A Comparative Analysis of Biodiesel Properties Derived from Meat Stall Wastes through Optimized Parameters

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Abstract. Biodiesel is considered as alternative green fuels that can be used in Internal Combustion engines as a replacement fuel for conventional diesel. Biodiesel is extracted from vegetable and animal sources which are rich in triglycerides. In this work, an attempt has been made to obtain and characterize the biodiesel from animal wastes such as chicken skin and pig tallow which are available in abundance and at an economical cost within the authors’ geographical location. Initially, the feedstock is decontaminated and subjected to conventional heating to convert it into fatty oil. Heating is carried out at different temperatures and for varying time to find out the optimal combination of time and temperature, which would result in maximum fat yield. The fatty oil is then subjected to the trans-esterification process with methyl alcohol in the presence of a catalyst to extract crude biodiesel. A de-canter funnel is used to separate the glycerine and biodiesel from the crude extract. The extracted biodiesel is mixed in different volume percentages with conventional diesel, and various thermochemical properties were evaluated as per ASTM standards. The test result indicated that the properties of the biodiesel blends were well within the limits as prescribed by ASTM standards.

1. Introduction
The last few decades have witnessed a huge transformation in the life of a common person due to the revolution in the growth of technology, in all sectors of industries. The lifestyle changes, particularly in developing countries, resulted in higher demands for industries, and higher energy requirements. The growing energy requirement of these industries is usually satisfied using petroleum distillates [1]. As per a study, it is said that the growth of a country through social and economic status is highly dependent on the availability and optimum utilization of its energy resources [2]. In general, any energy requirement of the industries in any country is largely fulfilled by fossil fuels, which include the burning of coal, petroleum products, and natural gas [3, 4].

Fossil fuels are categorized under conventional or non-renewable energy sources as they require more than thousands of years to be restored. From an economic point of view, these conventional energy sources are becoming expensive due to limited availability and high demands, which will ultimately result in increased cost of production in industries [5, 6]. Also, the burning of these fossil fuels releases carbon dioxide into the atmosphere to cause environmental pollution, the greenhouse
effect, and one of the reasons for global warming. These disadvantages of conventional fuels have resulted in the discovery and use of non-conventional energy sources such as solar energy, hydro energy, wind, and tidal sources, which are considered green energy sources as they do not cause much environmental pollution and also they are renewable energy sources [7, 8]. Biodegradable, which is an alternative energy source similar to conventional petrochemical diesel and unlike petrochemical diesel, which can be extracted directly from vegetable oil and animal fats. Unlike conventional petrochemical diesel, biodiesel is environmentally friendly fuel as it is low in toxic, biodegradable, emits less sulfur when burned. Biodegradable can be extracted from both edible and non-edible oils such as palm, peanut, sunflower, jatropha, castor oil, cottonseed oil, etc. [9, 10].

The disadvantage of utilizing cooking oils for biodiesel production may directly affect the food chain, influence the scarcity of cooking oil, and contribute to economic inflation [11]. Besides, using vegetable oils as the source of biodiesel production may pose some challenges such as procurement, cost, transportation, and storage of feedstock, which inhibit the use of fresh vegetable oils [12, 13]. In recent years, animal waste fats, which are composed of “triglycerides” have been tried and used for biodiesel production. Animal fats are generally composed of triglycerides, some form of proteins, water, different minerals, and unwanted impurities. Compared to edible oils, animal waste fats are available in abundance and usually generated from animal slaughterhouses, restaurant wastes, veterinary services, food farming industries, and so on. Animal fats from these sources are not suitable for human consumption, and hence they are either used as low-cost feeding for animals or disposed of as a waste product [14, 15]. The biodiesel extracted from vegetable oils, plant-based sources, and animal fats can be readily used in the existing diesel engines without much engine modifications as it is primarily composed of fatty acid methyl ester obtained from “Trans-esterification” triglycerides of the feedstock [16, 17].

The resulting biodiesel is similar to the petrochemical diesel, and both can be blended in any proportions without many difficulties. Given these characteristics and attractive properties of biodiesel, the extraction of biodiesel from different renewable sources has become a topic of interest [18]. Many experiments and researches are going on in the field of production of biodiesel from animal fats due to the availability of animal feedstock in abundance. Animal fats such as chicken wastes, mutton fats, beef, and pork tallow, duck tallow, pork skin, and pork lard are a few of the many available animal-based feedstocks, which are used for biodiesel production [19]. They produced biodiesel and verified the quality of it against the petrochemical diesel as per the standards of the National Agency of Petroleum. A blend of beef tallow and soybean oil has been used for biodiesel production using sulfonated polystyrene compounds as catalysts [20]. The production of beef tallow into biodiesel and its comparison with the biodiesel produced from vegetable oils is studied and reported by Nelson et al., the study was conducted based on the parameters such as availability of raw materials, the efficiency of biodiesel produced, and the economy of conversion [21].

Similarly, a study conducted by Chakraborthy et al. [22] reports the conversion of goat tallow into biodiesel using infrared radiation assisted reactor, and they reported a substantial reduction in conversion time compared to the conventional process. Some studies also report the use of fish oil for biodiesel production and they compared the properties of fish oil biodiesel with cooking oil biodiesel. Beef tallow, chicken skin, and pork lard were used for the production of biodiesel, and different purification methods [23] and they concluded that animal fats could be considered as a potential source for biodiesel production. From the review of literature, it can be summarized that in today’s energy requirements, biodiesel can be one of the promising alternatives to conventional energy sources. The biodiesel extracted from edible oil and other plant-based feedstock is commercially produced and used as a blend with petrochemical diesel. But, the plant-based feedstock for biodiesel has its disadvantages, such as causing inflation and other economic concerns [24]. Hence it is required to look at the alternative source of feedstock for biodiesel production. Animal-based sources are one of the alternatives that have the potential to be used as feedstock for biodiesel production as they are cheap and available in abundance. The research is undertaken by many researchers worldwide to analyze and characterize different animal-based feedstock for biodiesel production. But, as the geographic location varies, the availability of feedstock sources also differs [25]. As per the geographic location and culture, the food habits of the population varies, and similarly, the animal
waste generated also changes. Because of these reasons, the current work is undertaken to analyze and characterize the animal feedstock available in the authors' geographic location [26]. The non-biodegradable waste such as waste plastics are also can consider and processed into biodiesel by adopting the pyrolysis process, and obtained fuels are characterized and tested in a diesel engine [27].

In this current work waste chicken skin, and pig tallow are considered as a potential source of feedstock for biodiesel production. The economical and widely used extraction method, i.e. Transesterification process is used for the conversion of animal fats into biodiesel. The extracted biodiesel is then subjected to different tests to find its thermochemical properties and to test its compatibility with conventional petrochemical diesel.

2. Materials and Methods

2.1. Materials

The present study is carried out to extract biodiesel from animal wastes which are geographically available in abundance from an economic point of view. For this purpose, waste chicken skin and pig tallow were selected as feedstock for the biodiesel production process. Chicken skin and pig tallow were procured from a local slaughterhouse. From the initial study, it was found within the Author’s geographical location; a local slaughterhouse can produce around 20-25 kg of chicken skin and pig tallow per day, which is generally considered as a waste product.

2.2. Experimental Method

The biodiesel extraction from chicken skin and pig tallow involves a series of different procedures that are carried out sequentially on the feedstock. The feedstock gathered from the source is initially cleaned with water to remove the contaminants from it. Each 1 kg of feedstock is agitated with 5L of filtered water for 10 minutes. This washing cycle is repeated 3-4 times until all the dust, and other impurities are washed out thoroughly from the feedstock.

2.3. Fat Extraction by Conventional Heating

The separation of “fat” from the feedstock is carried out by following the conventional heating method. Both the feedstock, chicken skin, and pig tallow are subjected to the heating process separately to extract the fat. One kilogram of feedstock (chicken skin and pig tallow) and three liters of water were added in a heating pot and kept on a conventional heater. The mixture of feedstock and water is then heated to a temperature above 50˚C for a specific duration of time until the fat tissue of the feedstock breakdown and oil is separated. The heating was carried out at different temperatures and for varying durations of time and the same is shown in table 1.

| Table 1. Parameters of Fat Extraction by Heating |
|-----------------------------------------------|
| Temperature, ˚C | 60 | 70 | 80 | 90 | 100 |
| Time, Minutes  | 20 | 25 | 30 | 35 | 40 |

2.4. Purification of Extracted Fat

At specific temperature and heating duration, the fat breaks down from the feedstock, and the “fat” separate from the fat tissues inside the pot. Then the pot is rested for 24 hours until all the water, and fat oil is separated. The oil is collected out and passed through filter papers to further purify it from the external wastes such as skin and fat tissue. The purified oil is again rested for 24 hours to separate any remaining water content, and pure oil is collected out.

2.5. Conversion of fat into biodiesel by the trans-esterification process

Trans-esterification is a chemical process where the triglycerides are reacted with short-chain alcohols such as ethanol and methanol using an acid or base catalyst to exchange the organic group of the triglycerides with the organic group of methanol or ethanol. In the present study, this trans-esterification method was used to convert the triglycerides extracted from chicken skin and pig tallow into biodiesel.
Figure 1. Trans-esterification of chicken skin into biodiesel

Trans-esterification of chicken skin into biodiesel: The chicken skin feedstock is cleaned and heated to get triglycerides in the form of the fat oil as per the procedure explained earlier. The separated oil from the chicken skin is passed through the filter paper to purify it from remains of skin and other impurities further. The purified oil is then subjected to the trans-esterification process to convert it into biodiesel, as shown in figure 1. A measured quantity of chicken fat oil (500ml) is transferred into a three-neck flask and heated gradually until the temperature of the oil reaches to 80˚C. The temperature is monitored using a thermometer dipped inside the oil through the three-neck flask. When the oil temperature reaches 80˚C, 125ml of methane alcohol and 3gm of sodium hydroxide (NaOH) is added gradually to the oil, and the mixture is continuously stirred. NaOH acts as a catalyst, and the methyl alcohol acts as a driver to start the trans-esterification reaction. A condensing system is used while heating the mixture to prevent any evaporation of methyl alcohol out of the trans-esterification setup.

The system is heated and continuously stirred for 2 hours after adding the methyl alcohol and NaOH. During this period the solution temperature is monitored continuously and maintained at 80˚C. After the reaction time is complete, it can be observed that the chicken fat oil is converted into crude biodiesel which is again a mixture of biodiesel and glycerine. The crude biodiesel is then transferred into a de-canter funnel for the separation process. The solution is allowed to rest for about 5 hours in the de-canter funnel at room temperature. Gradually the biodiesel, NaOH, and glycerin are separated in the de-canter funnel. The glycerine is collected at the bottom of the de-canter funnel whereas the pure biodiesel settles above it. The glycerine is then removed from the funnel, and pure biodiesel is collected out for the further process.

Trans-esterification of Pig Tallow into biodiesel: Similar to the chicken skin trans-esterification process, the feedstock in the form of pig tallow is cleaned and heated to get triglyceride fat oil as per the procedure explained earlier. The separated oil from the pig tallow is purified by passing it through the filter papers. The purified oil is then subjected to the trans-esterification process to convert it into biodiesel, as shown in figure 2.
Figure 2. Trans-esterification of pig tallow into biodiesel.

As explained earlier, the fat oil from pig tallow (500ml) is transferred into a three-neck flask and heated up to 80°C. A solution of Potassium Hydroxide (3gm) and methyl alcohol (125ml) is mixed with the heated fat oil and continuously stirred in the three-neck flask. The process is continued for 2 hours, and the temperature is maintained at 80°C. After the reaction period is complete, the crude biodiesel is transferred to the de-canter funnel for the separation process and allowed to rest for 5 hours. The glycerine is settled at the bottom of the funnel and biodiesel gets collected at the top. The biodiesel is collected out from the de-canter funnel for further processing.

3. Results and Discussion

3.1. Fat Extraction from the Feedstock

Figure 3. Graph showing the fat oil yield from heating (a) Chicken Skin and (b) Pig Tallow for different heating durations at different temperatures

The initial stage of biodiesel extraction from animal waste is to convert animal waste into triglycerides, i.e. in common words “fat.” This is achieved through the heating process. The fat oil extraction from the chicken skin and pig tallow are explained in detail earlier. The heating process is carried out for different durations of time at different temperatures to find out the optimum time and temperature that would yield the maximum fat oil from the feedstock, and these parameters are shown in Table 1.
As per the selected heating parameters, the experiments were conducted by individually heating the chicken skin and pig tallow for different durations at different temperatures. The full factorial experimental design was framed by changing one variable at a time for each trial of the experiment. A total of 25 experiments were conducted twice as per the experimental design, and the oil yield is measured after each experiment trial. The average results of the two trials are considered as the final fat oil yield, and the results are noted down.

It was found from the experiments that the oil yield varies with change in the heating time and temperature. Figures 3(a) and 3(b) indicate the graphs of the fat oil yield from heating chicken skin and pig tallow for different heating durations at different temperatures respectively. The optimum combination of heating temperature and heating time which would give maximum fat yield from chicken skin and pig tallow are indicated in Table 2.

### Table 2. The Optimum Combination of Temperature and Time for Maximum Fat Yield.

|                          | Chicken Skin (per kg) | Pig Tallow (per kg) |
|--------------------------|-----------------------|---------------------|
| Optimum Temperature, °C  | 80                    | 80                  |
| Optimum Time, minutes    | 30                    | 25                  |
| Fat yield, ml            | 460                   | 890                 |

### 3.2. Biodiesel Blends

#### Table 3. Biodiesel Blends and Their Nomenclatures

| Biodiesel Nomenclature | Blend (% by Volume) |
|------------------------|---------------------|
|                        | Chicken Skin, %     | Pig Tallow, %       | Diesel, %     |
| CP0D100                | 00                  | 00                  | 100           |
| C100D0                 | 100                 | 00                  | 00            |
| C10D90                 | 10                  | 00                  | 90            |
| C20D80                 | 20                  | 00                  | 80            |
| C30D70                 | 30                  | 00                  | 70            |
| C40D60                 | 40                  | 00                  | 60            |
| C50D50                 | 50                  | 00                  | 50            |
| P100D0                 | 00                  | 100                 | 00            |
| P10D90                 | 00                  | 10                  | 90            |
| P20D80                 | 00                  | 20                  | 80            |
| P30D70                 | 00                  | 30                  | 70            |
| P40D60                 | 00                  | 40                  | 60            |
| P50D50                 | 00                  | 50                  | 50            |
| C05P05D90              | 05                  | 05                  | 90            |
| C10P10D80              | 10                  | 10                  | 80            |
| C20P20D60              | 20                  | 20                  | 60            |

The trans-esterification process is used for the conversion of triglycerides into biodiesel, and the process of trans-esterification for chicken skin and pig tallow is explained in other sections. 500ml of triglycerides obtained from chicken skin and pig tallow are individually subjected to the trans-esterification process by adding measured quantities of methyl alcohol and a suitable catalyst. The obtained crude biodiesel after the trans-esterification process contained both glycerine and biodiesel and were separated by using the de-canter funnel. It was found that 500ml of chicken skin and pig tallow have yielded 365ml and 475ml biodiesel respectively. The obtained biodiesel from chicken skin and pig tallow are blended individually and in combination with the petrochemical diesel in different combinations as indicated in Table 3.
volume fractions. Thus obtained blended biodiesel is characterized to find out various fuel compatibility properties. Table 3 indicates the different biodiesel blends and their nomenclatures.

3.3. Properties of Chicken Biodiesel and its Blends.
Different thermochemical tests were carried out on the biodiesel blends to find out their thermo-chemical properties. Properties such as flash point, fire point, kinematic viscosity, density, calorific values, and carbon residue (content) were evaluated for all biodiesel blends as per ASTM standards. The variation of these thermo-chemical properties with change blending volume is discussed in the following sections.

Figure 4. Comparison between the flashpoints of different biodiesel blends

Flashpoint or flash point temperature of the biodiesel blends are evaluated as per the ASTM D93 standards. In general, flash point temperature has defined a measure of biodiesel tendency to form a flammable mixture with air under laboratory conditions, and it is one of a property to determine the flammability hazard of the biodiesel. Figure 4 shows a graph of the variation in flashpoints of various biodiesel blends. The comparison between the blending volume of chicken skin and pig tallow based biodiesel can also be observed from the graph. The pure petrochemical diesel has a flashpoint of 56°C, and it can be observed that the flashpoint temperature is increasing gradually with an increase in blending volume, and the pure biodiesel exhibits the highest flash point temperature. It can be observed from the graph that the biodiesel extracted from pig tallow is more flammable compared to the biodiesel extracted from the chicken skin. And, the flashpoint temperature further increases if both the extracted biodiesels are blended in equal quantities with the petrochemical diesel.

Figure 5 depicts the kinematic viscosity of different biodiesel blends and their comparison with one another. The kinematic viscosity of the biodiesel and its blends are estimated as per the ASTM D445 standards. As any fuel used in an engine acts as a lubricant also, it becomes essential to evaluate its kinematic viscosity. And having the right values of these parameters ensures that the biodiesel’s storage, handling, and operational conditions. Thus, it becomes essential to evaluate the kinematic viscosity of all the biodiesel blends. The kinematic viscosity of all the biodiesel combinations are evaluated, and the results are shown graphically in Figure 5. It can be observed that the kinematic viscosity of petrochemical diesel is lowest compared to the biodiesel blends and the kinematic viscosity was found to be highest for pure extracted biodiesel without any mix. Compared to the blends based on chicken skin the pig tallow based biodiesels have exhibited higher values of kinematic viscosity and the hybrid biodiesel exhibited still higher level of kinematic viscosity values.
The calorific value in kJ/kg of the biodiesel blends was evaluated using a standard bomb calorimeter by following the standard test methods. The obtained values are graphically tabulated as shown in Figure 6. The graphs indicate that the pure petrochemical diesel is having more calorific value and the calorific value reduced with the addition of biodiesel to it. The blending percentage is inversely proportional to the calorific value, and it may be attributed to the higher oxygen content of the biodiesel than the petrochemical diesel. Compared to pig tallow based biodiesel blends, the chicken skin based biodiesel was found to be having higher calorific values. The hybrid blends which contained both the chicken fat and pig tallow based biodiesel exhibited the lowest range of calorific values compared to their counterparts due to its higher oxygen contents.
graphically compared through Figure 7. It can be observed that the biodiesel and its blends have lower carbon content compared to the petrochemical diesel. As per ASTM D524 – 15, the maximum carbon content for any biodiesel is less than 0.05 or 5%, and it can be observed that almost all the blends fall under the standard prescribed limits.

4. Conclusion

The research paper presents experimental procedures followed to extract biodiesel from animal wastes such as chicken skin and pig tallow, which are available in abundance and at economical cost. The extracted biodiesel from chicken skin and pig tallow are blended with petrochemical diesel in different volume percentages. The investigation of the thermochemical properties of all the biodiesel blends is carried out, and the conclusions are as follows:

Chicken skin and pig tallow – waste products from animal slaughterhouses can be successfully used for biodiesel extraction. The heating process was used to convert the feedstock into triglycerides, and per kg of each type of feedstock has yielded around 460 ml and 890 ml of fat oil from chicken skin and pig tallow respectively. The optimum parameters that would yield maximum fat yield were found to be 80°C and 30 minutes for chicken skin, 80°C, and 25 minutes for pig tallow. The transesterification process was carried out to convert the extracted triglycerides into crude biodiesel. The process was carried out at 80°C for 2 hours by mixing a measured quantity of methyl alcohol and a catalyst. It was found that 500ml of chicken skin and pig tallow have yielded 365ml and 475ml biodiesel, respectively.

The different volume percentage of extracted biodiesel was mixed with petrochemical diesel to form various blends. Thermo-chemical properties such as flash point, kinematic viscosity, calorific value, and carbon content were evaluated by following standard test methods as specified by ASTM. It was found that the test results of almost all blends were within limits prescribed by ASTM D 6751 and hence can be concluded that they may be used as a compatible replacement of conventional diesel. The fire point evaluation of different biodiesel blends was carried out, and it was found that, compared to conventional diesel, the blends exhibited higher fire point temperature and pure biodiesel extract exhibited the highest fire temperature. The blending volume is found to be directly proportional to the fire point temperature, i.e. as a larger volume of biodiesel lesser will be the flammability of the blend. Similar results were obtained concerning kinematic viscosity of the biodiesel blends. As the volume of mixing increased, the kinematic viscosity of the blend is found to be reducing, and comparatively pure biodiesel extract was found to be having the lowest value of kinematic viscosity.

The carbon residue value of the biodiesel is one of the criteria to predict the carbon deposits in the combustion chamber. Compared to conventional diesel, the biodiesel blends were found to be having lesser carbon content, and the pure biodiesel is the one with the lowest one. As the biodiesel from
animal extract has more oxygen content, their combustion will result in lesser carbon emission, and hence the biodiesel and its blends can be considered as green fuels. The calorific value of the biodiesel was found to be lower compared to petrochemical diesel and increasing the blending volume has resulted in reducing the calorific value of the biodiesel. The 10% blended biodiesel was found to be having nearly equal calorific value as that of conventional diesel.

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