuel compared to diesel fuel as shown in Table 2 [30]. Accordingly, lower BSFC by about 6.3% obtained with GCWOB compared to WCOB which may be attributed to the higher heating value and lower density for GCWOB compared to WCOB. Same trend for BP and BSFC was observed with WCOB from different mixed sources [31]. However, the results indicated a reduction in BP of 34.5% and an increase of 28% in BSFC with biodiesel compared to pure diesel. This indicates better engine performance with WCO biodiesel from single specified source. Though property measurement shows a reduction of 7.8% in the heating value of GCWOB compared to diesel fuel, the cetane number is enhanced by about 6% which can contribute in improving the combustion efficiency. From economic point of view, the cost of produced biodiesel will be much more lower than the cost of mineral diesel as their source is free which represent about 75% of the total biodiesel production cost.

CONCLUSION

In this work, biodiesel fuel has been produced from grilled chicken waste oil (GCWO) and waste cooking oil (WCO) using potassium hydroxide as homogenous catalysts. According to the results obtained in this study the following finding can be addressed;

- Biodiesel yield and conversion obtained from grilled chicken waste oil was greater than waste cooking oil. Maximum yield and conversion of biodiesel are 94.935% and 97.54% respectively achieved at optimum operating variables are 60 °C reaction temperature, 3h reaction time and 0.45% wt KOH concentrations.
- Though property measurement shows a reduction of 7.8% in the heating value of GCWOB compared to diesel fuel, the cetane number is enhanced by about 6% which can contribute in improving the combustion efficiency.
- The obtained engine BP with both biodiesels found to be lower that of diesel fuel and the better engine

BP obtained with GCWOB compared to WCOB during the whole engine speed. Higher BP by about 8.3% obtained with GCWOB compared to WCOB.

- Both biodiesels reveals higher BSFC during the whole engine speed with maximum increase found to be 11.7% and 18.8 with GCWOB and WCOB respectively at 1800 rpm engine speed. Accordingly, Lower BSFC by about 6.3% obtained with GCWOB compared to WCOB.
- Biodiesel fuel from GCWO reveals better production characteristics, fuel property and engine performance compared to WCOB.

Accordingly, waste oil can be considered as a source of biodiesel which is locally available and free of cost that can be used in the future as a viable source of biodiesel in the future that can be used and in the same time reduce the environmental impact of these waste through re-use of these oil.

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AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] Shahid EM, Jamal Y. Production of biodiesel : A technical review. Renew Sust Energy Rev 2011;15:4732–4745. [CrossRef]

[2] Talebian-kiakalaieh A, Aishah N, Amin S, Mazaheri H. A review on novel processes of biodiesel production from waste cooking oil. Appl Energy 2013;104:683–710. [CrossRef]

[3] Lapuerta M, Herreros JM, Lyons LL, García-contreras R, Briceño Y. Effect of the alcohol type used in the production of waste cooking oil biodiesel on diesel performance and emissions. 2008;87:3161–3169. [CrossRef]

[4] Ali OM, Mamat R, Abdullah NR, Abdullah AA. Characteristic of blended fuel properties and engine cycle-to-cycle variations with butanol additive. AIP Conf Pro 2015;1660: 070006. [CrossRef]

[5] Al-Doori WHAR. Influence of steam injection on the performance of combined cycle power plant. J Eng Appl Sci 2011;6:390–396. [CrossRef]

[6] Permpool N, Bonnet S, Gheewala SH. Greenhouse gas emissions from land use change due to oil palm expansion in Thailand for biodiesel production. J Clean Prod 2015;134:1–7. [CrossRef]

[7] Hagos FY, OM Ali, Mamat R, Abdullah AA. Effect of emulsification and blending on the oxygenation and substitution of diesel fuel for compression ignition engine, Renew Sust Energy Rev 2017;75:1281–1294. [CrossRef]

[8] Ali OM, Mamat R, Faizil CKM. Characterization of blended biodiesel fuel properties with small portion of butanol as a fuel additive. Appl Mech Mater 2014;465–466:137–141. [CrossRef]

[9] Ali OM, Yusaf T, Mamat R, Abdullah NR, Abdullah AA. Influence of chemical blends on palm oil methyl esters' cold flow properties and fuel characteristics. Energies 2014;7:4364–4380. [CrossRef]

[10] Najim YH, Ahmed AH, Al-Abdraba WMS. Effect of castor oil biodiesel blending ratio on diesel engine performance and emissions. IMDC-SDSP 2020, 28-30 June 2020, Cyberspace. Conference or Workshop Item (Paper). [CrossRef]

[11] Ahmed AH. Ali OM, Mohammed AE, Daoud RW, Ibrahim TK. Enhancement of engine performance with high blended diesel-biodiesel fuel using iso-butanol additive. IOP Conf Ser Mater Sci Eng 2019;518:032013. [CrossRef]

[12] Al-Taha WH, Osman HA. Performance analysis of a steam power plant: A case study. MATEC Web Conf 2018;225:10. [CrossRef]

[13] Santori G, Di G, Moglie M, Polonara F. A review analyzing the industrial biodiesel production practice starting from vegetable oil refining. Appl Energy 2012;92:109–132.

[14] Koh MY, Idaty T, Ghazi M. A review of biodiesel production from Jatropha curcas L . oil. Renew Sust Energy Rev 2011;15:2240–2251. [CrossRef]

[15] Keskin A, Koca A, Gürü M, Dog B. Biodiesel production from waste animal fat and improvement of its characteristics by synthesized nickel and magnesium additive. 2009;50:498–502. [CrossRef]

[16] Al-Doori WHAR. Parametric performance of gas turbine power plant with effect intercooler. Modern Appl Sci 2011;5:173. [CrossRef]
[17] Pandey RK, Rehman A, Sarviya RM. Impact of alternative fuel properties on fuel spray behavior and atomization. Renew Sust Energy Rev 2012;16:1762–1778. [CrossRef]
[18] Raheman H, Ghadge SV. Performance of compression ignition engine with mahua (Madhuca indica) biodiesel. Fuel 2007;86:2568–2573. [CrossRef]
[19] Hoekman SK, Broch A, Robbins C, Ceniceros E, Natarajan M. Review of biodiesel composition , properties, and specifications. Renew Sust Energy Rev 2012;16:143–169. [CrossRef]
[20] Ali R, Mamat OM, Masjuki HH, Abdullah AA. Analysis of blended fuel properties and cycle-to-cycle variation in a diesel engine with a diethyl ether additive. Energy Convers Manag 2016;108:511–519. [CrossRef]
[21] Ali OM, Mamat R. Improving engine performance and low temperature properties of blended palm biodiesel using additives. A review. Appl Mech Mater 2013:68–72. [CrossRef]
[22] Ali OM, Mamat R, Faizal CKM. Palm biodiesel production, properties and fuel additives. Int Rev Mech Eng 2012;6:1573–1580.
[23] Silitonga AS, Masjuki HH, Mahlia TMI, Ong HC, Chong WT, Boosroh MH. Overview properties of biodiesel diesel blends from edible and non-edible feedstock, Renew. Sust Energy Rev 2013;22:346–360. [CrossRef]
[24] Rezania S, Mahdinia S, Oryani B, Cho J, Kwon EE, Bozorgian A, et al. Biodiesel production from wild mustard (Sinapis Arvensis) seed oil using a novel heterogeneous catalyst of LaTiO3 nanoparticles. Fuel 2022;307:121759. [CrossRef]
[25] Gojun M, Šalić A, Zelić B. Integrated microsystems for lipase-catalyzed biodiesel production and glycerol removal by extraction or ultrafiltration. Renew Energy 2021;180:213–221. [CrossRef]
[26] Singh S, Pandey D, Saravanabhupathy S, Daverey A, Dutta K, Arunachalam K. Liquid wastes as a renewable feedstock for yeast biodiesel production: Opportunities and challenges. Environ Res 2021;207:112100. [CrossRef]
[27] Mathew GM, Raina D, Narisetty V, Kumar V, Saran S, Pugazhendi A, et al. Recent advances in biodiesel production: Challenges and solutions, Sci. Total Environ. 794 2021;79:148751. [CrossRef]
[28] Im-Orb K, Arpornwichanop A, Simasatitkul L. Process intensification approach for design and optimization of biodiesel production from palm fatty acid distillate. Biotechnol Rep (Amst) 2021;30:e00622. [CrossRef]
[29] OM Ali, Mamat R, Najafi G, Yusaf T, Safieddin Ardebili SM. Optimization of biodiesel-diesel blended fuel properties and engine performance with ether additive using statistical analysis and response surface methods. Energies 2015;8:14136–14150. [CrossRef]
[30] Awad OI, Mamat R, Ali OM, Sidik NAC, Yusaf T, Kadirgama K, et al. Alcohol and ether as alternative fuels in spark ignition engine: A review. Renew Sust Energy Rev 2018;82:2586–2605. [CrossRef]
[31] Yesilyurt MK. The effects of the fuel injection pressure on the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel-diesel blends. Renew Energy 2019;132:649–666. [CrossRef]