

# **Synthesis of Biodiesel from Residual Animal Fats and Analysis of Properties**

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**ABSTRACT:** This paper deals with the synthesis of biodiesel from residual goat tallow at laboratory scale, determination of free fatty acid profile, lowering the level of free fatty acid content for decrement of the viscosity to meet the standards for usage in diesel engines. The obtained product is also tested for different rheological, thermodynamic and physical properties such as Viscosity with respect to temperature, Shear Stress with respect to temperature, Calorific value, Flash point, Fire point, PH value, density etc. These results are then compared with existing standards for petroleum diesel. Further a comparison of the cost of the produced biodiesel with petroleum diesel has also been provided.

**KEYWORDS:** Alternative fuel, Biodiesel, Residual animal fats, Properties, Cost

## **I. INTRODUCTION**

Biodiesel has become one of the most important alternatives to substitute energy provided by fossil sources. Biodiesel is nontoxic and biodegradable and produces less particulate matter. The production of biodiesel has many economic and environmental advantages [1, 2]. Biodiesel can be synthesized from different varieties of feed-stocks such as edible vegetable oils (e.g. Canola oil, sunflower oil, etc.), non-edible vegetable oils (e.g. Jatropha oil, Pongamia oil, etc.), waste cooking oils, and animal fats. Price and availability are important factors that determine different types of feedstock used for biodiesel production from one region of the world to another [3]. Biodiesel is biodegradable, nontoxic, is free of aromatics and dioxins, its high flash point makes it safer for storage and transportation [4-6]. It can be used directly on direct injection engines, resulting in similar performance and lower unburned hydrocarbons, particulate matter and carbon monoxide emissions as compared to diesel fuel [7-9]. There are different processes used to transform fats and oils to biofuel among which transesterification seems to be very promising. It generates products commonly known as biodiesel (alkyl esters of fats or oils). It is the most commonly used method to reduce viscosity of animal fats and vegetable oils. This biodiesel production technique has been reported to have particular advantages over other processes: (i) reaction conditions are mild, (ii) the process is environmentally friendly and (iii) a wide variety of feedstock can be processed through this technique [3].

The work of the authors in this paper is divided into two stages: 1) Related work for processing and synthesis of biodiesel from goat tallow [3] at laboratory scale 2) Experimental section wherein tests for various Rheological properties, Thermodynamic properties, and Physical properties are conducted.

## **II. RELATED WORK**

**Extraction of animal fats.** Animal residuals (Goat Tallow) of 1kg is collected from a local slaughterhouse and is melted at a temperature around 130 °C. This removes the moisture completely from the residuals and animal fat of 540

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ml is extracted in the form of liquid. These extracted animal fats contain various types of impurities such as gums, protein residue and suspended particles in the form of solid, which is separated by percolation and filtration. Thus a pure form of animal fat is made ready for processing and production of biodiesel.

**Determination of Free Fatty Acid content and pre-treatment.** Chemical composition of oils and fats used in the biodiesel synthesis can influence processing and storage conditions, due to the percentage of unsaturated fatty acids. High free fatty acid content of the oil caused transesterification reaction to fail and led to soap production. So it is important to have free fatty acid profile less than 0.5% in the animal fats [10]. In our sample, initially, the free fatty acid profile of the animal fats by following a set of titration procedures [11] was found to be 1.08%. Therefore, two alternative ways of purification were used in this work: (a) the “wet wash” and (b) the “dry wash” with magnesium silicate, brand name Magnesol [12]. Finally the obtained product had a free fatty acid profile of 0.45% suitable for undergoing transesterification reaction.

### III. EXPERIMENTAL SECTION

**Transesterification reaction.** The pre-treated animal fats with an amount of 500ml of weight 410g was put in a beaker with a capacity of 800ml. A solution of methanol and KOH is made, in which KOH of weight 36.9g (9% wt. of the pre-treated animal fats) is added to 3190ml of methanol weighing 2460g (with a molar ratio of 6:1 to the pre-treated animal fats). Potassium hydroxide (with a mass fraction of  $w = 0.002$ ) was used as a catalyst for the transesterification reaction. The beaker with the animal fats was placed on the electric induction heater and allowed to heat up to a constant temperature of 85°C. The reaction begins when the stirrer is dipped into the beaker (with a mixture of animal fats and methanol KOH solution) and immediately rotated on the stirring machine at a rate of 800rpm. This reaction is continued for 3 hours and continuous stirring at a constant temperature of 85°C. After 3 hours of continuous reaction, the resulting glycerine was removed by settling after 12 h, and the resulting ester phase was washed in three steps, as described elsewhere [12-16]. The biodiesel yield amounted to approximately 350 ml.

For determining behaviour of the viscosity and shear stress with respect to temperature of the obtained biodiesel, a rheometer (RHEOPLUS/32 V3.40 21005047-33024) was used.

Measurement of the calorific value was done using Oxygen Bomb Calorimeter (1341 plain jacket calorimeter by Parr Instruments, USA) following test procedure as per ASTM standard E870-82(2013)

Tests for Flash Point and Fire Point were carried out using Pensky Martin closed up apparatus (Jaincolab Model no. 1580)

Finally, tests for PH value and density were carried out using laboratory PH meter (PHS-3C) and Hydrometer respectively.

### IV. RESULTS AND DISCUSSION

- The behaviour of viscosity and shear stress of the biodiesel were measured at different temperatures (32.4°C-38.8°C) as shown in Table 1 and Graph 1a and 1b. Also, Thirty number of measurement points were taken with respect to time in order to determine viscosity and shear stress at 40°C until constant values were obtained represented by Table 2 and Graph 2a and 2b.

Measured Pts.	Temperature [°C]	Shear Stress [Pa]	Viscosity [Pa.s]	Speed [1/min]	Torque [µNm]
1	38.8	0.637	0.0130	38.7	33.5
2	35.8	0.643	0.0137	38.7	33.7
3	33.8	0.653	0.0143	38.7	33.9
4	32.4	0.661	0.0149	38.7	34.1

**Table 1.** Viscosity (Pa.s) and Shear stress (Pa) variation of the biodiesel sample at different temperatures.

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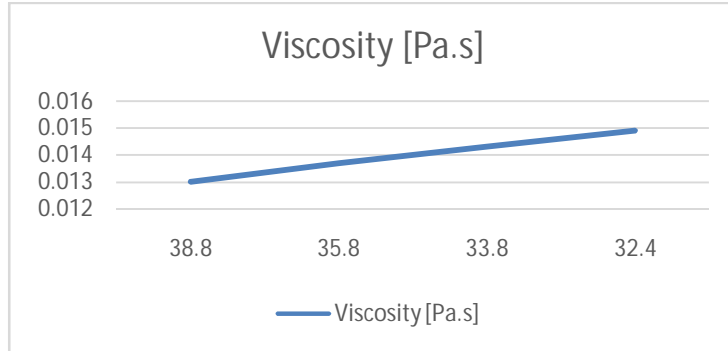
Measured. Pts.	Time [s]	Start Time [s]	Shear Stress [Pa]	Viscosity [Pa.s]	Speed [1/min]	Torque [ $\mu$ Nm]
1	5	10.2	0.628	0.0126	38.7	33.4
2	10	15.2	0.623	0.0125	38.7	33.1
3	15	20.2	0.62	0.0124	38.7	32.9
4	20	25.2	0.623	0.0125	38.7	33.1
5	25	30.2	0.624	0.0125	38.7	33.1
6	30	35.2	0.617	0.0123	38.7	32.8
7	35	40.2	0.615	0.0123	38.7	32.6
8	40	45.2	0.613	0.0123	38.7	32.6
9	45	50.2	0.618	0.0124	38.7	32.8
10	50	55.2	0.616	0.0123	38.7	32.7
11	55	60.2	0.609	0.0122	38.7	32.3
12	60	65.2	0.607	0.0121	38.7	32.2
13	65	70.2	0.611	0.0122	38.7	32.4
14	70	75.2	0.61	0.0122	38.7	32.4
15	75	80.2	0.607	0.0121	38.7	32.2
16	80	85.2	0.604	0.0121	38.7	32.1
17	85	90.2	0.604	0.0121	38.7	32.1
18	90	95.2	0.607	0.0121	38.7	32.2
19	95	100	0.604	0.0121	38.7	32.1
20	100	105	0.599	0.012	38.7	31.8
21	105	110	0.598	0.012	38.7	31.8
22	110	115	0.601	0.012	38.7	31.9
23	115	120	0.601	0.012	38.7	31.9
24	120	125	0.596	0.0119	38.7	31.7
25	125	130	0.593	0.0119	38.7	31.5
26	130	135	0.595	0.0119	38.7	31.6
27	135	140	0.598	0.012	38.7	31.8
28	140	145	0.596	0.0119	38.7	31.6
29	145	150	0.592	0.0118	38.7	31.4
30	150	155	0.592	0.0118	38.7	31.4

**Table 2.** Viscosity (Pa.s) and Shear stress (Pa) for thirty measuring points until a constant value of viscosity and shear stress is obtained at 40°C.

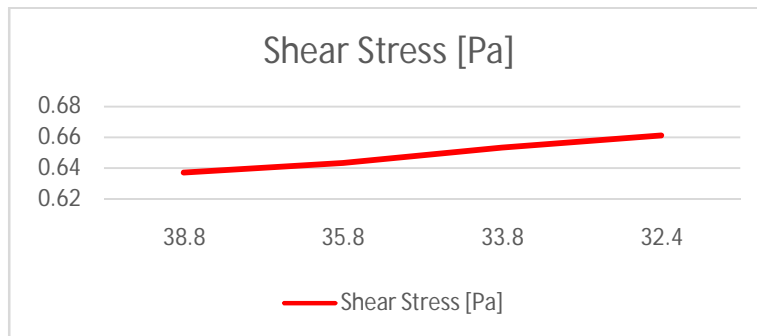
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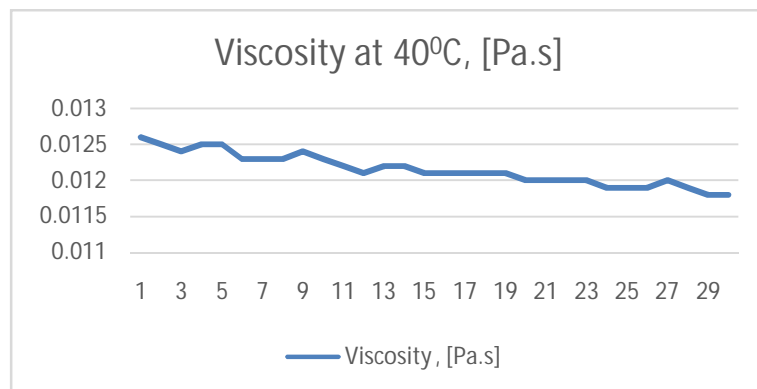
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**Graph 1a.** Variation of viscosity with changing temperature.



**Graph1b.** Variation of shear stress with changing temperature.

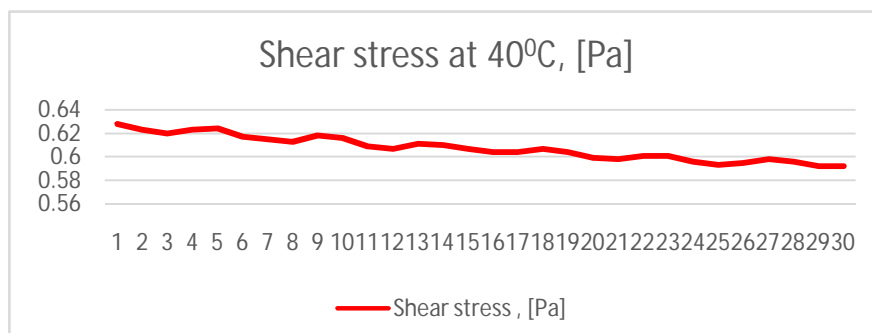


**Graph 2. (a)** Viscosity measurement up to time period of 150s at 5s interval at 40°C until a constant value of 0.0118 Pa.s was observed.

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**Graph 2. (b)** Shear stress measurement up to time period of 150s at 5s interval at 40°C until a constant value of 0.592 Pa was observed.

2. The Calorific value of the sample for three readings was found to be as follows:

Sample	Reading 1	Reading 2	Reading 3
Gross Calorific Value (Cal/gm)	6989.67	6990.21	6990.41

Therefore, average calorific value of the sample =  $\frac{6989.67+6990.21+6990.41}{3} = 6990.097$  Cal/gm

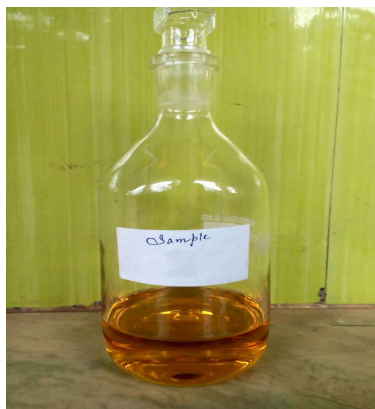
- The Flash Point and the Fire Point of the sample were found to be 58°C (136.4°F) and 70°C (158°F) respectively. These properties do not have influence in the operation of the motors; however, it is related to the inflammability, and it serves as an indication of the precautions that must be taken during handling, transport, and storage of the fuel [18]. With regard to biodiesel, the specification of the flash point has the objective to limit the amount of alcohol in this biofuel. In agreement with the ANP, the minimum limit for the flash point is 38 °C and our biodiesel sample presents a flash point of 58 °C. Consequently, the biodiesel can be considered a safer fuel with regard to stockpiling and fire risk [19].
- The PH value of the biodiesel initially was measured to be 10.17 at room temperature. The reason for high PH in the unfinished biodiesel was KOH left over from transesterification reaction. The sample was further treated by water washing, filtering and drying [3]. Eventually the final and pure biodiesel measured a PH value of 6.51
- The value of density of the sample at 20°C was calculated as 857.3kg/m<sup>3</sup> which is within specification (ASTM 6751). The density and other characteristics such as volatility and viscosity are usually independent, and they exert a great influence in processes such as the injection of fuel and its preparation for the automatic ignition. Consequently, acceptable parameters should be obtained for each physicochemical property with the objective of optimizing the combustion process of the engine [18].

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## The Sample



**Fig 3.** The sample at room temperature

The colour of biodiesel can vary from very dark brown to very light yellow [2]. In our sample the colour was neither very light nor very dark and it was liquid at room temperature 20°C as can be seen from the picture.

**Table3.** A comparison of the properties of the sample biodiesel and petroleum diesel

Fuel property	Sample Biodiesel (from Animal Fats)	Petroleum Diesel*
Kinematic Viscosity @ 40°C	13.8 cSt	2.0-4.5 cSt
Calorific Value	6990.097 Cal/gm	~10000 Cal/gm
Density @ 20°C	857.3kg/m <sup>3</sup>	820-845
Flash Point	58°C	60°C-80°C
Fire Point	70°C	70 °C-90 °C
PH Value @ 20°C	6.51	~7

\* The Data mentioned are cited from IS 1460: 2005 AUTOMOTIVE DIESEL FUEL — SPECIFICATION (Fifth Revision) and linked references.

**Cost Comparison.** The cost of production of 350 ml of the sample was calculated to be Rs 53.55 considering 90% recovery of the used chemicals and catalysts (excluding charges and costs associated with laboratory equipments)[20]. Therefore the cost of the sample per Litre can be calculated to be Rs 153. This cost is however quite high in comparison to present day diesel price of Rs 54.31/Litre in the state of Meghalaya, India.

## V. CONCLUSION

The use of biodiesel has not expanded into developing countries, because it is not competitive in prices with petroleum diesel. Our work emphasizes on purification and pre-treatment of the biodiesel for removal of free fatty acid and also to study the properties of biodiesel (from animal fats) with petroleum diesel and compare the respective prices thereafter. It can be assured that there is a vast scope for upgrade of the biodiesel and biodiesel blends in future arena. Hence the undertaken project aims to contribute some part in the presently growing biodiesel industry.

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