PRODUCTION OF HIGH QUALITY BIODIESEL FROM WASTE CHICKEN FATS

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Abstract

Non-food biomass as an alternative renewable source for liquid biofuel is one of the promising solutions to help solve the worsening interrelated issues of energy consumption, climate change, and environmental pollution brought by the use of diminishing petroleum-based fuel. In this study, waste chicken fats are used as raw material in the production of biodiesel. The conversion underwent two major processes: oil extraction and transesterification processes. Experimental runs and analyses were done using central composite design of the response surface methodology with chosen operating variables. The result showed that the increase in reaction time and temperature significantly improved the oil yield with outcome ranging between 59.36–74.01% by weight. FTIR spectral analysis identified alkanes, alkenes, ketones, aldehydes, esters, aromatics, and ethers in the produced oil from chicken fats. In the transesterification process, the biodiesel yield ranges between 60–76% by volume with an average yield of 70.92%. Based on the numerical model produced, the increase of the reaction time had an adverse effect on the yield, but methanol affected otherwise. Alkanes, carbonyl, aromatics, ether, aliphatic iodo, and aryl disulfides composed the final product after refining. At optimized conditions, the biodiesel has a high heating value of 39.7 MJ/kg which is within the standard of 35–40 MJ/kg. This study has demonstrated that the waste chicken fats, which gave headaches to poultry dressing plants manager in terms of disposal, is a good biomass for liquid biofuel production, with the huge implication in the search for alternative energy source.

Keywords: *biodiesel production; chicken oil; transesterification; chicken fats; biofuel*

1.0 Introduction

Poultry dressing plants are now continually challenged because of the voluminous wastes generated like chicken fats. This problem would continue to aggravate considering the increasing demand for chicken meat needed of the growing human population. In 2010, about 33.4 million tons of poultry meats were produced worldwide (Feddern, Vivian, Cunha, 2011). In the Philippines, more than 4,200 metric tons of chicken meats were produced annually which subsequently generate tons of wastes predominantly disposed of in the environment. For each chicken, the fat content was accounted to range from 2.6–23.5% (Latshaw & Bishop, 2001). Chicken fats generation is estimated to increase at the rate of 6% annually (Flanagan, 2012). Improper disposal of these chicken fats threatens the environment because of the subsequent pollution of mankind's precious resources: water, land, and air.

Currently, these chicken fats were incinerated. Among the associated environmental problems of incineration were the release of unwanted pollutants to the atmosphere like carbon dioxide, heavy metals and toxic gases (Arazo, 2014). Besides, incineration process is costly due to high energy requirement and the need of expensive pollution control facilities and equipment (Manara & Zabaniotou, 2012). Another untoward way of disposing of chicken fats is through burying. Unfortunately, chicken fats buried underground produce leachate that release pollutants and contaminate the ground water. In the positive side, there is a claim that fats could be processed for pharmaceuticals, cosmetics, cooking oil, and oil for painting purposes (Ameta & Ame-

ta, 2013). However, these applications only used the selective part of waste fats. The residual fats, in greater volume than the carefully chosen parts, still gave headaches to poultry dressing plant managers. Discarded residual chicken wastes can be the place for pathogenic microorganisms to grow. Hence, there is a need to find ways so that these waste chicken fats cannot be regarded as a problem but a resource in the production of valuable products.

The government mandate from different countries to use renewable bio-based sources instead of petroleum-based energy sources coupled with waste-to-energy research agenda have encouraged many researchers to find sustainable alternative fuel sources.

This work investigated the use of waste chicken fats as a raw material for the production of liquid biofuel. It underwent two-stage processes: oil extraction and transesterification with biodiesel as the end product. To optimize the combination of considered variables, response surface methodology was used in designing the experiment and in analyzing the results. Optimization determined the best combinations of the variables to produce optimum yields and characteristics of the desired product: the oil and the biodiesel.

2.0 Materials and Methods

2.1 Experimental Design

Central Composite Design (CCD) of the Response Surface Methodology (RSM) was used in the study using Design Expert 7.0 software. RSM is the collection of mathematical and statistical techniques that helps to improve the study and find the relative significance of the several affecting factors even in the complex interactions (Prakash, Palanikumar, J, & Nithyalakshmi, 2011). The primary purpose of RSM is to identify the field that satisfies the operating variable to reduce cost, increase product yield, reduce the production time and create statistical data about the result.

The 0 coded level is the average values of the factors needed while -1 and 1 are assigned as the low values and high values of the operating variables. The -2 and 2 of the coded level are the negative and positive alpha that is considered as the minimum and maximum range values of the chosen variables. The initial value of the factor was based on the different study of biodiesel and extraction of oil processes.

In oil extraction, the operating variables, which are reaction time and reaction temperature, were set according to the experimental design (Table 1). Using the CCD of the RSM, about 13 runs were conducted.

Table 1. Range and Coded Levels of Independent Variables for Oil Extraction Process

Operating Variables	Coded Level				
	-2	-1	0	1	2
Reaction time, h	1	2	3	4	5
Reaction temperature, °C	100	120	140	160	180

In oil refining for biodiesel production, the reaction time, catalyst loading and methanol to oil ratio were varied (Table 2). Using CCD of the RSM, 20 runs were conducted.

Table 2. Range and Levels of Independent Variables for Transesterification Process

Variable	Coded Level				
	-2	-1	0	1	2
Reaction time, min	15	20	25	30	35
Catalyst loading, wt%	0.9	1.1	1.3	1.5	1.7
Methanol to oil ratio, vol%	15	20	25	30	35

2.2 Extraction of Oil from Waste Chicken Fats

The waste chicken fats were collected at the public market of Balingasag, Misamis Oriental, Philippines. Before oil extraction, the water from chicken fats was thoroughly drained.

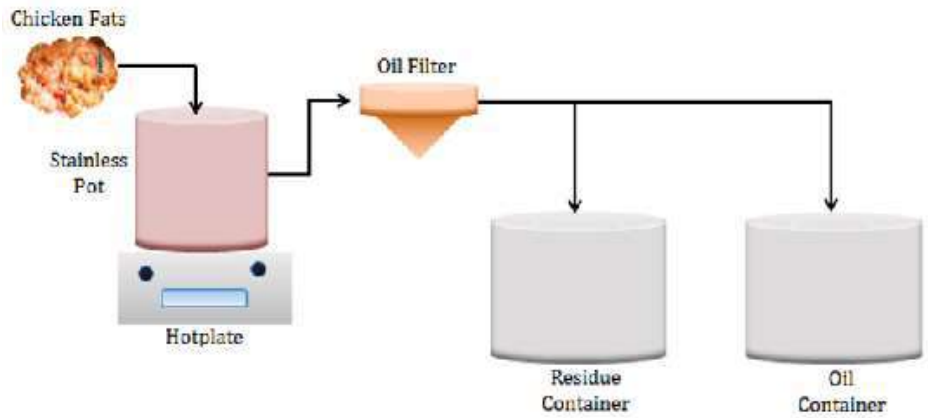

Figure 1. Diagram of Oil Extraction Process from Chicken Fats

The oil, scientifically known as free fatty acids, from chicken fats, was extracted using a hot plate with stainless pot as reaction container (Figure 1). The reaction temperature and reaction time were set according to the experimental design. The reaction temperature was monitored using laboratory thermometer. After the reaction time had been completed with the desired temperature, the mixture was filtered separating the residue from the oil. The oil was cooled to room temperature and subsequently weighed to determine the mass of of the oil yield.

2.3 Transesterification of Extracted Oil from Chicken Fats

The extracted chicken oil was refined through transesterification to convert it into ester through potassium hydroxide as catalyst and methanol as reactant (Figure 2).

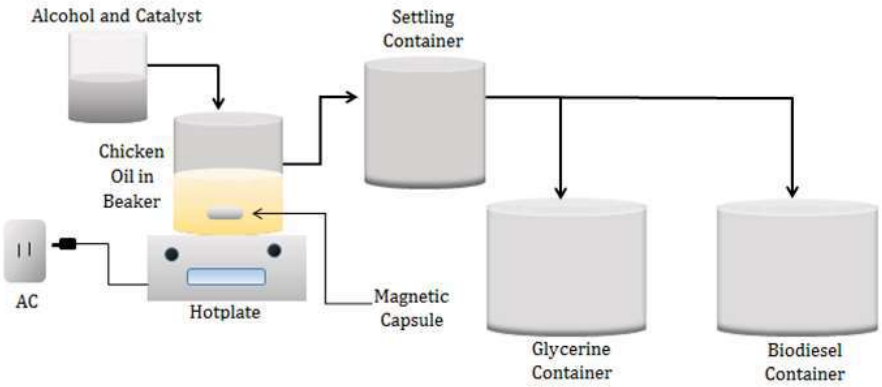

Figure 2. Procedural Diagram of Biodiesel from Chicken Fats Oil

The mixture of oil, methanol, and potassium hydroxide based on the experimental run was heated and continuously stirred at 60–80 °C in the hot plate using heat resistant container. After the experimental run, the mixture was cooled down allowing complete separation of different components for 12 h. The bio-oil was separated from the mixture of glycerin, water, and catalyst by decantation.

2.4 Product Analysis

Percent yields of extracted oil and the produced biodiesel were determined using analytical balance. The pH values of the yields were determined using the pH meter. The densities of the yields were computed using the standard ratio of mass and volume of a given sample.

Bomb Calorimeter following ASTM D4809 determined the high heating value (HHV) of the product. FTIR analysis identified the functional groups found in the product yields.

2.5 Modeling and Optimization

The percentage yields of the experimental runs underwent graphical modeling to determine the interactive effects of the chosen operating variables. The 3D models were generated using the Design Expert 7.0 software.

Analysis of variance through CCD determined the models that best fit the gathered data. Reduced models were generated in predicting the percentage yield by eliminating the insignificant terms with a p-value greater than 0.05.

Numerical optimization was done considering the criteria to determine the optimum conditions that best fit in predicting the yield. About 3–5 suggested solutions with high desirability were chosen for verification runs. The run with lowest relative error to the predicted values was considered as an optimum combination of the operating variables.

3.0 Results and Discussion

3.1 Oil Yield from Chicken Fats

The result of the experimental runs showed variations in the extracted oil yield (Table 3). The yield of 59.36–74.10% is comparable to the result of another study with a yield ranging from 64.5–81.7% (Ruth Amusan, 2008).

Table 3. Oil Yield Extracted from Waste Chicken Fats

Run	Chicken Fats, g	Reaction Time, h	Reaction Temperature, °C	Percent Yield, wt%
1	100.4	2	120	59.36
2	100.0	3	180	65.60
3	100.4	3	140	68.92
4	100.0	3	100	67.40
5	100.4	4	120	70.12
6	100.2	3	140	64.07
7	100.4	1	140	74.10
8	100.4	2	160	69.52
9	100.4	3	140	67.13
10	100.2	3	140	67.47
11	100.2	3	140	67.27
12	100.4	4	160	59.96
13	100.4	5	140	65.94

The highest oil yield was 74.1% (at 1 h and 140 °C) while the lowest yield was 59.36% (at 2 h and 120 °C). The significance of the result was statistically analyzed by ANOVA (Table 4).

Table 4. Analysis of Variance of the Percentage Yield of Oil from Chicken Fats

Source	Sum of Squares	df	Mean Square	F Value	P-Value Prob > F
Model	102.53	3	34.18	7.01	0.0099 [a]
A – Reaction Time	30.01	1	30.01	6.16	0.0349 [a]
B – Reaction Temp	4.61	1	4.61	0.95	0.3561 [b]
AB	67.91	1	67.91	13.94	0.0047[a]
Residual	43.85	9	4.87		
Lack of Fit	31.27	5	6.25	3.4378	0.2625 [b]
Pure Error	12.58	4	3.14		
Cor Total	146.38	12			

a=significant; b= not significant

With Design Expert 7.0 software, the experimental result generated a reduced Two-Factor Interval (2FI) model at which insignificant terms are omitted. The model is found appropriate and best fitted in predicting the oil yield (p-value=0.0099) justifying the effectiveness of the model to have 0.99% chance only that error would occur due to noise. The model is further validated by the not significant lack of fit with a p-value of 0.2625 supporting its reliability and best fitting.

3.2 Numerical Modeling of Oil Yield

The reduced 2FI model in predict-

ing the oil yield in terms of actual factor is given in Eq 1.

$$Yield = -10.46706 + 27.26082A + 0.58706B - 0.20602AB \quad [Eq\ 1]$$

where % yield was the predicted response variable (percentage yield of oil extracted); variable A is the reaction time (h), and variable B is the reaction temperature (°C).

In the model equation in Eq 1, the positive coefficient of A and B implied that increase in reaction time and temperature, when taken singly, would result in a subsequent increase in oil yield. The negative coefficient of AB indicates that there is the antagonistic interactive effect of time and temperature that inhibit the increase of yield. The result implies that optimum conditions should be determined because interaction effect of these variables prohibits the increase of the yield.

3.3 Effects of Operating Variables to Oil Yield

The effects of the operating variables on the percentage yield of oil were determined through 3D model graph. Only the interactive effects of reaction temperature and time have a significant effect on the model with a p-value of 0.0047 (Table 5). Hence, only the interactive effects of these two variables are shown (Figure 3) and discussed.

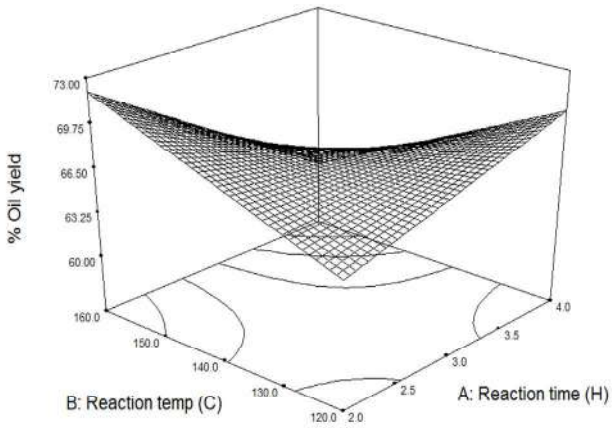

Figure 3. The 3D Response Surface Plot showing the Effect of the Operating Variables in the Oil Yield

As illustrated in Figure 3, at the minimum time (2 h) the increase of temperature (120–160 °C) resulted in increasing in oil yield. At the minimum time, the yield is high because it does not give extra time for the oil to volatilize and for secondary thermal cracking to occur. At maximum temperature (160 °C) and maximum time (4 h) the oil yield significantly decreased. The decline can be attributed to overheating at a high temperature whereby low boiling components of the oil volatilize (i.e., volatile organic compounds and aromatic groups). This result means that thermal cracking happened giving way for volatilization to occur. At the maximum time (4 h) and low temperature (120 °C), the yield was higher mainly because of the gradual extraction of the oil without overheating. At the minimum time (2 h) and minimum temperature (120 °C), the yield is low because gradual extraction happened at a low temperature which requires a longer period to be completed.

3.4 Properties of Chicken Oil at Optimized Conditions

The suggested optimal conditions from the analysis using RSM were verified in the actual runs. The oil yield results of the actual runs were compared to theoretical values and summarized in Table 5.

Table 5. Optimization and Verification of the Oil Yield, pH, and Density

Experiment	Variables		Responses		
	Reaction time, h	Reaction temperature, °C	Yield of oil, wt%	pH	Density, g/L
CCD	2	130	67.55	5.61	900.93
Verification run	2	130	67.80	5.80	893.99

Criteria: *Maximize – % Oil yield; Minimize – Reaction time, Reaction temperature, Density; In range – pH.*

The theoretical best optimum conditions were 130 °C and 2 h with predicted theoretical values of 67.55 wt% oil yield, 5.68 pH, and 900.93 g/L density. Verification runs result obtained 67.80 wt% of oil yield (0.37% error), 5.8 pH (3.39% error) and 893.99 g/L density (0.77% error). This result means that the actual values supported the validity of the generated models with errors less than 5% making the model reliable and appropriate in predicting the values.

Table 6. The FTIR Functional Groups of Chicken Oil Extracted from Waste Chicken Fats

Compound	Wavelength Peak, cm^{-1}		Functional Group
	Range	Actual	
Alkane	2850-3000	2925	C-H stretch
Carbonyl	1670-1820	1743	C=O stretch
Aromatic	1400-1600	1467	C=C stretch
Ether	1000-1300	1165	C-O stretch

The extracted oil at optimized condition underwent FTIR spectral analysis within the range of 1000–4000 cm-1 wavelengths to identify the functional groups. This helped to justify that the extracted oil from chicken fats is good for biodiesel conversion. The functional groups found in extracted oil where identified (Table 6) and the spectral peaks specifying the presence of identified compound like alkane (C-H stretch), carbonyl (C=O stretch), ether (C-O) and aromatic (C=C stretch) compounds are presented in Figure 4.

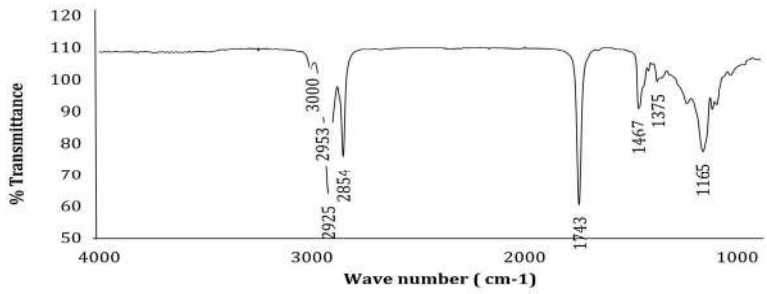

Figure 4. Fourier Transform Infrared Radiation (FTIR) Spectrum of Chicken Oil Extracted from Waste Chicken Fats

The presence of hydroxyl, carbonyl, and aromatic functional groups are good indicators that chicken oil is a good biomass for biodiesel production. The peak at 2850 cm-1 to 3000 cm-1 indicated the presence of C–H bond in the CH3 and CH2 alkanes group. The peak at 1743 cm-1 suggested the presence of carbonyl groups (C=O stretch) like ketones, aldehydes, and ester in the oil. The actual peak of 1467 cm-1 proposed the presence of aromatics in the form of C=C stretch. The FTIR spectrum peaks of 1000–1300 cm-1 suggested the presence of ether. The result of the FTIR spectra indicated the presence of possible compounds present in the oil like alkanes, alkenes, ketones, aldehydes, esters, aromatics, and ether. It implied that extracted oil from chicken fats is a good liquid biofuel needing refining process to improve its quality and components.

3.5 Biodiesel Yield from Chicken Fats Oil

The biodiesel yield ranged between 60%–76% as shown in the result of the experimental runs (Table 7). The result of the transesterification process in converting oil to biodiesel was good and comparable to the previous result with a yield between 67.17%–76.8% by volume (Mata, T. M., Cardoso, N., Ornelas, M., Neves, S., Caetano, 2008).

The percentage yield between 60–76% by volume implied that the oil from the chicken fats could be refined into more useful biofuel product with high product recovery. It is, therefore, a significant advantage in biofuel industry of consuming the sustainable waste fats from poultry dressing plants into biodiesel production.

Table 7. Percentage Yield of the Biodiesel from Chicken Fats Oil

Run	Operating Variable				Response	
	Oil, mL	Reaction time, min	Methanol, vol%	Catalyst loading, wt%	Density, g/mL	% Yield, vol%
1	100	25	35	1.3	0.936	60.00
2	100	25	25	1.7	0.763	69.60
3	100	15	25	1.3	0.947	76.00
4	100	25	25	0.9	0.834	74.40
5	100	25	25	1.3	0.857	76.00
6	100	25	25	1.3	0.809	72.00
7	100	35	25	1.3	0.835	73.60
8	100	25	25	1.3	0.914	68.80
9	100	20	30	1.5	0.875	65.38
10	100	25	25	1.3	0.895	74.40
11	100	30	30	1.5	0.857	68.46
12	100	20	20	1.5	0.889	70.83
13	100	30	20	1.1	0.807	70.00
14	100	25	25	1.3	0.915	69.60
15	100	20	20	1.1	0.894	75.00
16	100	20	30	1.1	0.906	73.85
17	100	25	15	1.3	0.756	63.48
18	100	30	30	1.1	0.851	70.00
19	100	30	20	1.5	0.839	72.50
20	100	25	25	1.3	0.892	74.40

Table 8. ANOVA of the Biodiesel Yield

Source	Sum of Squares	df	Mean Square	F Value	P-Value Prob > F
Model	280.83	5	56.17	12.26	0.0001 [a]
A –Reaction time	4.95	1	4.95	1.08	0.3161 [b]
B –Catalyst loading	28.27	1	28.27	6.17	0.0263 [a]
C –Methanol to oil ratio	19.35	1	19.35	4.22	0.0590 [b]
AB	23.09	1	23.09	5.25	0.0415[a]
C^2	205.17	1	205.17	44.78	<0.0001[a]
Residual	64.15	14	4.58		
Lack of Fit	22.34	9	2.48	0.30	0.9456[b]
Pure Error	41.81	5	8.36		
Cor Total	344.99	19			

a=significant; b= not significant

The statistical analysis through ANOVA (Table 8) showed that the reduced model was significant (p-value=0.0001). The not significant lack of fit probability value (0.9456) implies that the model is reliable and best fitting to predict the biodiesel yield.

3.6 Numerical Modeling of Biodiesel Yield

The quadratic model equation generated by CCD using the Design Expert 7.0 software was found well fitted and can predict the biodiesel percentage yield (Eq. 2).

$$\%Yield = 76.57942 - 2.31962A - 49.11378B + 5.273C + 1.69872\,AB - 0.10986\,C^2 \quad \text{[Eq 2]}$$

where %Yield is the predicted percentage yield of biodiesel; A is the reaction time in minutes; B is the catalyst loading in percentage by volume, and C is the methanol to oil ratio in percent volume by volume.

The capability of reduced quadratic model was justified by the ANOVA result shown in Table 8. The p-value of 0.0001 implies that the model has only 0.01% chance of committing an error in predicting the percentage yield of biodiesel. This outcome means that there is an assurance of 99.99% that the biodiesel can be correctly calculated using Eq 2. The positive coefficients of AB (p-value=0.0415) suggested that the interaction of time and catalyst loading would significantly increase the biodiesel yield when their values are increased. Similarly, the negative coefficients of the variable B (p-value=0.0263) and C2 (p-value=0.0001) indicated the significant decrease of biodiesel yield when the numerical values of catalyst loading and methanol to oil ratio are increased, respectively.

3.7 Effects of Time and Catalyst Loading to Biodiesel Yield

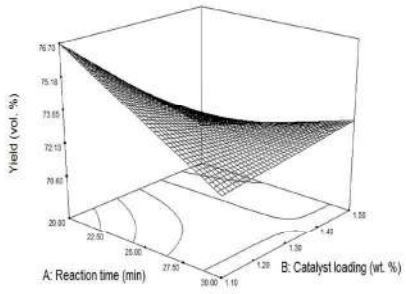

Figure 5. The 3D Response Surface on the Effects of the Operating Variables in the Percentage Yield of Biodiesel through Transesterification Process

In Figure 5, effects of the operating variables were illustrated. It can be observed that biodiesel yield was high (76.70 vol%) at minimum catalyst loading (1.1 wt%) and reaction time (20 min). High biodiesel yield was observed at minimum reaction time because it had less time for liq-

uid components to volatilize via secondary thermal cracking. This outcome is exemplified in the result at maximum reaction time (30 min) with less yield because it had more time for the liquid components to volatilize and proceed to secondary thermal cracking. Catalyst loading did not affect the yield at maximum reaction time (30 min) because its purpose is to hasten or slow down reaction without affecting the biodiesel percentage yield (Daniyan, Dada, & Oladunjoye, 2015). The 3D model illustrated that the catalyst loading did not affect the yield but time significantly do. The result implies that longer reaction time would decrease the yield due to thermal cracking that converts some components of the liquid oil into gaseous products.

3.8 Properties of the Biodiesel at Optimized Conditions

Numerical optimization analysis of the RSM suggested optimum conditions in producing biodiesel considering the operating variables and the chosen responses was done.

Based on the analysis, optimum biodiesel production can be done at 20 min reaction time, 20% methanol to oil ratio by volume, and 1.1% catalyst loading. With these given conditions, the predicted results would be 75.05% by volume of biodiesel yield, 0.87 g/mL density. Actual runs, as shown in Table 9, validated the predicted values with 76.67 % by volume biodiesel yield (2.11% error), and 0.87 g/mL density (1.14% error). The actual runs results proved the reliability of the generated model of predicting the biodiesel yield given the values of the operating variables with a tolerable error of less than 5%.

Table 9. Optimization and Validation to the Properties of Biodiesel Compared to Standards

Experiment	Operating Variable			Response	
	Time (min)	Catalyst (wt. %)	Methanol (vol. %)	Biodiesel (vol. %)	Density (g/ml)
Standards	-	-	-	67.17-76.80	0.86
CCD	20	1.1	20	75.05	0.87
Verification	20	1.1	20	76.67	0.88

Criteria: *Maximize – % yield; Minimize –time, temperature, Catalyst loading, Methanol/oil ratio*

Based on the standard, the density of the produced biodiesel is comparable to the ASTM minimum standards of 0.8 g/mL (Montero, 2011). The biodiesel produced at optimum condition underwent pH analysis, and the value was determined by the pH meter. The actual result of the biodiesel produced in the optimum condition obtained a pH value of 8.27. This result is desirable considering that biodiesel will be fueled to engines made up of metals. Unlike other acidic biodiesel, the engine using this fuel will not suffer corrosion in its pipelines and internal combustion engine parts.

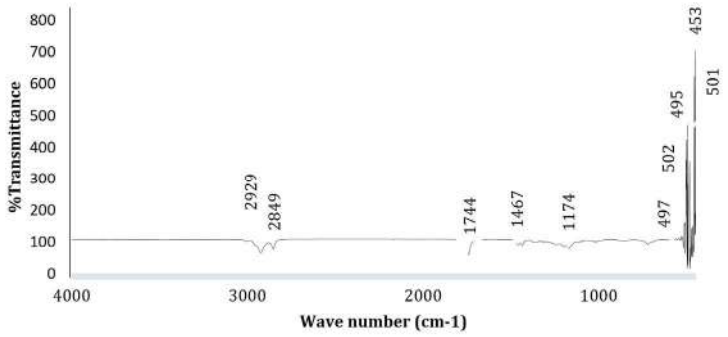

Figure 6. Fourier Transform Infrared Radiation (FTIR) Spectrum of Biodiesel through Transesterification Process

The high heating value of the biodiesel produced at optimum conditions was 39.7 MJ/kg which is within the minimum standards of 35–40 MJ/kg (Arazo, 2014; Montero, 2011; Seta Biofuel Testing, 2016). This outcome implies that the biodiesel from wastes chicken fats contains the needed energy to run an engine using commercial biodiesel nowadays.

The FTIR analysis identified the functional groups present in the liquid product produced at optimum conditions within the wavelength of 450–4000 cm-1. The identified groups were shown in Table 10, and the spectra are best illustrated in Figure 6.

Table 10. FTIR Functional Groups of Biodiesel through Transesterification process

Class of Compound	Wavelength Peak, cm^{-1}		Functional Group
	Range	Actual	
Alkane	2850-3000	2929	C-H stretch
Carbonyl	1670-1820	1744	C=O stretch
Aromatic	1400-1600	1467	C=C stretch
Ether	1000-1300	1174	C-O stretch
Aliphatic iodo	500-600	501	C-I Stretch
Aryl disulfides	430-500	453	S-S Stretch

The FTIR analysis suggested the possible presence of alkane (C–H stretch), carbonyl (C=O stretch), aromatic (C=C stretch), ether (C–O stretch), aliphatic iodo (C–I stretch), and aryl disulfides (S–S stretch).

The peak at 2929 cm-1 is attributed to C–H stretch which represents the presence of alkanes (2850–3000 cm-1) functional group. The spectra showed the bending of methyl, including the gem-dimethyl and tertbutyl. The peak also described that the CH3 and CH2 are present in the C-H bond of the alkane functional group. Carbonyl (C=O stretch) functional group was indicated by the peak at 1670–1820 cm-1 with a high peak at 1744 cm-1. The possible carbonyl groups are esters, ketones, and aldehydes. These proved that the product contained biodiesel component. The aromatic functional group in the wavelength between 1400–1600 cm-1 is particularly observed at peak 1467 cm-1. The presence of C–O stretch (1000–1300 cm-1) is best illustrated in 1174 cm-1 wavelength which confirmed the presence of carboxylic acids, esters, and ethers. The C–I stretch was found in the wavelength peak of 501 cm-1 which rep-

resents the aliphatic iodo compounds. Aryl disulfides in the wavelength between 430–500 cm-1 was particularly illustrated in 453 cm-1 suggesting the presence sulfides containing functional groups (Coates, 2000).

The presence of ester, aldehydes, ketones, carbonyl and other functional groups are good indicators that the resulting product contained the functional groups of biodiesel. The presence of sulfides and iodo compound are expected since the raw material were waste chicken fats from living organisms. Further purification or removal of these halogenated substances will help improve the biodiesel product.

4.0 Conclusions

The following conclusions are drawn based on the results of the present investigations:

1. Wastes chicken fats is a good raw material for oil extraction with percent recovery ranging between 59.36% to 74.10% by weight.

2. The oil yield can be modeled by response surface methodology with high reliability. Particularly, the reduced Two Factor Interval (2FI) best fit in modeling the extraction of oil from chicken fats and found significant with 99.01% accuracy.

3. In oil extraction, long reaction time resulted in high oil yield, but reaction temperature has no significant effect.

4. The extracted chicken oil indicated the presence of alkanes, alkenes, ketones, aldehydes, esters, aromatics, ether and other functional groups.

5. Chicken fats oil can be converted to biodiesel product with notable percent recovery ranging between 60% to 76 % by volume.

6. The biodiesel yield can be modeled through response surface methodology whereby 99.99% of the variability can be explained by the generated reduced quadratic model.

7. High methanol to oil ratio affirmatively increase the biodiesel yield but long reaction time would result otherwise.

8. FTIR spectra proved the production of biodiesel from chicken fats oil considering the presence of esters, ketones, aldehydes, alkanes, carbonyl, aromatic, and ether.

9. The biodiesel product has the needed energy to run engines with a high heating value of 39.7 MJ/kg, comparable to the biodiesel minimum ASTM standard of 35 to 40MJ/kg.

10. One ton of dried chicken fats can produce 667 L bio-oil and 573 L biodiesel.

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