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Production and characterization of biodiesel obtained from transesterification of lipid from goat tallow

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Abstract

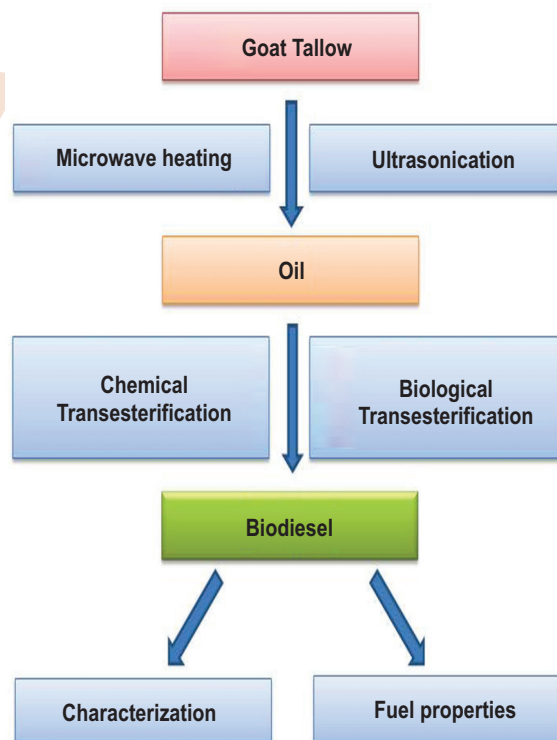
Aim : The present study was conducted to optimise the production of biodiesel from goat tallow by chemical and biological transesterification and to analyse the fuel characteristics of biodiesel.

Methodology : Lipid from goat tallow was extracted after subjecting the tallow to ultrasonication and microwave heating. The lipid obtained was converted to biodiesel by chemical and biological transesterification processes.

Results : Microwave heating of goat tallow with hexane produced 550 ml of oil whereas ultrasonication method produced 350 ml and 430 ml with Hexane and Hexane : Isopropanol (3:2) as solvent mixture, respectively. When one litre of this oil was subjected to transesterification reaction, 750 ml and 640 ml of biodiesel was produced by chemical and biological methods under optimized conditions (temperature 60°C for chemical and 35°C for biological transesterification). GC-MS analysis of transesterified oil indicated linolenic acid, pentadecanoic acid and stearic acid as major lipid components in goat tallow. Fuel properties were tested as per ASTM standards.

Interpretation : The biological process (either with the enzyme or with organism), if properly designed can definitely be an advantageous as this process is cost effective and environmental friendly. Goat tallow can be a potential candidate for the production of biodiesel, an alternate to fossil fuel, which is the need of the hour.

Key words : Biodiesel, Fuel properties, GC-MS analysis, Goat tallow, Transesterification



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Introduction

Biodiesel is gaining importance as one of the most important substitute for the depleting fossil fuels. The increase in oil prices, depletion of oil reserves, rise in concern for pollution caused by fossil fuels like petroleum, coal and natural gas are forcing the scientific community to look for alternative fuels and renewable sources of energy that can partially or totally substitute fossil fuels. At present, India is producing only 30% of the total petroleum fuel requirement; the remaining 70% is being imported (Murugesan *et al.*, 2009), and with increasing population and increased use of energy in different sectors, the energy demand in India is expected to grow approximately 4.8% per annum. With this ever increasing demand of energy in India, there is a need for alternative fuel sources so that valuable foreign currency reserves can be saved for other development activities (Sushma, 2014).

Biodiesel can be defined as fatty acid methyl or ethyl esters from vegetable oils or animal fats. Biodiesel is portable, renewable, biodegradable, oxygenated fuel with promising properties. It has higher combustion efficiency, lower sulphur and aromatic content, higher cetane number, higher biodegradability and a better emission profile. It is safe to handle and is also non-toxic (Lapuerta *et al.*, 2005; Balat and Balat, 2010; Raju *et al.*, 2016).

Vegetable oils, food-industry wastes, waste oils and agricultural wastes are the common raw materials used for the production of biodiesel. Although more than 95% of the world biodiesel is produced from edible oil, continuous and large-scale production of biodiesel from edible oil has recently been a great concern because they compete with food materials – the food versus fuel dispute (Mustafa, 2011). Non-edible plant oils have been found to be a promising source for the production of biodiesel. The use of waste cooking oil for biodiesel production reduces the cost of raw materials and will meet the need to synthesize biodiesel because of its sleazy price and broad source (Lou *et al.*, 2008). As triglycerides, animal fats can also be used for biodiesel production just as easily as plant oils. The usage of greases and animal fats eliminates the need to dispose them, besides contributing to the supply of biodiesel (Janaun and Ellis, 2010). Animal fats are readily available because slaughter industries are generally well managed for product control and handling procedures.

India has the world's largest population of livestock with 191 million cattle, 70 million buffaloes, 139 million sheep and goats, 10 million pigs and more than 200 million poultry. About 36.5% of the goats, 32.5% of the sheep, 28% of the pigs, 1.9% of the buffaloes and 0.9% of the cattle are being slaughtered every year in India, generating a huge amount of solid and liquid wastes. Among the solid wastes, lipid - rich solid waste, namely, nearly 5-10% tallow is generated in each year from slaughter houses (Ramani and Sekaran, 2015). Chakraborty *et al.* (2014) suggested goat tallow as a feedstock for biodiesel production. Besides pollution and hazard aspects, in many cases meat,

poultry and fish processing wastes have a potential for recycling raw materials or for conversion into useful products of higher value (Ramani *et al.*, 2012).

Biodiesel can be produced by four primary ways viz., direct use and blending, microemulsions, thermal cracking (pyrolysis) and transesterification (Meher *et al.*, 2006). Among them transesterification is the most popular method (Ma and Hanna, 1999), where the organic group of an ester is exchanged with the organic group of an alcohol. Worldwide, biodiesel is largely produced by methyl transesterification of edible and non-edible oils. The concept of methyl transesterification is gaining attention as methanol is derived from renewable biomass sources. These reactions are often catalysed by the addition of an acid or base catalyst or enzymes (biocatalysts), particularly lipases to improve reaction rates and yield. Transesterification reduces the viscosity of end product *i.e.*, biodiesel (Demirbas, 2003). The molar ratio of glycerides to alcohol, catalysts, reaction temperature, reaction time, free fatty acids and water content of oils or fats affect the transesterification reaction.

Efficient utilization of by-products has direct impact on the economy and environmental pollution of the country. Non-utilization or under utilization of by-products not only leads to loss of potential revenues but also leads to added and increasing cost of disposal of these products. Non-utilization of animal by-products in a proper way may create major aesthetic and catastrophic health problems. In the present study conversion of lipid from goat tallow to biodiesel by chemical and biological methods was investigated, subsequently ascertaining its suitability for diesel engines.

Materials and Methods

Goat tallow used in the biodiesel production was obtained from a slaughterhouse in Chennai, Tamil Nadu, India. The total oil content in the goat tallow was extracted by microwave heating (Mahesar *et al.*, 2008) and ultrasonication. To one kilogram of goat tallow, 1200 ml hexane was added and this mixture was subjected to microwave heating for 20 sec whereas one kilogram of tallow in two different solvent mixture Hexane and Hexane:Isopropanol (3:2) was subjected to ultrasonication for 6 hrs (Oscar Ultrasonic – Model CMM 3010). Oil obtained from goat tallow was filtered with non-absorbent cotton and measured with a measuring cylinder.

Transesterification process: The extracted oil was transesterified to methyl ester (biodiesel) by sodium methoxide following the method of Charoentairakool and Juthagate (2011) and Ramesh Kumar *et al.* (2014). For transesterification, the oil was preheated to 60°C and sodium methoxide was added slowly to it. The reaction mixture was maintained at same temperature for 1 hr with 100 rpm agitation. When the mixture was allowed to cool, the biodiesel layer (upper layer) separate from the glycerin layer (bottom layer). The upper layer was washed with water to remove the excess methanol and catalyst (Farroq *et*

al., 2013). The effect of temperature on biodiesel yield was studied by varying the reaction temperature from 45°C to 65°C. Similarly, the effect of reaction time on the biodiesel yield was studied by varying the reaction time from 50 to 70 min. For biological transesterification, lipase was used as catalyst. The reaction mixture contained 1 l of oil, 6.8 g of lipase and 150 ml of methanol (Su et al., 2007). In this process, the effect of temperature was studied by varying the reaction temperature from 30°C to 50°C and the incubation period from 1 to 7 hrs.

Fuel properties: Biodiesel (B100) and B20 blend, prepared by taking 20 ml of biodiesel with 80 ml of diesel, were tested for their fuel characteristics: kinematic viscosity at 40°C ($\text{mm}^2 \text{s}^{-1}$), density (g cc^{-1}), flash point (°C), fire point (°C), pour point (°C), sulfur contents (%), ash (mass %), calorific value (KJ kg^{-1}), carbon residue, acid number (KOH g^{-1}), water content (vol %) and cetane number as per standard protocols of ASTM standards (ASTM Standards, 2010). These tests were carried out in duplicates. The fatty acid methyl esters thus obtained were analysed by injecting 1 μl of sample into GC (Agilent Technologies 6890,

USA), following this a Mass Spectroscopic analysis of the sample using Electron impact ionization–mass spectrometry (JEOL GC MATE -II, Japan) was also carried out. By comparing the results with NIST database and area normalization method, the percentage of each fatty acid was calculated.

Results and Discussion

Goat tallow being a waste, contains appreciable amount of fatty acids which can be converted to biodiesel through transesterification (Chakraborty and Sahu, 2014). When tallow was subjected to microwave extraction of lipids, it resulted in 550 ml of fatty acids from one kilogram of tallow. Ultrasonication of tallow with solvents hexane and hexane:isopropanol (3:2) resulted in 350 ml and 430 ml of fatty acids implying that 1.81, 2.86 and 2.33 kg of goat tallow is required to produce one litre of oil. When one litre of this oil was subjected to transesterification reaction 750 ml and 640 ml of biodiesel was produced by chemical and biological methods, respectively, under optimized conditions. The yield of biodiesel by NaOH was fast and efficient

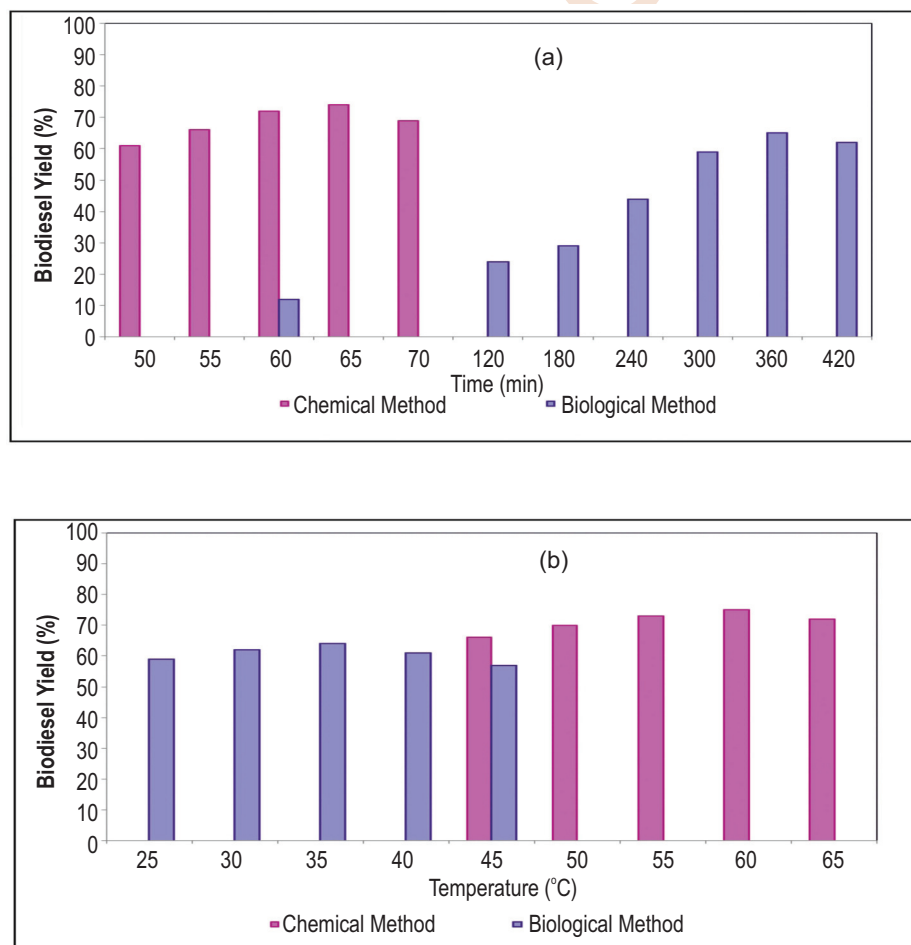
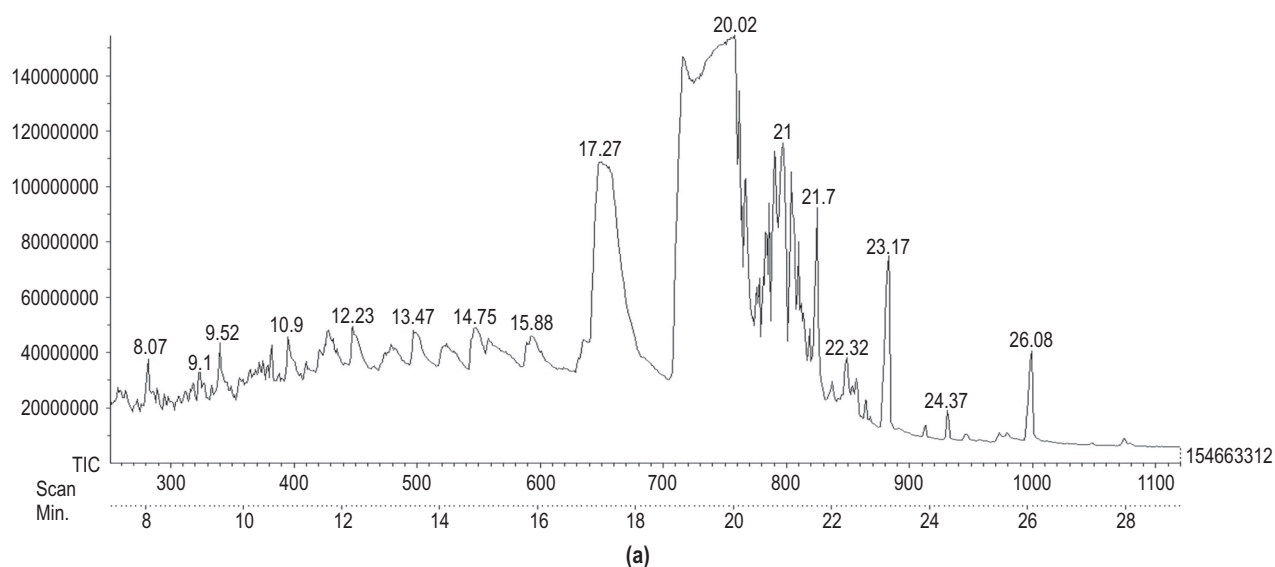


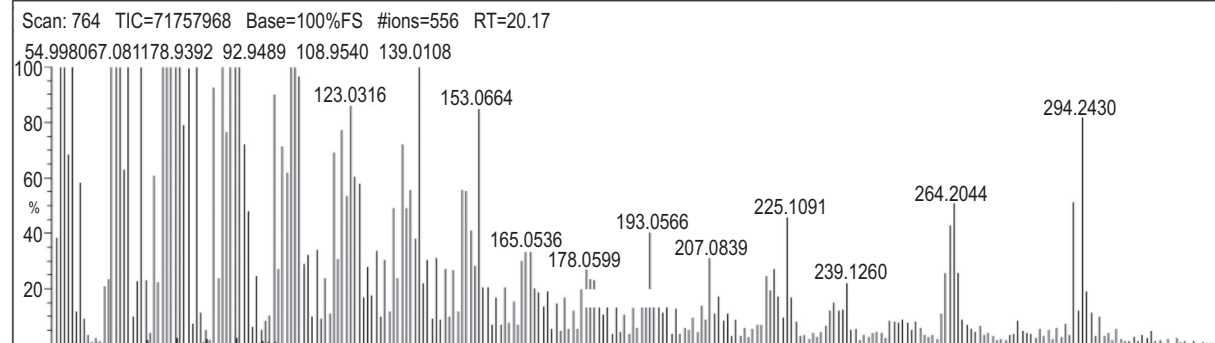
Fig. 1: Effect of (a) time and (b) temperature on chemical and biological transesterification of oil from goat tallow.

as compared to biological catalyst. Even though the conversion of tallow was very less and slow, the result seems to be promising as the enzyme was found to act on the animal tallow bringing about 61% conversion taking nearly 6 hrs (Fig 1a). In an economic perspective, soyabean oil is considered to be high yielding and cost effective. The only disadvantage is lipase transesterification of soyabean oil requires a lengthy incubation period compared to

tallow (Mousdale, 2008). This aspect puts tallow ahead of soyabean oil in terms of production time. When the effect of temperature on biodiesel yield was studied, chemical method required temperature 60°C while biological method required 35°C for maximum yield (Fig. 1b). Esterification reactions are endothermic; an increase in reaction temperature tends to push the reaction process in the synthesis direction (Gumel *et al.*, 2011;



(A)



(B)

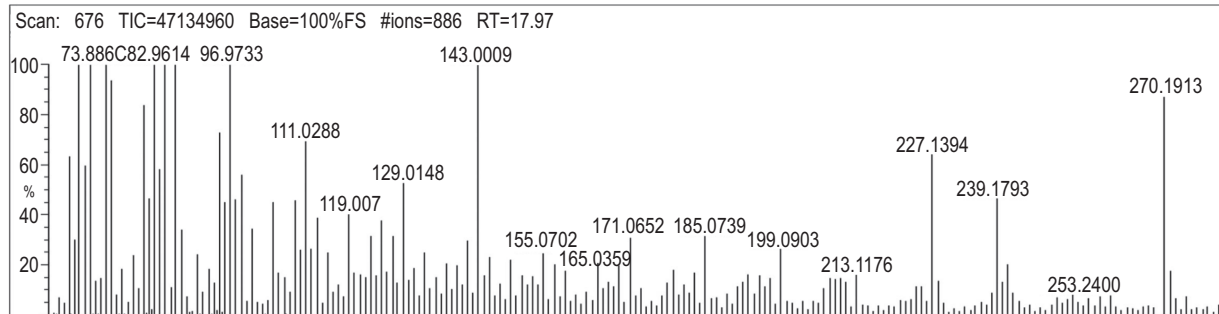


Fig. 2: GC-MS spectra of biodiesel from goat tallow produced by biological transesterification: (a) Gas Chromatogram (b) Mass spectrum corresponding to the RT value of 20.17 min and (c) Mass spectrum corresponding to the RT value of 17.97 min.

Table 1: Comparative analysis of Fuel Properties of Biodiesel produced from tallow by chemical and biological transesterification with commercial diesel

Parameters	Chemical method		Biological method		Diesel
	B100	B20	B100	B20	
Yield (%)	75		64		
Density (g cc ⁻¹)	0.87	0.85	0.88	0.86	0.83
Kinematic viscosity at 40°C (mm ² sec ⁻¹)	4.8	4.0	5.1	4.3	1.9-4.1
Flash point (°C)	98	75	120	106	93
Fire point (°C)	104	79	126	110	65
Cetane number	64	56	60	58	47
Ash (mass %)	0.2		0.21		
Calorific value (KJ kg ⁻¹)	40362		37082		
Pour point	60C		80C		
Sulphur content	> 2 PPM		Nil		
Carbon residue	Nil		Nil		
Acid number (KOH g ⁻¹)	2.1		2		
Water content (vol %)	<0.02		<0.03		

Huang *et al.*, 2015). Further, the increase in temperature increases the number of collisions between substrate molecules, resulting in an accelerated reaction rate. The typical properties of biodiesel and its blend (20%) in comparison with commercial diesel are presented in Table 1. A biodiesel yield of 75% through chemical method indicates the high potential of chemical process compared to 64% yield obtained from biological process. A slight increase in density of biodiesel compared to commercial diesel is attributed to the presence of unsaturated short chain fatty acids. Resistance to flow of a liquid due to internal friction is measured in terms of viscosity and the ratio of dynamic viscosity to the density of oil is defined as kinematic viscosity (Verma *et al.*, 2016). The amount of fuel atomization greatly depends on kinematic viscosity. Although, a pure biodiesel obtained by chemical and biological methods have higher kinematic viscosity, a B20 blend reduced it significantly. It is comparable to that of commercial diesel, and hence, would lead to good vaporization, higher combustion and less emissions.

Pure biodiesel will have higher flash point. But the biodiesel obtained by chemical and biological processes have significant amount of volatile impurities which decreases the flash point moderately and is observable in most of the biodiesel obtained from various sources. The flashpoint of the biodiesel obtained from goat tallow by chemical and biological method was found to be 98 and 120 respectively. Esmaeili *et al.* (2018) have reported a slightly higher values of density (0.884 g cc⁻¹), kinematic viscosity (5.6 mm² sec⁻¹) and flash point (183.85°C) for the biodiesel obtained from goat tallow. Higher flash points were reported for animal fats obtained from different animals like 171 (chicken fat), 172 (beef tallow) and 147 (pork lard) (Mata *et al.* 2014).

The chain length of fatty acids defines the quality of biodiesel significantly. Short chain fatty acids enhance the properties of biodiesel nearly to that of commercial diesel. The

increased presence of short chain fatty acids in tallow makes it qualify as better biodiesel precursors (Hoekman *et al.*, 2012). Of different fatty acid methyl esters found in the GC-MS (Fig. 2), major FAMES present in biodiesel are pentadecanoic acid methyl ester (R_T value of 17.88 min) and octadecadienoic acid methyl ester (R_T value of 20.17 min). GC-MS indicates that these two fatty acids compose a significant percentage of total composition of methyl esters obtained from goat tallow by both the processes. Recently, Maulidiyah *et al.* (2017) also reported the presence of octadecadienoic acid with an R_T value of 21.68 min in biodiesel from industrial liquid waste of crude palm oil processing. Apart from these, tridecanoic acid (R_T value of 15 min), cyclopropaneoctanoic acid (R_T value of 21.7 min), tricosanoic acid (R_T value of 24.7 min) and tetracosanoic acid (R_T value of 26.13 min) are present in the biodiesel (Tomaz *et al.*, 2012). Zayed *et al.* (2017) reported the presence of cyclopropane octanoic acid and tetracosanoic acid in the biodiesel obtained from 75% sunflower and 25% soyabean oil.

This work provides scope for the production of biodiesel from goat tallow which is sparingly used. The biological process if properly designed can definitely be an advantage as this process is cost effective and environmental friendly.

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