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Biodiesel Production from Chicken Fat Using Nano-calcium Oxide Catalyst and Improving the Fuel Properties *via* Blending with Diesel

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In this research, biodiesel was produced using chicken fat in the presence of calcium oxide nano-catalyst. To do so, the effect of various parameters like temperature, reaction time, catalyst amount and methanol to oil ratio was investigated on the biodiesel production. The results showed that the best conditions for biodiesel production were obtained such as the temperature of 65 °C, methanol to oil ratio of 1:9, the catalyst amount of 1 wt.% and reaction time of 5 h which in these conditions the biodiesel efficiency was determined 94.4%. Then, for improvement of fuel properties, they were mixed with diesel in different ratios (B25, B50 and B75) and their properties such as flash point, cloud point, pour point, kinematic viscosity and density were analyzed according to international standards. The results showed that the mixture ratio of B75 and B100 had density and viscosity in the range of standard. Additionally, this fuel should not be used in cold weather since its pour point is greater than zero.

Keywords: Biodiesel, Chicken fat, Calcium oxide nanocatalyst, Transesterification

INTRODUCTION

Increased demand for energy, reduced resources of fossil fuels, and environmental problems associated with climatic changes due to the effect of combustion of the fossil fuels have motivated many researchers around the world to undertake extensive research to find appropriate alternative sources of energy to supply human's needs [1]. Biodiesel is one of such clean and renewable energies which can serve as an appropriate alternative to fossil fuels and replace petroleum-based diesel without changing the current diesel engines [2]. Biodiesel is a non-toxic, available, and biocompatible fuel which generates lower amounts of greenhouse gases [3-4]. Biodiesel can be directly used in diesel engines as it possesses similar properties to those of conventional motor diesel. Also, biodiesel produces smaller amounts of exhaust-emitted carbon monoxide, suspended micro-particles, unburned hydrocarbons, and sulfur oxide compared to diesel [5]. The main sources for the production of biodiesel include plant oils, animal fats and microalgae oils [6]. There are various methods for producing biodiesel from plant oils and animal fats, of which one can refer to pyrolysis, dilution or micro-emulsion and transesterification processes. Of the mentioned methods, transesterification is the most common, economic, and appropriate method for biodiesel production [7-8]. This popularity relies on the advantages offered by this method such as the similarity between properties of the produced biodiesel and conventional diesel, high conversion yield, low cost and suitability for industrial scale production [9]. Transesterification is a chemical process wherein triglyceride reacts with alcohol in the presence of a catalyst. This process resembles hydrolysis process, except that water is replaced by alcohol. Suitable alcohols for this purpose include methanol, ethanol, propanol, and butanol. Of these alcohols, methanol is of lower cost and offers more physical and chemical advantages [7-8,10].

Also, various basic, acidic, and enzyme catalysts can be used in transesterification process. When it comes to

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biodiesel production, basic catalysts are often the catalysts of choice because of their higher efficiency than those of acidic and enzyme catalysts, so that the basic catalysts have gained larger deals of attention [11]. Recently, nano-catalysts have been used to produce biodiesel, because of their high catalytic efficiency, large specific surface area, high resistance to saponification and good rigidity [12].

Biodiesels produced from different oils usually have viscosities close to that of diesel. Furthermore, even though the heating value of biodiesel is just slightly lower than that of diesel, its cetane number and flash point are higher than those of diesel. Considering the properties of biodiesel, this fuel can be seen as a candidate fuel for replacing diesel [13]. In addition, biodiesel is a fuel which can be used either in pure form or as a mixture with diesel fuel [14-15].

The aim of this research is to investigate the effect of different parameters such as temperature, reaction time, catalyst amount, and methanol to oil ratio on biodiesel production using chicken fat oil in the presence of calcium oxide nanocatalyst. The produced biodiesel under optimal conditions was then mixed with diesel at different mixing ratios and their characteristics (flash point, cloud point, pour point, viscosity and density) were determined. The characteristics were then compared to those under standard conditions to come with the best mixing ratio between biodiesel and diesel, so as to obtain the best properties of the mixed fuel. To the best of authors' knowledge, this is the first report of the application of CaO nanocatalyst for the preparation of biodiesel from chicken fat.

MATERIALS AND METHODS

Materials

Calcium oxide nanocatalyst with 99.9% purity and particle size of 50 nm was procured from Sigma Aldrich Company and used in the present research. To characterize the morphology of nano-CaO structure, scanning electron microscopy (SEM) analysis was used. Furthermore, methanol was purchased from Merck Company (Germany). The oil used was prepared from chicken fat which was obtained from slaughterhouses in southern Iran (Bushehr province).

Methods

Extraction of oil from chicken fat. first step, chicken fat was washed to remove wastes and blood because residual waste may burn by heating, thereby changing the color of the produced oil or lowering its quality. The fats were then placed in a colander at ambient temperature to drain its water content. The fats were subsequently divided into smaller parts to facilitate the oil extraction process. Fats were then placed in a large vessel and mildly heated on the flame of the oven with the vessel lid closed to have the fat texture liquefied to oil. This process took three hours to accomplish. Afterwards, the obtained oil was passed through a filter to become free of suspended and waste material. Prior to use, the obtained oil was heated at 100 °C to remove any remaining water content.

Analysis of chicken fat using gas chromatography. Fatty acids contents of the obtained oil from chicken fat were determined using gas chromatography (GC). In this investigation, Varian CP-3800 GC was utilized. The apparatus was equipped with a flame ionization detector (FID) and a capillary column of 30 m in length. Helium was used as the carrier gas. Flow rates of nitrogen, hydrogen and air were set to 30, 30 and 300 ml/min, respectively. The fatty acids content of the extracted oil from the chicken fat are presented in Table 1.

Biodiesel production method. In order to produce biodiesel from chicken fat using calcium oxide nanocatalyst, transesterification method was utilized. A condenser was further used to avoid methanol vaporization and better control the reaction temperature. At first, 50 g of chicken oil was poured in a two-necked flask and the flask was placed on a heater to reach the temperature 65 °C. Then, the methanol-catalyst mixture was introduced into the flask. The time at which the oil was mixed with methanol and catalyst was recorded as the starting time of the experiment.

The smaller neck of the flask was sealed with a plastic cap through which a thermometer was introduced into the solution to control the solution temperature without letting the methanol leave the flask.

Determination of optimal conditions. In the present research, the effects of parameters such as methanol to oil molar ratio, catalyst amount, reaction temperature, and

Table 1. Fatty Acid Contents of Chicken oil Using GC Analysis

Fatty acid	Molecular formula	Chemical formula	Molecular weight	Content (%)
Palmitic acid	C16:0	$C_{16}H_{32}O_2$	256.42	28.65
Stearic acid	C18:0	$C_{18}H_{36}O_2$	284.48	6.93
Oleic acid	C18:1	$C_{18}H_{34}O_2$	282.46	43.13
Linoleic acid	C18:2	$C_{18}H_{32}O_2$	280.45	12.51
Linolenic acid	C18:3	$C_{18}H_{30}O_2$	278.49	0.01
Myristic acid	C14:0	$C_{14}H_{28}O_2$	228.37	7.9

reaction time were investigated on the biodiesel production. The yield of biodiesel production was used as the criterion for reporting optimal biodiesel production conditions. In order to find the optimal value of each parameter, other parameters were kept constant. Accordingly, in the first stage, reaction temperature, reaction time and catalyst amount were set to 65 °C , 4 h, and 1.5 wt.%, respectively, and different methanol to oil molar ratios (1:4, 1:16, 1:9, 1:12 and 1:15) were tested; the best results were reported with the methanol to oil ratio of 1:9. In order to determine the best values of other parameters, experiments were conducted according to the details given in Table 2. Further, reported in this table is the yield of biodiesel production under these conditions.

Analysis of the biodiesel produced under optimal conditions. After examining the laboratory conditions for biodiesel production, properties of the produced fuel such as viscosity, density, flash point, cloud point, and pour point were examined and analyzed according to international standard procedures (*e.g.* ASTM D6751 and EN 14214).

RESULTS AND DISCUSSION

SEM Analysis of the Nanocatalyst

In the present research, scanning electron microscopy (SEM) was used to determine the structure of calcium oxide nanocatalyst on a Mira3-XMU. In an attempt to determine the size of the nanoparticles, the SEM was used to take an image of the particles, as can be observed in Fig. 1. As can be seen in Fig. 1, most of the particles were smaller than 100 nm in size.

Effect of Methanol to Oil Ratio on Reaction Yield

Effect of methanol to oil molar ratio (1:4, 1:16, 1:9, 1:12 and 1:15) on biodiesel production using calcium oxide nanocatalyst was investigated. Figure 2 shows the effect of methanol to oil molar ratio on the yield of biodiesel production. The best methanol to oil ratio under the mentioned operating conditions was found to be 1:9 as it ended up with a yield of biodiesel production from the chicken fat of 90%. With a yield of 65%, the methanol to oil ratio of 1:4 returned the lowest biodiesel production yield. Biodiesel production yield followed an increasing trend when methanol to oil ratio was changed from 1:4 to 1:9, while the yield changed to a decreasing trend for methanol to oil ratios beyond 1:9. This was because, with increasing the content of methanol, glycerin was extensively dissolved in the excessive methanol, keeping the methanol from reacting with the catalyst and hence making methanol separation from biodiesel and glycerin very difficult.

Table 2. Experimental Conditions for Determining the Optimum Conditions on Biodiesel Production

Run No.	Time (h)	Temperature (^oC)	Catalyst amount (wt.%)	Methanol/Oil molar ratio	Biodiesel yield (%)
1	4	65	1.5	4:1	65
2	4	65	1.5	6:1	72
3	4	65	1.5	9:1	90
4	4	65	1.5	12:1	87.4
5	4	65	1.5	15:1	76
6	4	65	0.5	9:1	81.5
7	4	65	1	9:1	91.2
8	4	65	1.5	9:1	82.04
9	4	65	2	9:1	82.4
10	4	65	3	9:1	75.28
11	4	50	1	9:1	82
12	4	55	1	9:1	84.72
13	4	60	1	9:1	86.84
14	4	65	1	9:1	92.6
15	2	65	1	9:1	72
16	3	65	1	9:1	74.62
17	4	65	1	9:1	90.4
18	5	65	1	9:1	94.4
19	6	65	1	9:1	82.04

Effect of Catalyst Amount on the Yield of Biodiesel Production

In order to investigate the effect of this parameter on biodiesel production, different weight percentages of the catalyst (0.5, 1, 1.5, 2 and 3 wt.%) were tested. The obtained results are shown in Fig. 3. As can be observed in this figure, with increasing the catalyst amount from 0.5 to 1 wt.%, the amount of biodiesel production increases. However, with further increasing the catalyst amount from 1 to 3 wt.%, the biodiesel production yield follows a decreasing trend. This is because, with further increasing the catalyst amount, cohesion and agglomeration of the particles resulted in the reduced active surface area and increased the viscosity of the solution, thereby reducing the biodiesel production yield [16].

Effect of Temperature on Biodiesel Production

Rate and yield of biodiesel production in transesterification process is particularly dependent on the reaction temperature. Figure 4 shows the effect of

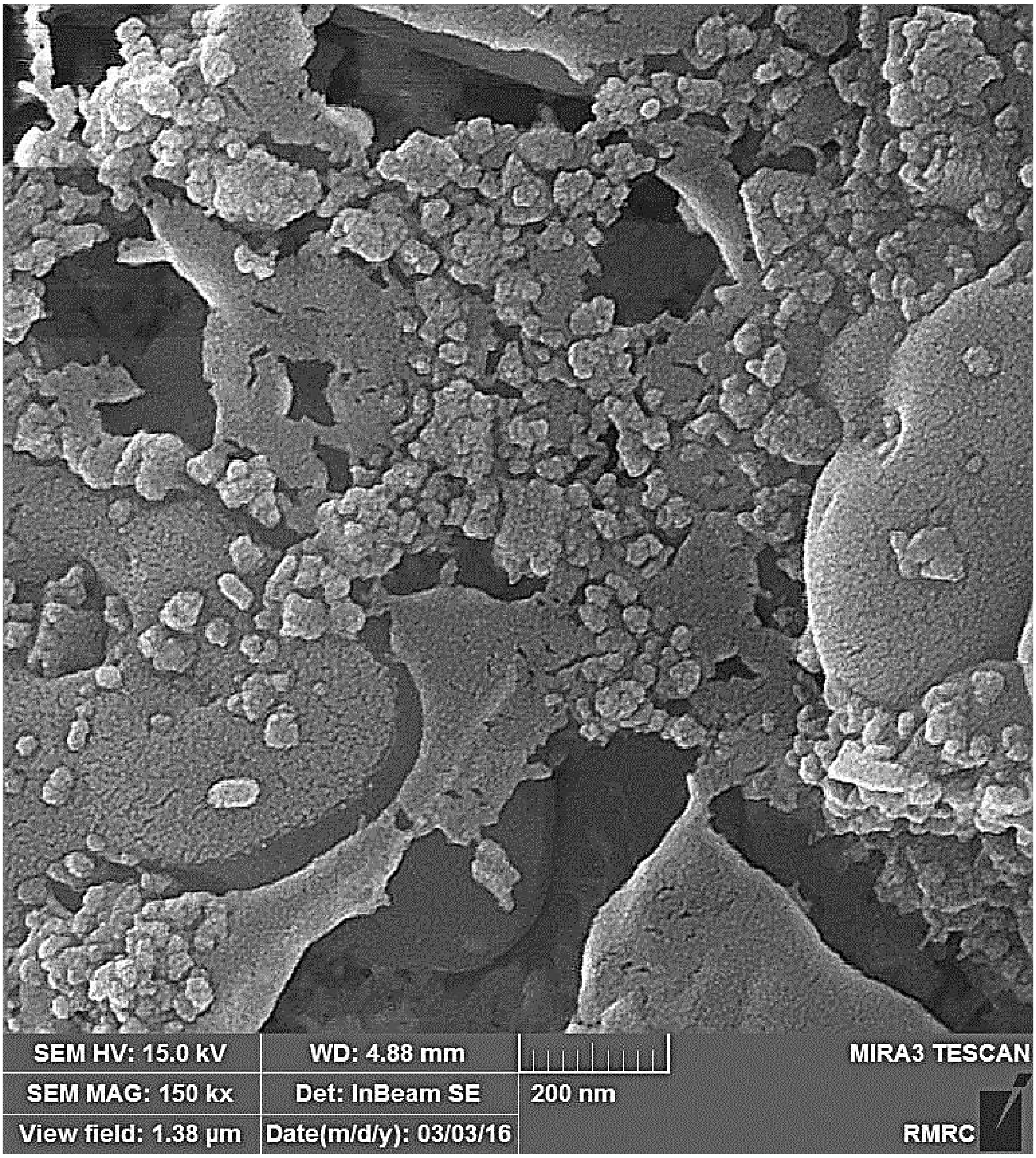

Fig. 1. SEM images of calcium oxide nanoparticles.

temperature on the yield of biodiesel production. As can be seen in this figure, with increasing the temperature, biodiesel production increases and the highest biodiesel production yield (92.6%) obtained at 65 °C.

Effect of Contact Time on Biodiesel Yield

In order to determine the effect of contact time on the yield of biodiesel production, effects of different reaction times (*e.g.* 2, 3, 4, 5 and 6 h) were evaluated under constant

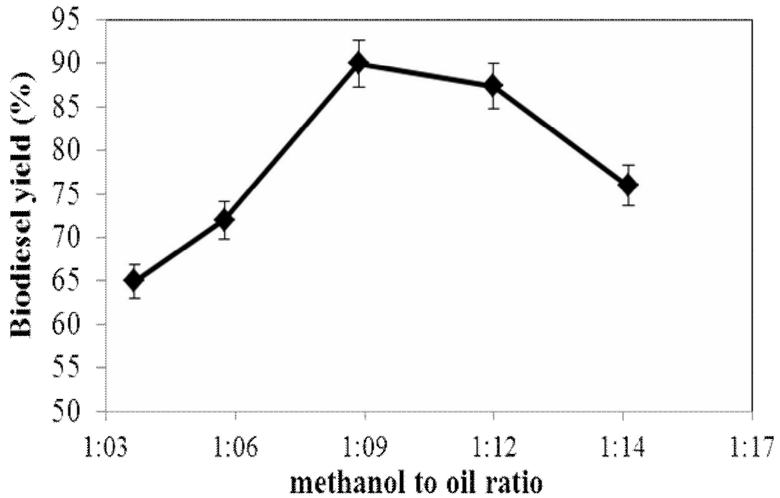

Fig. 2. Effect of methanol to oil ratio on the biodiesel yield (conditions: catalyst amount 1.75 wt.%, temperature 65 °C, mixing speed 1500 rpm and time 4 h).

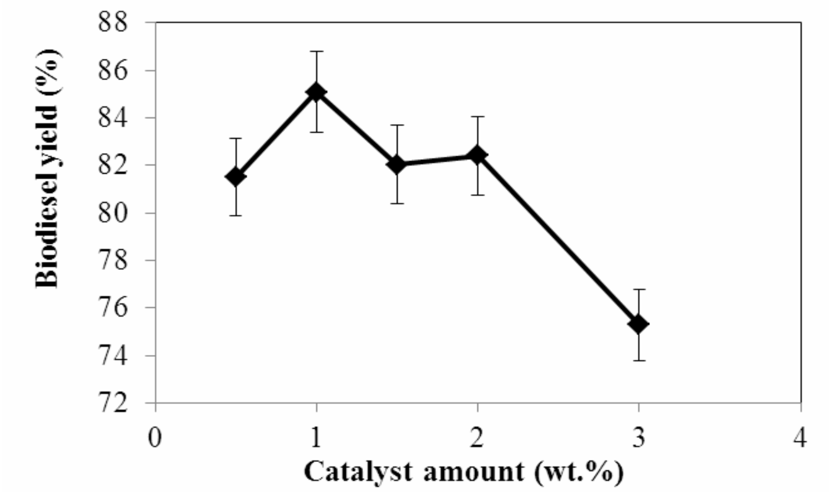

Fig. 3. Effect of catalyst amount on the biodiesel yield (conditions: temperature 65 °C, mixing speed 1500 rpm, methanol to oil ratio 9:1 and contact time 4 h)

operating conditions in terms of stirring rate (1500 rpm), reaction temperature (65 °C), methanol to oil ratio (1:9), and amount of catalyst (1 wt.%). The results are presented in Fig. 5. As can be seen in Fig. 5, with increasing the reaction temperature, biodiesel production increased, so that the maximum biodiesel production (94.4%) occurred in 5 h. The reaction is slow due to the mixing and dispersion of methanol in oil, and the biodiesel yield rises from 2 to 5 h during the reaction time. Since the biodiesel production reaction is a reversible chemical reaction, at longer times after the formation of biodiesel, the biodiesel bonds may break up to the original reactants, and for this reason the biodiesel yield decreased after 5 h. In other words, excessive reaction time reduces product yield because of the

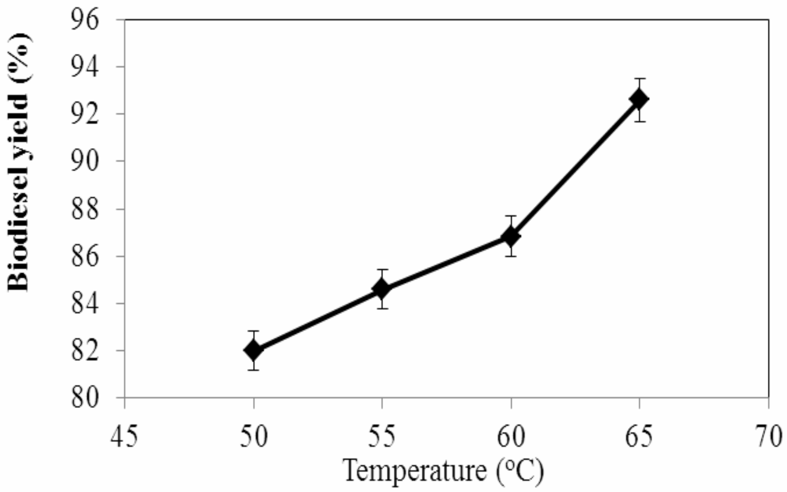

Fig. 4. Effect of temperature on biodiesel yield (conditions: amount of catalyst 1 wt.%, mixing speed 1500 rpm, methanol to oil ratio 9:1 and contact time 4 h)

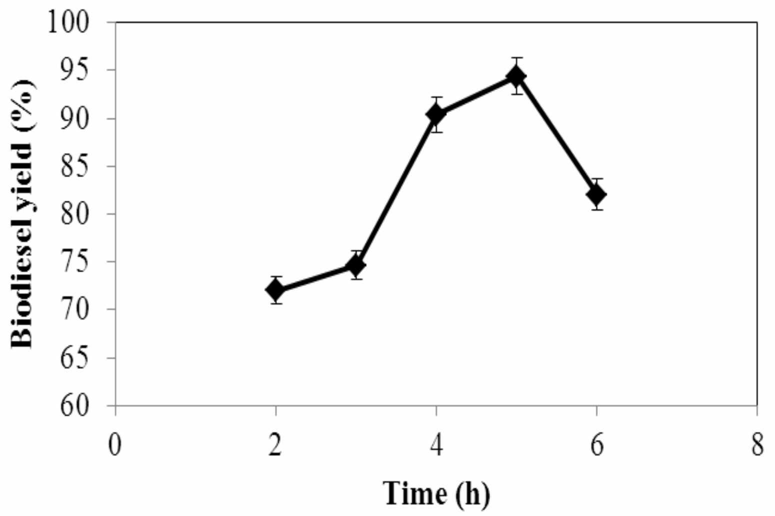

Fig. 5. Effect of time on biodiesel yield (conditions: amount of catalyst 1 wt.%, mixing speed 1500 rpm, methanol to oil ratio 9:1 and temperature 65 *°C*).

backward reaction, resulting in a loss in esters as well as causing more fatty acids to form soaps.

Mixing Biodiesel with Diesel

After preparing biodiesel in the best conditions (temperature = 65 °C, time = 5 h, methanol to oil ratio = 1:9 and catalyst amount = 1 wt.%), to improve properties of the biodiesel as a fuel, it was mixed with diesel at different ratios (B25, B50 and B75). Also, density, viscosity, cloud point, flash point and pour point of the mixtures were determined and then compared to international standards, as reported in Table 3.

Table 3. Physical Characterization of Produced Biodiesel from Chicken Fat in the Presence of Calcium Oxide Nanocatalyst

Test	EN-14214	ASTM D-6751	B00	B25	B50	B75	B100
Density (at 15 °C)	900-860	-	830	845	862	873	881
Viscosity (at 40 °C)	-	1.9-6	3.1	3.3	3.8	4.23	4.85
Flash point (°C)	>120	>130	88	92	100	130	170
Cloud point (°C)	-	-	3	4	5	6	7
Pour point (°C)	-	-	-8	0	2	3	4

As can be observed in this table, most of the properties of the produced biodiesel and its mixture with diesel at different ratios were in the range of standard values. Meanwhile, flash points of B00, B25 and B50 were out of the standard range. Therefore, as far as the use of the produced fuel from chicken fat is concerned, mixing it with diesel as B75 or B100 fuel will end up with very good results. Furthermore, since pour point of all of the considered mixtures was above zero, such fuels are not suitable for the cold climate.

CONCLUSIONS

In the present research, biodiesel was produced using chicken fat in the presence of nano-CaO to produce a clean, high-quality fuel in accordance with related standards. On this basis, the effect of parameters such as methanol to oil molar ratio (1:4, 1:6, 1:9, 1:12 and 1:15), CaO nanocatalyst amount (0.5, 1, 1.5, 2, and 3 wt.%), reaction temperature (50, 55, 60 and 65 °C), and reaction time (2, 3, 4, 5 and 6 h) were investigated on the biodiesel production yield. Obtained results indicated the highest yield of biodiesel production of 94.4% under conditions in terms of reaction temperature (65 °C), reaction time (5 h), methanol to oil ratio (1:9) and catalyst amount (1 wt.%).

The produced biodiesel under optimal conditions was further mixed with diesel at different mixing ratios followed by measuring flash point, cloud point, pour point, viscosity, and density of the mixtures. According to the obtained results, among the various mixtures studied in this research, B75 and B100 exhibited better densities, viscosities, and flash points at the corresponding standard ranges. Therefore, the biodiesel produced from chicken fat and B75 and B100 mixtures can be used as alternative fuels to diesel.

Conflict of Interests Statement: The authors declare that there is no conflict of interests.

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