International Research Journal of Environment Sciences ISSN 2319–1414
Vol. 3(6), 67-74, June (2014) Int. Res. J. Environment Sci.

Quantification of fat in Chicken's feather Meal for its conversion into Biodiesel

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Available online at: www.isca.in, www.isca.me
Received 22nd May 2014, revised 11th June 2014, accepted 21st June 2014

Abstract

Increased demand of fuel due to rapid increment in urbanization has led to the depletion of non-renewable resources. To combat this situation and reduce the negative environmental consequences of fossil fuels, alternative biofuels from renewable resources have been a focus of intensive research. Biodiesels; a diesel replacement, are derived usually from renewable feedstock like vegetable oils and animal fats. However, different animal based waste products can also be utilized to produce biodiesels, which also has an advantage of minimizing waste and reducing environmental pollution. Therefore, the present study is aimed to introduce new, environmental friendly and cost-effective processes of biodiesel production through fat extracted from feather meal by transesterification process. Different parameters of feather meal (i.e. extracted fat and recovered fat) were investigated to show their potential of conversion into biodiesel. Moreover, the fuel properties like acid value, relative density, kinematic viscosity, pH, cloud point, water and sediment test, methanol test, visibility and emulsification is also investigated to check out their viability against the ASTM D6751 and EN 14214 biodiesel specifications. The amount of extracted fat lied between 381.5g to 403.25g from 1kg. Acid value found out by volumetric titration had values 0.43mg KOH.g-1 to 0.48mg KOH.g-1 whereas the viscosity found out by viscometer ranged between 4.35mm2/s to 4.65mm2/s. The results thus showed that a low cost fuel with recommended properties is produced through cheap and viable approach. Now, it's the government's responsibility to pay attention towards new technological innovations to overcome the global fuel crisis.

Keywords: Non-renewable resources, biodiesel, feather meal, transesterification, ASTM standards.

Introduction

Fossils drive energy resources such as petroleum; coal and natural gas have played a significant role in the economic development of human beings. However, these energy resources are nonrenewable and are projected to be exhausted in the near future due to over extraction and utilization. Moreover, they are raising several environmental problems such as rising greenhouse gases and carbon dioxide levels in the atmosphere[1]. Therefore, due to escalating demands for energy and elevated petroleum cost coupled with scarcity of known petroleum reserves has prompted an urgency to develop or employing modern technologies and efficient bioenergy conversion processes, which are becoming competitive cost-wise with fossil fuels[2] and also to meet energy challenges of the millennium[3].

Biodiesel, a replacement of petroleum diesel, derived from biological sources received increasing attention globally as it lessens the dependence on petroleum products, the energy crisis and environmental pollution[4]. ASTM defined biodiesel as "a fuel composed of mono alkyl esters of long-chain fatty acids derived from renewable vegetable oils or animal fats"[5]. There are four primary ways by which biodiesel is produced: thermal cracking (pyrolysis), direct use and blending, microemulsions, and transesterification. However transesterification reaction is the most commonly used method[6] which is basically a classic chemical process used to convert the vegetable oils and animal fats into biodiesel. It generally involves a three step reversible reaction in which initial triglycerides yields a mixture of fatty acid methyl ester (FAME) and glycerol in the presence of three catalysts: acid, alkali and enzyme[7].

Various raw materials including plant oils, animal fats, microbial mass and other waste materials are used for biodiesel production[8]. The most popular plants feedstock used are jatropha, soybean, safflower, coconut, canola, cottonseed, karanj, groundnut, palm, olive, peanut, rapeseed, and sunflower[9] whereas the most popular animal feedstock are beef tallow, chicken fat, yellow grease, lard, hemp oil, lamb fat, waste cooking oil and the greasy by-product from omega-3 fatty acid production[10].

Currently, most of the biodiesel production is achieved using vegetable oils as the chief starting material. However, the main obstacle in using plant oils as feedstock is that they are non-economical and non-feasible due to the prohibitive cost and the fact that they compete with the food market. Consequently, novel feedstocks such as inedible animal fats are thought to be the most suitable and cheapest source as it reduces animal waste disposal costs and environmental impacts simultaneously[11]. Also from last several years, world's meat production has increased significantly and in 2010 it has reached 237.7 million tons especially the consumption of poultry meat increased significantly due to relatively low price and also it is not forbidden by any religion[12].

Therefore, the large-scale production and consumption of food animals generated massive residues from animal processing-plants and creating enormous waste disposal problem for the slaughterhouse that could be used in the processing of alternate fuel, reduces animal waste disposal costs and environmental impacts simultaneously[13]. Chicken fat extracted from chicken's waste is shown as a promising feedstock for biodiesel production because as unlike conventional biofuel sources such as corn, vegetable oil and sugar cane it is not in demand for human food. Therefore, the present study is designed to emphasize on processing and characterization of biodiesel from poultry waste (i.e. chicken's feather meal) by the process of transesterification and then characterized its fuel properties according to standard test methods.

Material and Methods

Materials: Commercially available feather meal, Potassium hydroxide (KOH), Methanol (HPLC grade), Hydrochloric acid, phenolphthalein, Diethyl ether and ethanol.

Steps Involved in the Experimental Design of Processing the Biodiesel: Extraction of fat from feather meal: Weighed about 75g of feather meal sample and stirred it continuously with 1000ml of distilled water at 90^oC for about 20 min on hot plate. By doing this, the absorbed fat melted and floated on the surface of water layer. Then removed the beaker from the hot plate and let the sample cooled down at room temperature.

Purification of fat of feather meal: The top layer of the fat formed on the water layer surface was then purified by centrifuged it at 15^0C for about 20min. After the centrifugation, the obtained fat content was collected in a separate beaker.

Saponification: The collected fat was then uniformly mixed with 1% KOH solution and centrifuged for about 15min to remove the free fatty acid in the form of soap. The obtained purified fat was then used for transesterification process.

Transesterification of fat of feather meal: The transesterification process was conducted as the purified fat was first heated at 70^oC for about 20min so that the traces of water present in it were removed. Then took 150g of fat and added 200ml of methanol and 200ml of 1%wt KOH and placed it on shaking incubator while setting the two parameters i.e. temperature and stirring rate. Three different temperatures were considered i.e. 30^0C, 40^0C, 60^0C as well as three stirring rates: 200rpm, 300rpm, 400rpm. This reaction was completed within 1.5 hrs.

Separation of biodiesel and glycerol: The above reaction mixture was refluxed at 70^0C for about 1hr while placed it in a Soxhlet apparatus. Then the reaction mixture was placed in a separating funnel and allowed it to cool at room temperature overnight for the separation of biodiesel and glycerol. The top layer of biodiesel was afterward placed in a rotary evaporator and subjected to low pressure conditions at 65ºC to facilitate the methanol extraction.

Biodiesel purification: After extracting the excess methanol, biodiesel suffered a washing process to remove the residual catalyst. First, 75mL of a diluted HCL solution (0.2%) was added to the biodiesel, then, the same amount of distilled water was repeatedly used to wash the biodiesel and ensure total removal of acid/base and salts. After this washing process, biodiesel was heated at 90ºC to evaporate the water present. Finally, the purified product was obtained.

Assessment of Biodiesel Quality: To quantify the amount of fat in feather meal samples and to ensure the quality of biodiesel, different quality parameters were carried out according to American Society of Testing and Materials and European standards (ASTM D6751, 2004 and EN 14214, 2009) [14-15].

Acid value (ASTM D664): Acid value was determined by using volumetric titration method. The test portion was first dissolved in a solvent (diethyl ether and ethanol at 70ºC) and titrated with a 0.1M solution of potassium hydroxide while using phenolphthalein as an indicator. The acid value of biodiesel must be <0.50mg $KOH.g^{-1}$ according to the European biodiesel standard ISO 14214[14].

Kinematic viscosity (ASTM D445): A test sample was placed first inside a calibrated viscometer, which then placed inside viscosity bath which set at constant temperature i.e. 40°C. Once in the bath, the time it took for a fixed volume of liquid to flow under gravity through the capillary of the viscometer was measured. Using that particular time and the calibration constant of the viscometer, the kinematic viscosity of test sample was calculated. The acceptable viscosity range described by ASTM D6751 or EN 14214 for biodiesel is $3.5\text{-}5.9mm^2s^{-1}$.[14]

Relative Density/Specific Gravity (ASTM D1298): Relative density is determined with the use of a hydrometer. This test was performed as fill the graduated cylinder of about 75-89% with the biodiesel being tested. Then placed the hydrometer into the liquid and giving it a few gentle swirls to remove any bubbles clinging to the bottom. Do not let the hydrometer touch the sides or bottom of the cylinder. It would reach a floating point where it was suspended in the liquid. Allowed the hydrometer to settle and read the measurement scale on the side of the hydrometer. The mark the biodiesel surface reaches on the hydrometer scale was its specific gravity. EN 14214 limits for relative density is $900kg/m^3$.[14]

pH: pH was determined by using a Digital pH meter or litmus paper. The pH meter was calibrated first as adjusting its neutral pH using distilled water then dipped its probe in biodiesel sample. However, make sure that probe did not touch the walls or edge of the beaker and stayed in a solution for few minutes. Biodiesel should have a pH of 7 [14].

Water and Sediment Test (ASTM D2709): To determine the water and sediment, first 100mL sample was taken in two identical centrifuged tubes and centrifuged at 800rpm centrifugal force at room temperature. After 10min, the tubes were removed and the amount of water and sediment present at the bottom was read off directly (down to 0.005mL). EN 14214 limits for water content is 500mg/kg[14].

Methanol test: Dissolve 25ml biodiesel and 225ml methanol. If the biodiesel is fully soluble in the methanol, forming a clear bright phase it is of good quality[14].

Emulsification: Combined equal part of biodiesel and water samples and shacked vigorously. If the resulting mixture separated quickly and the biodiesel phase on top appeared clear and bright whereas the water phase at the bottom appeared clear and free of debris, the biodiesel is of good quality[14].

Cloud Point (ASTM D2500): The cloud point of the fuel was determined by visually inspecting for a haze to become visible when it is cooled (in a refrigerator, for example)[14].

Visibility: Biodiesel should be clear, translucent with the golden or amber color[14].

Results and Discussion

Figure-1 demonstrates the synthesis of biodiesel from the feather meal by the action of transesterification while using methanol and KOH as catalyst. Two different kinds of feather meals depending on type of feed source i.e. feather meal given to egg laying poultry and the feather meal which was given to growth broilers were taken commercially. The total fat content of the feather meal samples were determined, and has been reported in table-1, prior to synthesize them into biodiesel in order to assess whether they have enough potential to convert into biodiesel. First, the amount of extracted fat from feather meal was evaluated whose values ranged between 381.5g to 403.25g. The high amount of extracted fat is achieved from feather meal sample that is given to broilers i.e. 403.25g than that of egg laying because it has high fat content as well as contains 20%crude protein and 2800Kcal/Kg energy[16].

Afterward, Recovered fat was obtained from extracted fat by the process of saponification as to saponify extracted fat and reduced its FFA level into desired level[17]. The amount of recovered fat lied between 331.62g to 354.62g. Subsequently, that recovered fat was used further for the synthesis of biodiesel. The quality of biodiesel was also assessed by determining its various quality parameters in accordance with specified ASTM D6751 and EN 14214 methods and has been reported in table-2.

Table-1
Quantification of fat from feather meals

Fat content	Egg laying	Growth broiler
Extracted fat obtained from feather meal (g)	381.5(± 0.707) – 385.5(± 1.414)	401.75 (± 2.475) - 403.25 (± 1.768)
Recovered fat obtained after saponification (g)	331.62(± 0.884) - 333.62 (± 0.884)	342.87 (± 0.884) - 354.62 (± 1.591)

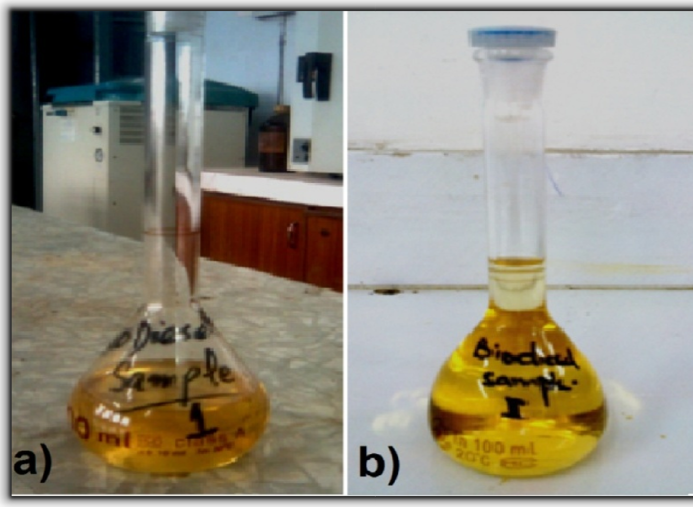

Figure-1
a) Biodiesel processed from egg-laying hen's feather meal sample, b) Biodiesel processed from broiler hen's feather meal sample

Acid value of biodiesel was measured by volumetric titration and its values were laid in between the 0.43mg $KOH.g^{-1}$ to 0.48mg $KOH.g^{-1}$ as shown in figure-2. According to European biodiesel standard ISO 14214 the acid value must be below 0.50mg KOH g^{-1}. Acid numbers will become elevated if the fuel ages, if the fuel is not properly manufactured or if there is presence of high FFA in biodiesel sample The calculated acid value of biodiesel meet the European biodiesel standard ISO 14214 that is its value must be <0.50mg $KOH.g^{-1}$ [18].

The kinematic viscosity of biodiesel was determined by using Viscometer and is depicted in Figure-3. It is important to determine viscosity because high viscosity leads to negative impacts on fuel injector performance and increased exhaust smoke[19]. Viscosity increases with the higher degree of saturation and the presence of free fatty acids (FFA) traces in a sample[20]. Therefore, high value of kinematic viscosity indicates that it contains relatively high amount of FFA. In the present study the values of kinematic viscosity ranged between 4.35mm^2/s to 4.65mm^2/s which demonstrated that they fall under the acceptable viscosity range for biodiesel according to ASTM D6751 or EN 14214 standards that is 3.5-5.9mm^2/s[21].

The values of Relative density of biodiesel samples were taken by using hydrometer at a constant specified temperature (usually 4^0C). The value of Relative density of biodiesel ranged between 874.5kg/m^3 to 881kg/m^3 and is shown in figure-4. Density of biodiesel basically depends on its purity and fatty acid composition. Density increases with increasing number of double bonds whereas decreasing chain length, explaining fuel is rich in unsaturated compounds. On the other hand, density can be decreased by the presence of low-density contaminants, such as methanol. In European biodiesel standard EN 14214 the limit for relative density of biodiesel given is 900kg/m^3 [16].

Table-2
ASTM Analysis of Biodiesel processed from Chicken's feather meals

Test	Test method	ASTM D6751and EN 14214 limits	Results
Acid value (mgKOH.g^{-1})	ASTM D664	< 0.50 mgKOH.g-1	0.43mg -0.48mg
Kinematic viscosity (mm^{2}s^{-1})	ASTM D445	3.5-5.9 mm^{2}s^{-1}	4.35-4.65
Relative Density/ Specific Gravity (kg/m^3)	ASTM D1298	upto 900 kg/m^3	874.5-881
Water and Sediment Test (mg/kg)	ASTM D2709	upto 500mg/kg	445mg/kg
Cloud Point (^{0}C)	ASTM D2500	N/A	4^{o}C
pH	-----------	7	7.44-7.72
Methanol test	-----------	N/A	Biodiesel completely mixed in methanol
Emulsification	-----------	N/A	Biodiesel float on surface and water at bottom
Visibility	-----------	Amber	Amber-amber brown

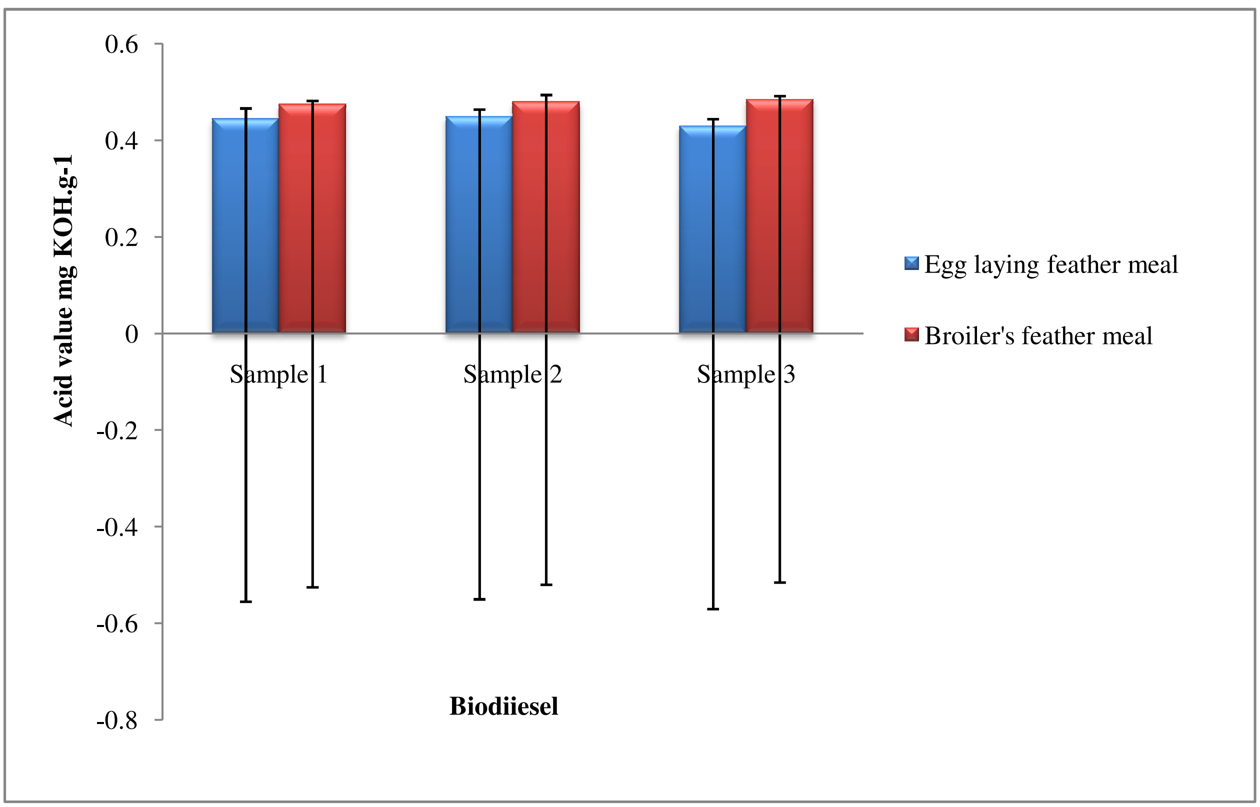

Figure-2
Comparison of Acid value (mg KOH.g^{-1}) of biodiesel processed from feather meal samples given to Egg laying and Broilers hen

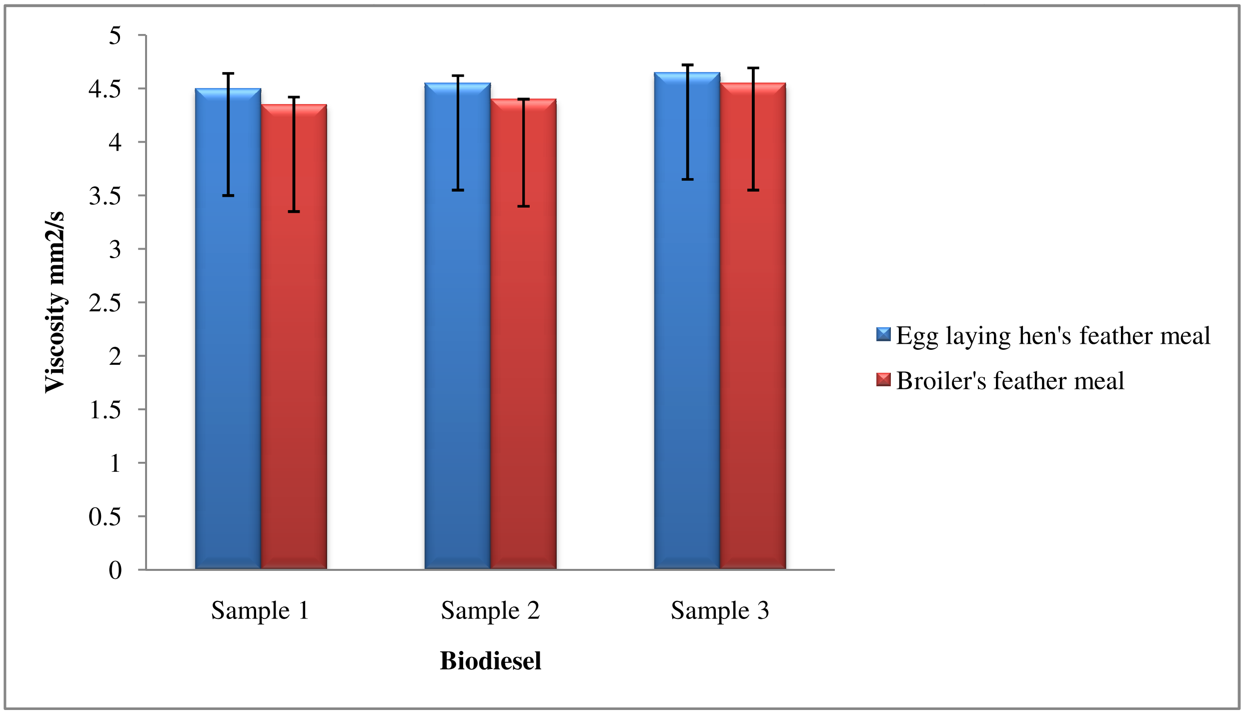

Figure-3
Comparison of values of Relative density (kg/m^3) of biodiesel processed from feather meal samples given to Egg laying and Broilers hen

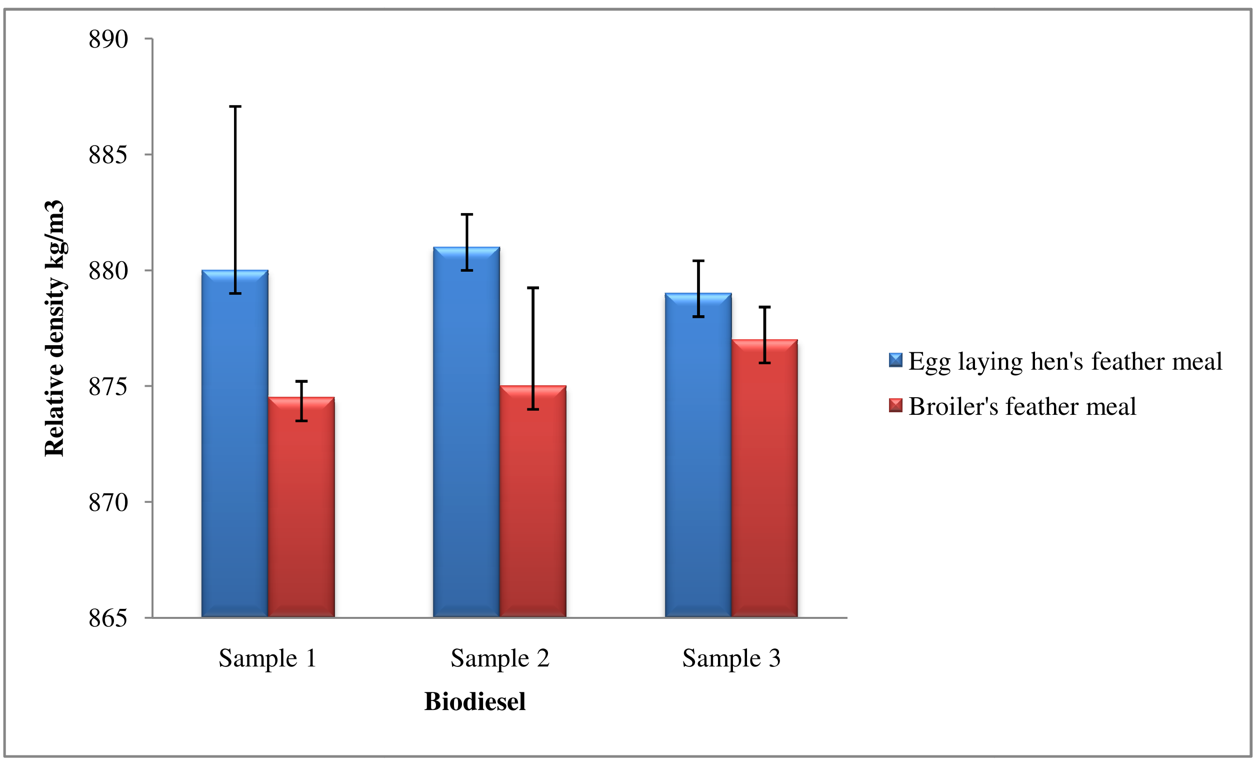

Figure-4
Comparison of values of Viscosity (mm^2/s) of biodiesel processed from feather meal samples given to Egg laying and Broilers hen

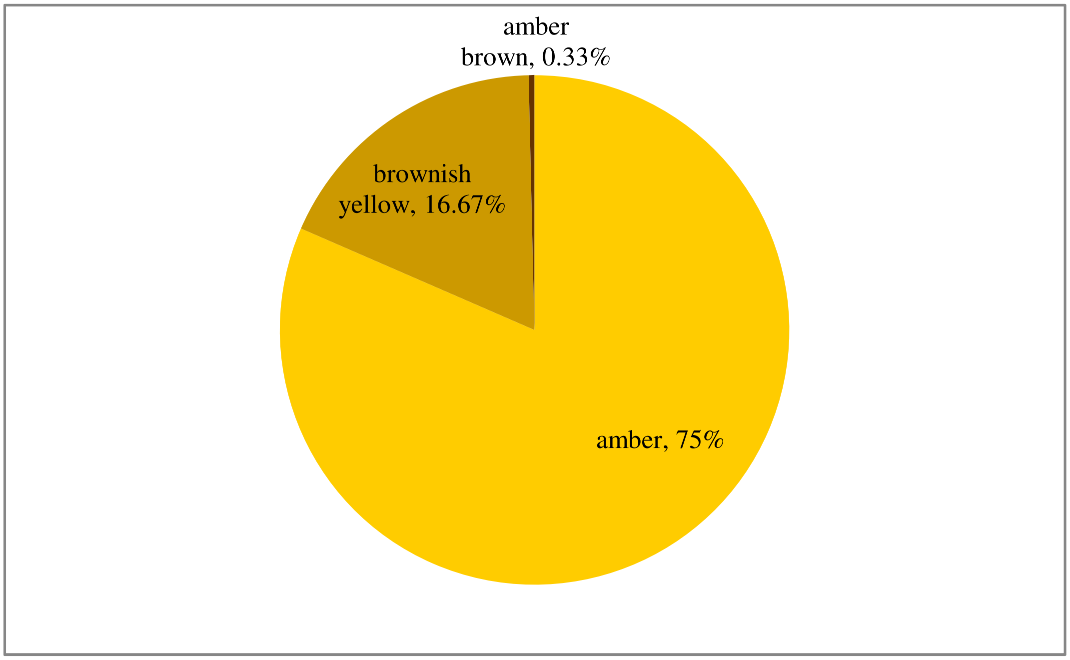

Figure-5
Pie chart showing the results of Visibility (%) of the product biodiesel processed from feather meal samples given to Egg laying and Broilers hen

pH test was conducted to find out the value of pH of biodiesel samples. Thus the value of biodiesel ranged between 7.44 to 7.72. According to ASTM standards washed biodiesel should have a pH 7. Slight deviation in pH readings from the standard value were happened because of the presence of traces of water in the product biodiesel that may left in washing process thus increases its pH. However all observed values were nearer to standard pH value for biodiesel and just slight deviations were observed[22].

Fuel should be bright, clear in appearance and free from water and sediment because excess water in it can leads corrosion and provides an environment for microbial growth. Moreover, the presence of these materials generally indicates poor fuel handling practices. Water and sediment test of product biodiesel were calculated by centrifugation process. The obtained results were comparable and meet with EN 14214 limits for water content that is 500mg/kg[23].

The methanol test was conducted by dissolving 25ml of biodiesel sample into 225ml of methanol. All the samples showed positive results indicating that the product biodiesel when mixed with methanol, fully and immediately dissolved in it forming a clear bright phase. This is because when biodiesel was refluxed in Soxhlet apparatus and in rotary evaporator, extraction of excess methanol and removal of suspended particles were taken place thus the biodiesel formed is of good quality and having no suspended particles[15].

Emulsification test was conducted as by combining equal parts of biodiesel and water (eg, 1ml/1ml) and shacked vigorously. All the samples shown positive results and meet with ASTM standards i.e. biodiesel float on the surface and clear water having no impurity settled at the bottom. This is because the washing of biodiesel with HCL and water was done properly and the end product obtained was free of soap or containing no other impurity thus indicating that the product biodiesel formed was of good quality[14].

The Cloud point is used to describe the low temperature operability of diesel fuel. The cloud point of the product biodiesel samples were seen when they are placed in a refrigerator at 4^{o}C. The cloud point observed of the product biodiesel is considered in appropriate range because limit for a cloud point is not given in ASTM standards due to the strongly varying weather conditions of each country. The maximum cloud point defined by ASTM D975 is the temperature that shall be equal to or lower than the tenth percentile lowest ambient temperature in that geographical area and seasonal timeframe. Each country can modify this specification based on their national meteorological data[20].

Visibility of product biodiesel is illustrated by Pie chart as shown in figure 5. 75% of the total samples showed that biodiesel formed was of amber in color. 16.67% indicating the color was brownish yellow while the rest 0.33% showed that the product formed is of amber brown in color. Golden or amber color of biodiesel was observed because chicken fat usually has some golden or transparent yellow color. Slight variations in color were observed from the standard color as prescribed in ASTM, 2004 standards either due to the difference in nutrient composition of feather meal samples or some personal error in maintaining temperature or in the amount of alcohol or catalyst addition. Biodiesel should be clear, translucent with the golden or amber color according to ASTM standards[24].

Conclusion

The present study concluded that the chicken feather meal have enough potential to process them into biodiesel because of high energy, fat composition and crude protein values. Fat extracted from the feather meal sample was processed into biodiesel by the process of transesterification after the significant reduction of free fatty acid (FFA) by saponification. As well as the quality of obtained biodiesel samples were evaluated according to EN 14214 and ASTM D6751 standards which presented that all the measured parameters results were in acceptable range. However the biodiesel may also blended with petroleum diesel to further increase in efficiency. Therefore, in the current situation of energy crisis and finite petroleum reserves, we can reduce the burden on finite petroleum reserve by producing biodiesel from a new, alternative and low cost feedstock like chicken's feather meal which also reduces the burden and cost of poultry waste disposal.

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