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The Production and Analysis of Biodiesel from Waste Chicken Skin and Pork Skin Fat and a Comparison of Fuel Properties to Petroleum Derived Diesel Fuel

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Abstract*—People today are increasingly health conscious and therefore shopkeepers tend to dispose of fatty chicken and pork skin. Chicken and pork skins thus are sources of solid waste that are usually not utilized. This paper deals with the production of useful biodiesel from utilizing the waste chicken and pork skins. Fat from the waste chicken and pork skins (sourced from local shops), was first extracted and subjected to transesterification. The products of transesterification were FAME (Fatty acid methyl esters) and glycerol. The FAME produced was tested for five parameters namely calorific value, pour point and cloud point when compared to ASTM E2515-11 standard values. Comparison of the obtained values of the five parameters with the standard values for diesel was performed to determine the viability of the biodiesel produced. The results of this experiment showed that the calorific values of FAME produced from chicken skin and pork skin fat were close to that of petroleum derived diesel. However, two test parameters namely kinematic viscosity and pour point differed when compared to diesel; this problem can be circumvented by modifying an automobile's internal combustion engine. Due to the relatively high yield value of biodiesel, it is feasible to utilize chicken skin and pork skin fat at a rural level to produce FAME that can be an alternative to diesel in this time of acute fuel scarcity.

***Keywords*— Fatty acid methyl esters, fuel test parameters, alternate fuel, catalyst, calorific value, feasibility**

I. INTRODUCTION

In India, chicken and pork farms supply chicken and pork to small, family owned shops called "Chicken Stalls" and "Pork Houses" where the animals are usually slaughtered and cut. Indians usually ask for skinless chicken or pork when ordering from these shops. Therefore, the skin is disposed of from these shops. This skin is disposed usually in the public drain and therefore becomes potentially hazardous solid waste in the environment.

After seeing the excess of chicken and pork skin/fat in the market, we realized that this waste could be used to create biodiesel. This biodiesel could be used to power automobiles (with modified engines), for domestic purposes and biodiesel could also be a cheaper source of fuel compared to refinery diesel [1]. After synthesizing the fuel, it was necessary to compare the values of certain parameters such as: calorific value, pore point, flash point, cloud point and density with another conventional fuel such as diesel or petrol sourced from fossil fuels.

If the values were to be comparable to the standard ASTM E2515-11 values, we could look into a large scale industrial production of biodiesel for domestic purposes in the future. This could be a viable alternative to the fossil fuels which are becoming extremely scarce.

II. EXPERIMENTAL

2.1 Materials:

Waste chicken skin, waste pork fat, distilled water, chloroform, methanol, sodium hydroxide pellets.

2.2 Apparatus:

- 4 beakers of 500ml each
- 2 beakers of 2L each
- Electronic balance accurate to .01g
- 1 Pressure cooker of 5L capacity
- 1 Kitchen knife
- 1 magnetic stirrer
- 5 separating funnels each of 1L capacity
- 1 Serological water bath
- 2 measuring cylinders of 1L capacity
- 1 stove top
- 1 box of matches
- 2 vertical clamp stands
- 3 glass rods
- 1 Oswald's viscometer

2.3 Extraction of Fat: Pork:

About 900 grams of pig skin along with a 3 cm layer of the adipose tissue along with remnant meat present under the skin was bought from a local pork shop. This was then cut into 3 cm long and 3 cm wide pieces that were immersed (not dissolved) in water inside a 2 Litre, borosil beaker. The contents of this beaker were poured into a vessel that was set inside a pressure cooker, which was quarter-filled with water. The mixture was cooked under a medium flame for about nine and a half minutes and was then cooled to room temperature; after this it was taken out and filtered into another, washed beaker [2]. The liquid portion obtained from filtration was then separated using a separating funnel. The white portion (or the aqueous layer) was separated from the pale-yellow layer (which, in this case, is the fat). After this, the aqueous layer was discarded, and the solid mass obtained in the muslin cloth used to filter the solid layer from the two liquid layers was further cut into smaller pieces, and was ground using a blender. The paste obtained was made up to about 1000 mL (using water), and was, once again, added to the vessel which was set inside the pressure cooker, and was allowed to cook for about six and a half minutes. The mixture obtained after cooking was cooled to room temperature and then filtered to remove the waste solid mass (that is eventually discarded), and was, again, separated into an aqueous layer and a fat layer. The fat layer is separated from the aqueous layer using a separating funnel, and any remaining fat in the aqueous layer is separated using chloroform ($CHCl_3$)., which is used as an indicator that readily dissolves in fat to produce a transparent yellow layer that can be separated using a separating funnel. The chloroform is evaporated by immersing the conical flask in which the fat is stored inside a water bath (thermostatically set to about 100 °C) for approximately 8 minutes. After this (since about 519 mL of fat was produced) about 4.14 grams of Sodium Hydroxide pellets (NaOH) was added to about 156 mL of methanol, and was dissolved thoroughly until the pellets disappeared. Since this was a highly exothermic reaction the beaker in which the reaction was transpiring had to be covered with Aluminium foil. This methanolic NaOH solution was added to the pork fat obtained, and acted as a catalyst for the formation of biodiesel.

2.4 Extraction of Fat: Chicken:

About 900g of waste chicken skin was bought from 'Suguna Chicken Stall'. The skin sample was manually de-feathered in the PES laboratory. After the skin was de-feathered, it was thoroughly washed using tap water. It was then cut into 3cm long, 1cm wide pieces that were immersed (not dissolved) in water inside a 1 Litre, borosil beaker. The contents of this beaker were poured into a vessel that was set inside a pressure cooker, which was quarter-filled with water. The mixture was cooked under a medium flame for about nine and a half minutes, and was taken out and filtered into another, washed beaker. The liquid portion obtained was separated into layers using Chloroform ($CHCl_3$). The three layers obtained were: a solid layer, aqueous and a layer containing triglycerides (or an organic/fat layer). The solid layer was separated from the aqueous and the organic layers using a filter funnel and filter paper, and the aqueous layer (which, in this case was white in color) was separated from the organic layer using a separating funnel. The organic layer was stored, temporarily in a conical flask, and the solid layer (or the solid mass) was thoroughly ground using a blender and was dissolved in approximately 300 mL of water. The mixture formed was further cooked in a pressure cooker by pouring the mixture into a vessel that was, once again, immersed into a pressure cooker quarter-filled with water and was allowed to cook. After seven minutes, the cooked solid layer was removed, and was filtered out to get rid of any solid sediment (known as 'solid mass'). The resulting liquid portion was separated in a separating funnel into an organic layer containing triglycerides and an aqueous layer. Chloroform was added to the aqueous layer to extract any remaining fat, and the aqueous layer was disposed along with the solid mass.

2.5 Preparation of FAME (Biodiesel) from Pork Fat

The formation of biodiesel is accomplished through a process called transesterification that involves the chemical combination of an alcohol (which, in this case, is methanol) and a triglyceride or a fat, (which, in this experiment, was obtained from pork skin and a thin layer of adipose tissue) to form fatty acid methyl esters (commonly known as 'biodiesel') and glycerol. This FAME has a general composition of oleic, palmitic, linoleic, palmitoleic, stearic, and miristic fatty acids in varied proportions; however, palmitic acid and linoleic acid are major constituents of FAME [2].Since this reaction is, intrinsically, an extremely slow reaction, NaOH is used as a catalyst to catalyze this reaction by combining NaOH with methanol [3].The picture below is a diagrammatic representation of the structures of the reactants and products involved in transesterification:

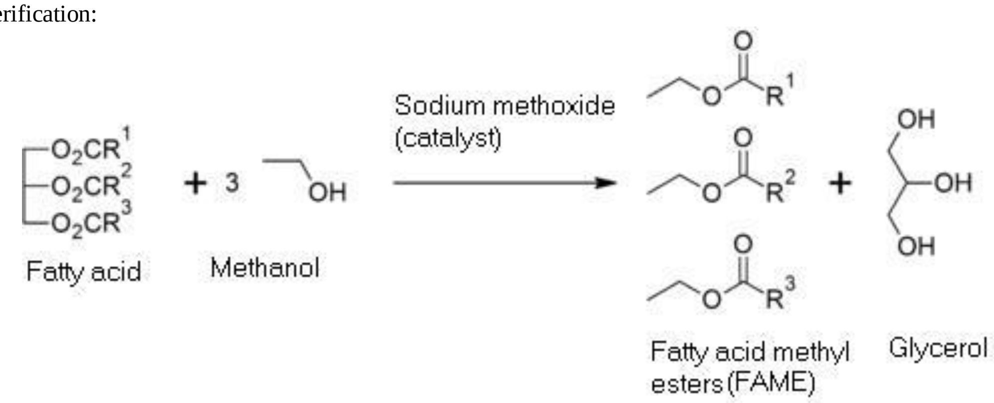

Fig. 1 General chemical equation for transesterification

Due to the optimum temperature of this reaction being approximately 68 ^{0}C, the extracted fat sample was placed on a magnetic stirrer that was set to 68 ^{0}C. A thermometer was also placed inside the fat sample and was constantly checked to make sure that the temperature of the fat did not go above or below the optimum temperature. After this, about 4.14 grams of NaOH pellets were dissolved in 156 mL of methanol. Once the pellets completely dissolved in methanol, the resulting solution was poured into the fat sample (that is currently on the magnetic stirrer), and a 2 cm long magnetic stir bar (that, in essence, stirs the two reactants due to the rotating magnetic field brought about by the magnetic stirrer) was placed inside the conical flask in which transesterification was occurring. After exactly 1 hour, the conical flask was removed from the magnetic stirrer, and the stir bar was taken out using forceps. The contents of the conical flask were then poured into a separating funnel, which was left overnight (approximately 8 hours). There were two layers formed by transesterification; one was a completely transparent layer, and one was a translucent yellow layer. The transparent layer, in this case, was waste glycerol, and the yellow layer was useful biodiesel that was initially 'washed' by gently washing the sample with warm water (at a temperature of about 45 ^{0}C) to get rid of any residual catalysts or soaps. The biodiesel is then dried and subjected to various tests that tested the following properties:

1. Cloud point
2. Pour point
3. Flash point
4. Density
5. Viscosity
6. Calorific value

2.6 Preparation of FAME (Biodiesel) from Chicken Fat

Methanolic sodium hydroxide solution was prepared in a beaker using 2.19 g of NaOH (Sodium Hydroxide) pellets (measured using an electronic balance) dissolved in 108 mL of ethanol. Once the pellets dissolved into the methanol with the help of a glass stirrer, the methanolic NaOH solution was poured into the fat sample with was placed inside the magnetic stirrer apparatus, and a 2 cm long magnetic stir bar (that, in essence, stirs the two reactants due to the rotating magnetic field brought about by the magnetic stirrer) was placed inside the conical flask in which transesterification was occurring. After exactly 1 hour, the conical flask was removed from the magnetic stirrer, and the stir bar was taken out using forceps. The contents of the conical flask were then poured into a separating funnel, which was left overnight (for approximately 8 hours). Unlike in Pork, the biodiesel produced from chicken fat was a deep yellow color, and the two layers formed from transesterification were a red and a yellow layer. While the red layer was waste glycerol, the yellow layer was useful biodiesel that was first 'washed' by gently washing the sample with warm water (that was at a temperature of about 45 ^{0}C) to get rid of any residual catalysts or soaps [4]. The biodiesel is then dried and subjected to various tests that tested the following properties:

1. Cloud point
2. Pour point
3. Flash point
4. Density
5. Viscosity
6. Calorific value

III. RESULT AND DISCUSSION

A. Tables

***Table I:* Amount of Materials Involved During the Course of Biodiesel Formation**

Material	Chicken Skin	Pork Fat
Amount of Raw Material Taken (g)	900	900
Volume of Fat (mL)	366	519
Volume of Methanol Added (mL)	108	156
Mass of NaOH Pellets Added (g)	2.91	4.14
Volume of Biodiesel Produced (mL)	333	447
Volume of Glycerol Obtained (mL)	141	221

For transesterification reaction the following formula was used to calculate the amount of methanol and NaOH:
1L of Fat requires 300mL of methanol
1L of Fat requires 8g of solid NaOH
Thus, Amount of methanol = Amount of fat in mL x 0.3
For Chicken: Amount of methanol = 336 x 0.3 = 108mL
For Pork: Amount of methanol = 519 x 0.3 = 156mL
And Mass of NaOH = Amount of fat in mL x 0.008
For Chicken: Mass of NaOH = 336 x 0.008 = 2.91g
For Pork: Mass of NaOH = 519 x 0.008 = 4.14g
Percentage Yield of Chicken Biodiesel=Volume of Biodiesel Produced/Amount of Raw Material Taken x 100
=333/900 x 100 = 37%
Percentage Yield of Pork Biodiesel=Volume of Biodiesel Produced/Amount of Raw Material Taken x 100
=447/900 x 100 = 49.6%

Table II: **Comparison of the experimental values of Chicken and Pork Biodiesel with ASTM values of Diesel Fuel:**

Sl. No.	Properties	Units	Protocol	Test Method	B100 (chicken)	B100 (pork)	Diesel
1	Density	g/cc	IS: 1448 (P 16)	ASTM D1448	0.85	0.91	0.85
2	Net Calorific Value (Lower Calorific Value)	MJ/kg	IS: 1448 (P 6)	ASTM D6751	41.2	47.7	43.4
3	Kinematic Viscosity	Cst	IS: 1448 (P 25)	ASTM D445	5.6	6.1	2.6
4	Pour Point	^{0}C	IS: 1448 (P 10)	ASTM D2500	-9	-15	-10
5	Flash Point	^{0}C	IS: 1448 (P 20)	ASTM D93	41	58	52
6	Cloud Point	^{0}C	IS: 1448 (P10)	ASTM D2500	4	3	8.9

B. Graphs

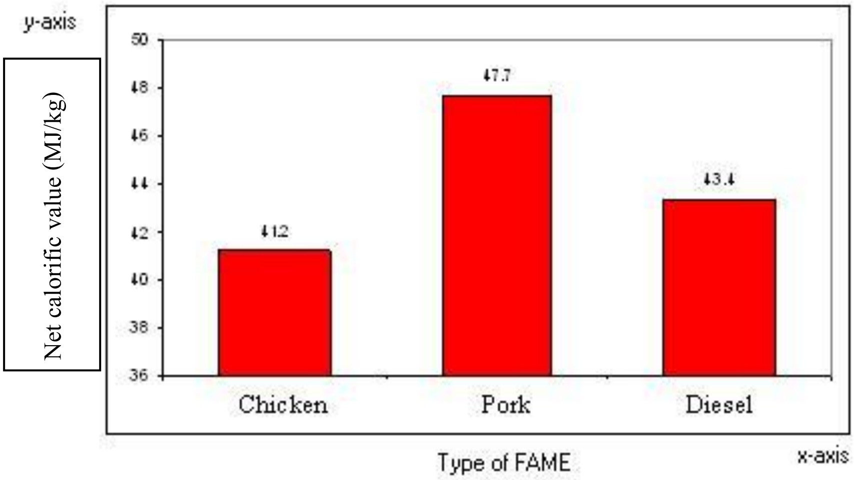

Fig. 1 Comparison of the net calorific values of different types of FAME (Bar graph)

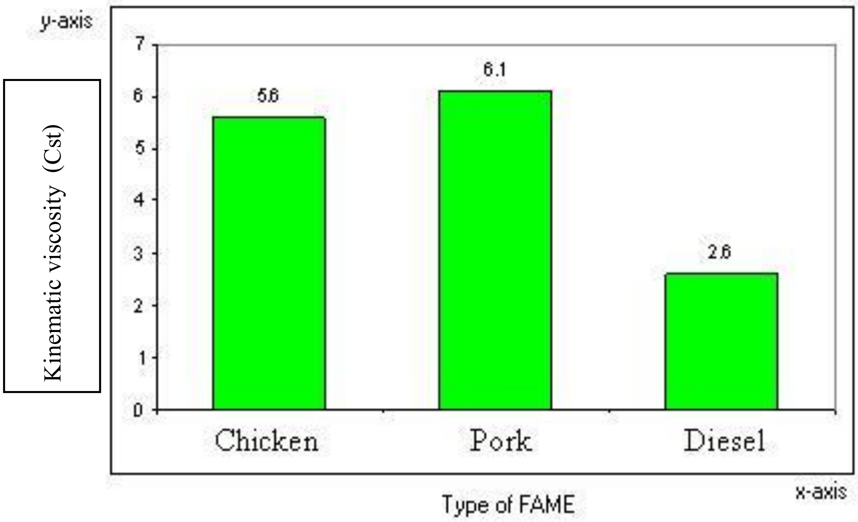

Fig. 2 Comparison of the kinematic viscosities of different types of FAME (Bar graph)

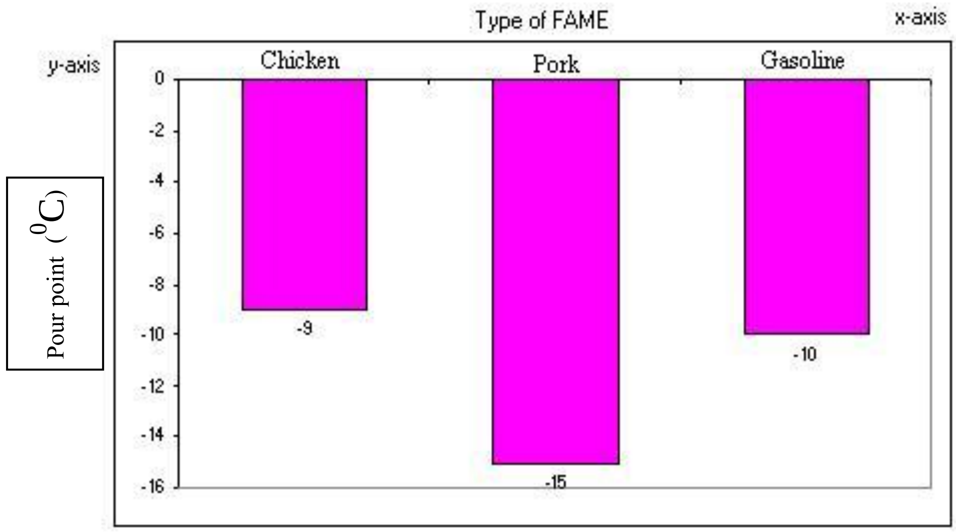

Fig. 3 Comparison of the pour points of different types of FAME (Bar graph)

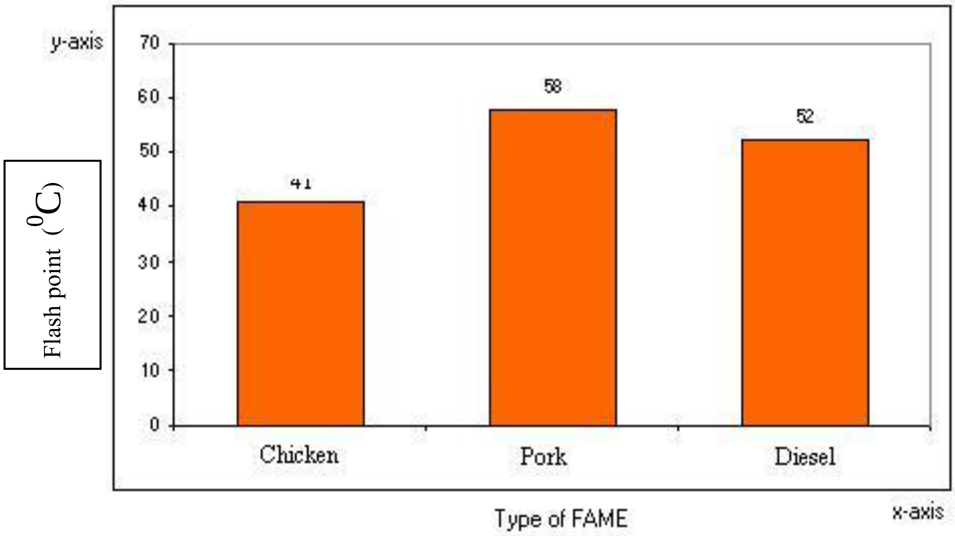

Fig. 4 Comparison of the flash points of different types of FAME (Bar graph)

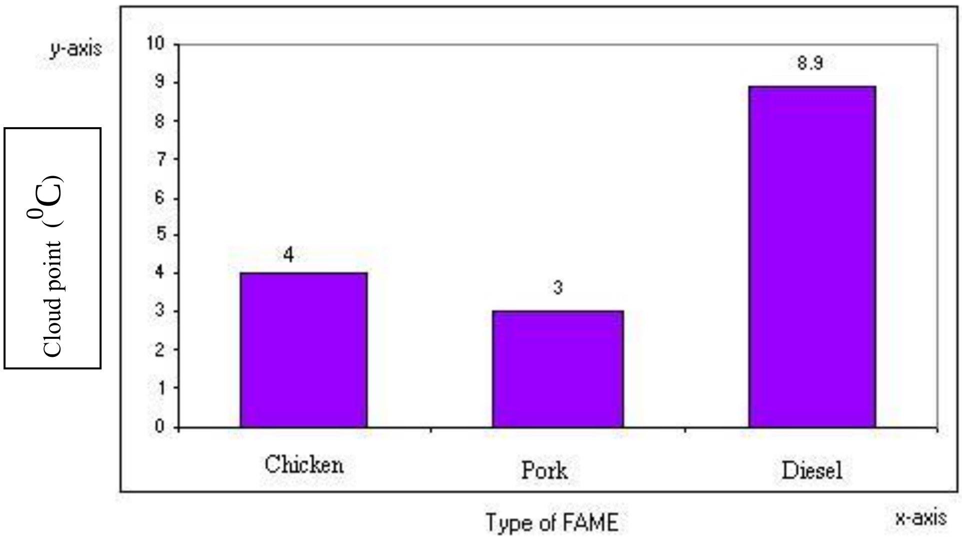

Fig.5 Comparison of the cloud points of different types of FAME (Bar graph)

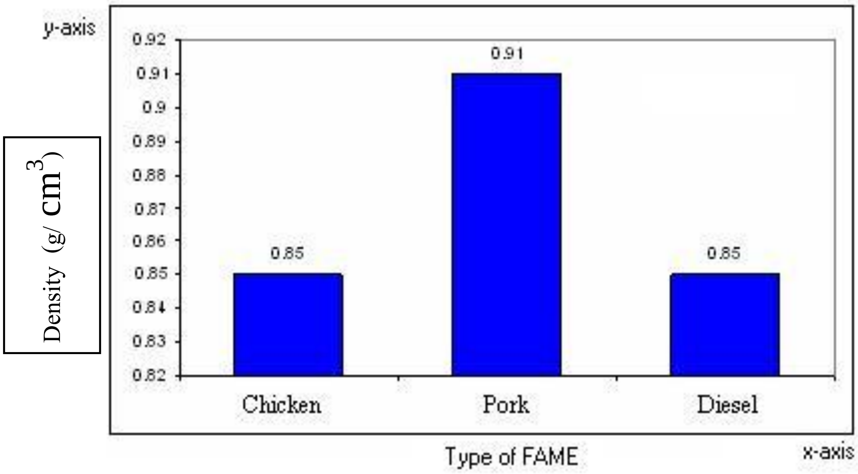

Fig. 6 Comparison of the densities of different types of FAME (Bar graph)

C. Pictures

Fig. 7 Cutting of de-feathered chicken skin into 3 cm long and 1 cm wide pieces using a scalpel

Fig. 8 Pressure cooking of de-feathered chicken skin immersed in water (this mixture is poured into an Aluminium vessel inside the pressure cooker) to form an organic layer, solid layer, and an aqueous layer.

Fig. 9 The formation of glycerol (the red layer at the bottom) and FAME or biodiesel (the yellow layer at the top) by transesterification

Fig. 10 A typical calorimeter used to obtain the calorific value of biodiesel

D. Analysis of the data obtained

The pour point, flash point and cloud point of the FAME (biodiesel) obtained from chicken skin are -9, 41, and 4^0C respectively and, similarly the pour point, flash point and cloud point of the pork biodiesel are -15, 58, and 3 ^{0}C respectively. Pour point is defined as the minimum temperature at which the fuel starts flowing; cloud point is the temperature at which the fuel changes into wax crystals; flash point is the temperature at which the fuel explodes to release heat energy needed to propel an internal combustion engine. For a fuel, it is better if the cloud point, pour point and the flash point are all relatively low. In our pork and chicken biodiesel samples, we noticed that the pour point, cloud point and flash point were lower than that of diesel fuel. However two significant drawbacks are the relatively high density of the pork biodiesel (which is 0.91 g/cc) and the high kinematic viscosities of both biodiesel samples. This means that in an internal combustion engine, there would probably be resistance against the flow of the fuel. These drawbacks can be overcome by modifying the internal combustion engine.

The calorific values of our chicken and pork biodiesel samples were 41.2 and 47.7 MJ/kg respectively and are close to the calorific values of Diesel fuel as prescribed by ASTM (43.4 and 48.0 MJ/kg respectively) [4]. The calorific value of a fuel is defined as the amount of heat energy given out per unit mass. Therefore, the proximity of the calorific values suggests the biodiesel' efficiencies as fuels and their possible use in the automobile industry due to their relatively latent high energy content. In addition, this biodiesel can be used in rural areas to power important agricultural machinery such as tractors, and for domestic purposes such as cooking. This would be a functioning model because of the feasibility of animal biodiesel producing plants in villages due to the practice of large amount of livestock rearing there.

Similar experiments have been carried out by other groups and we have obtained literature values that nearly correspond to that of this experiment. In the paper 'Biodiesel Production from Waste Chicken Fat based Sources,' [4], the density and viscosity of biodiesel produced from chicken fat were 5.5 Cst and 0.864 g/cc respectively, and the net calorific value of chicken biodiesel obtained in the paper 'Production and Analysis of Chemical Properties of Chicken Fat Based Biodiesel and its various Blends,' [5] was 39.34 MJ/kg. The slight differences in the values between our experiment and the other two experiments result from the utilization of chicken fat rather than chicken skin in the formation of biodiesel.

IV. CONCLUSIONS

The FAME produced by the transesterification of chicken skin (that is usually considered solid waste) is found to be a good, alternative fuel source. The fuel properties tested on FAME produced from both chicken skin and pork skin fat are comparable to corresponding ASTM values for petroleum derived diesel. A modular reactor can, therefore, be built to efficiently produce biodiesel from chicken skin at a rural level to facilitate an alternative fuel to run tractors and other diesel-power requirements. However, the internal combustion engines must be modified to accommodate the differing cloud point and kinematic viscosity values of the biodiesel produced from chicken skin fat. Additionally, the increased usage of chicken skin biodiesel can effectively address the solid waste management problem.

V. ACKNOWLEDGEMENTS

We would like to acknowledge the help of a few individuals over the course of this research: Dr. Venkatappa Krishnamurthy who was of immense help in locating resources, allocating laboratory timings, and guiding us through the entire biodiesel formation process, Ms. S.H. Kavitha, whom we met at the university biotechnology department, was a great help in the data collection process as well as briefing us on the principles behind the transesterification process, Prof. Jawahar Doreswamy, CEO of PESIT, who recommended us to Dr. Krishnamurthy and PESIT (People's Educational Society Institute of Technology), a four-year university located in Bangalore, India, for extending their laboratory resources and chemistry apparatus for the entire course of our experiment.

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