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Environment-friendly Biodiesel Production from Waste Animal Fats

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Abstract: As fossil fuels are limited sources of energy, this increasing demand for energy has led to a search for alternative sources of energy that would be economically efficient and environmentally sound. The purpose of this work was to utilize available animal fat waste to produce biodiesel through transesterification. Extracted oil from beef tallow was trans esterified with methanol in presence of a KOH catalyst. The condition for transesterification was 5:1 methanol:oil molar ratio, 55-60°C temperature for are action time of 10 hours. The resulting products were confirmed by FTIR and evaluated by ASTM analyses. The resulting biodiesel exhibited moderate density (0.875g/cm 3), average dynamic viscosity (4.98 Cp at 40°C), average kinematic viscosity (5.70 cSt at 40°C), high flash point (162°C), low cloud point (4°C), low pour point (-1°C), and high calorific value (11175.20 BTU/lb).
Keywords: *alternative energy, biodiesel, transesterification, FTIR, fuel characteristics*

1. Introduction

During the last century, the consumption of energy has increased due to the change in lifestyle and significant growth of the population. This increase in energy demand has been supplied using fossil resources, which caused the crisis of fossil fuel depletion, the increase in its price and serious environmental impacts such as global warming, acidification, deforestation, ozone depletion, Eutrophication and photochemical smog. As fossil fuels are limited sources of energy, the increasing demand for energy has led to a search for alternative sources that are economically efficient, socially equitable, and environmentally sound.

Two of the main contributors to this increase in energy demand are transportation and the basic industry sectors. The transport sector is a major consumer of petroleum fuels such as diesel, gasoline, liquefied petroleum gas(LPG) and compressed natural gas (CNG) [5]. Demand for transport fuels has risen significantly during the past few decades. The demand for transport fuel has been increasing and expectations are that this trend will remain unchanged for the coming decades. In fact, with a worldwide increasing number of vehicles and a rising demand for emerging economies, demand will probably rise even harder. Transport fuel demand is traditionally satisfied by fossil fuel. However, resources of these fuels are running out; prices of fossil fuels are expected to rise. In addition, combustion of fossil fuels has detrimental effects on the climate. The expected scarcity of petroleum supplies and the negative environmental consequences of fossil fuels have spurred the search for renewable transportation biofuels [8]. Biofuels appear to be a solution to substitute fossil fuels because sources will not run out, they are becoming cost competitive with fossil fuels, they are more environment-friendly and are available for distribution and use.

Conventional fuels, however, are predicted to become scarce) as ‘petroleum reserves are limited [5]. As a result, these fuels are set to become increasingly costly in the coming decades. Renewable fuels, made from biomass, ‘have enormous potential and can meet the present world energy demand[3]. Biomass can be used for energy in several ways; one of these is the conversion into liquid or gaseous fuels such as ethanol and bio-diesel for use in mobile source combustion[13].

The potential of biofuels appears to be enormous from an economic, political and environmental perspective. The advantages of biofuels are manifold. They appear to be more environment-friendly in comparison to fossil fuels considering the emission of greenhouse gasses when consumed. The energy content of biofuels differs from conventional fuels. Total energy output per liter of biofuel is determined by the feedstock used, region where the feedstock is grown, and production techniques applied. For example, biodiesel has an energy ratio compared to diesel of about 1.1 to 1, which means that its energy contents are 87% of those of diesel[17].

Biodiesel production is a very modern and technological area for researchers as an alternative fuel for diesel engines because of the increase in the petroleum price, its renewability and the environmental advantages. Biodiesel can be produced from renewable sources such as vegetable oil, animal fat and used cooking oil. Currently, the cost of biodiesel is high as compared to conventional diesel oil because most of the biodiesel is produced from pure vegetable oil. Extensive use of edible oils may cause other significant problems such as starvation in developing countries. However, the cost of biodiesel can be reduced by using low-cost feedstock such as waste animal fat. It is estimated that the cost of biodiesel is approximately 1.5 times higher than that of diesel fuel due to the use of food grade oil for biodiesel production. It is reported that the prices of biodiesel will be reduced approximately to half with the use of low cost feedstock[16]. In the last years, meat production has increased significantly. World meat production reached 237.7 million tons in 2010, from which 42.7%, 33.4%, 23.9% corresponds to respectively pork, poultry and beef (Feddern et al., 2010). Consequently, a large volume of residues from animal processing-plants has been generated in countries with intensive livestock production. Within agro-industrial residues, lipid sources may be used as feedstock to biodiesel supply, helping to solve inappropriate environmental disposal, besides contributing to energy demand[6].

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Biodiesel is a renewable and clean source of energy. Biodiesel production from animal fat through transesterification is non-polluting. No combustion takes place in the process, meaning there is zero emission of greenhouse gasses to the atmosphere. Therefore, using biodiesel from waste as a form of energy is a smart way to combat global warming. Biodiesel generation helps cut reliance on the use of fossil fuels. In addition, the raw materials (animal fats) used in the production of Biodiesel are renewable as animals will continue to grow.
The objective of the current study was to collect pure fat and residual fat from slaughterhouse for conversion to oil by heating process. Extracted oil was trans esterified with methanol to produce biodiesel. The biodiesel produced was analyzed for various parameters by applying ASTM standard methods. Properties of biodiesel were compared with international standards to measure its quality.

2. Materials and Methods

2.1Collection of animal fats

Beef tallow was collected from a butcher shop in Sylhet and transferred in the laboratory for further processing.

2.2 Processing and analysis of fats

2.2.1 Washing and heating

The tallow collected was washed with water to remove dust and other external materials. Then it was heated at 100ºC for 90 minutes on a hot plate to extract oil from pure and residual waste.

2.2.2 Filtration

The extracted oil was filtered to remove impurities such as residual meat pieces.

2.2.3 Transesterification process

Transesterification reaction was carried out using 5:1 molar ratio of methanol to oil. 200 ml of the oil extracted from beef tallow were mixed with 40 ml methanol and 2.8-gram KOH with continuous stirring for 10 minutes at 55-60ºC.After the reaction was complete, the sample was kept in a separating funnel for 8-10 hours to separate biodiesel from residual glycerin. The resulting upper layer was distinguished as biodiesel, while the lower layer as glycerin.

2.2.4 Biodiesel production and analysis

The glycerol was removed from the bottom of the separatory funnel. The biodiesel produced was then washed with distilled water to remove excess methanol, KOH and unwanted soap. After washing, the biodiesel was dried overnight in an oven at 105ºC. Then the biodiesel was ready for use.

2.2.5 Characterization of biodiesel

The properties of biodiesel such as kinematic viscosity, dynamic viscosity, flash point, density, pour point, cloud point and calorific value were measured to analyze the quality of the biodiesel produced by following ASTM D-445, D-445, D-93, D-1298, D-97, D-5773 and D-240protocols, respectively.

3. Results and Discussion

3.1 Oil extraction from beef tallow

The beef tallow was taken in both pure and residual forms. The percentage extraction of oil was different for each sample. In case of residual tallow, one kilogram of residual beef tallow was converted into 54.17% oil On the other hand, one kilogram of pure beef tallow was converted into 89.01% oil. The difference in the conversion rates may be owed to the presence of several impurities like free fatty acids, Na, K, Ca, Mg, P, unsaponifiable matter and humidity in residual tallow(Morales et al., 2011).

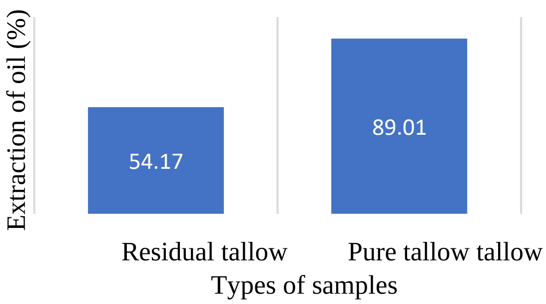

Figure 1: Percentage extraction of oil from pure and residual beef tallow.

3.2 Beef tallow analysis

The beef tallow was analyzed for the following properties. The results obtained are shown in Table 1.

3.2.1 Density

Density at 25ºC of beef tallow was 0.921 g/cm^3.The ASTM standard for the density of beef tallow at 25ºC is 0.920 g/cm^3[18]. Density of used vegetable oil (cooking oil) varies between 0.904 and 0.918 g/cm^3[4]. Therefore, beef tallow can be also used as cooking oil.

3.2.2 Viscosity

The dynamic and kinematic viscosity of beef tallow at 40℃ was 38.1cP and 43.85cSt, respectively. The ASTM standard for dynamic and kinematic viscosity of beef tallow at 40ºC are 42.6cP and 46.37cSt, respectively[14].Therefore, it can be said that the values of the viscosities determined were within the acceptable range.

3.2.3 Flash point

The flash point of beef tallow was determined at around 190℃. The ASTM standard flash point of beef tallowis202℃ (Lezsovits et al., 2012).

3.2.4 Water Content

The beef tallow used was completely water free. According to the study conducted by Lezsovits et al (2012) [12], the moisture content in animal beef tallow was found to be 0.00%.

Table 1: Properties of beef tallow.

Specifications	Beef Method	ASTM Standards	
		Results	Methods
Density at 25℃ (g/cm^3)	0.921	0.920	ASTMD-12980
Dynamic Viscosity at 40℃ (cP)	38.10	42.60	ASTMD-445
Kinematic Viscosity at 40 (cSt)	43.85	46.37	ASTMD-445
Flash Point (℃)	190.0	202.0	ASTMD-93
Water Content (%)	0.00	0.00	ASTMD-95

3.3 Biodiesel analysis

The biodiesel produced from beef tallow was analyzed for the following properties. The results obtained are shown in Table 2.

3.3.1 Density

The density of the biodiesel obtained was 0.875 g/cm^{3}at 25℃. The ASTM standard for density of biodiesel at 25℃ is 0.86-0.90 g/cm^3[2]. In this study, the density of the biodiesel produced is within this range. Therefore, it can be said that the value of the density determined was within the acceptable range.

3.3.2 Dynamic Viscosity

The dynamic viscosity of the biodiesel produced was found to be 4.98cP at 40℃.The ASTM standard for dynamic viscosity of biodiesel at 40℃ is 4.698cP[14]. The dynamic viscosity of the biodiesel produced is approximately equal to the standard value and therefore can be said to be within acceptable range.

3.3.3 Kinematic Viscosity

The kinematic viscosity of the biodiesel at 40℃was found to be 5.70cSt; the ASTM standard value is 1.9-6.0cSt[10]. Kinematic viscosity is an important element in the performance of fuels used in engines as both low and high viscosities can have negative effects on engine performance. While low viscosities do not provide sufficient lubrication for the precision fit of fuel injection pumps, high viscosities leads to the formation of large droplets upon injection[10]. As the kinematic viscosity of the biodiesel produced is within the standard values, therefore it may be used as a fuel for engines.

3.3.4 Flash point

The flash point of the biodiesel was found to be approximately 162℃. The ASTM standard for flash point of biodiesel is greater than 130℃[11]. Fuels with higher flash points are less flammable or hazardous than fuels with lower flash points. Therefore, using the biodiesel produced as fuel would pose lower risk.

3.3.5 Cloud point

The cloud point of the biodiesel was recorded at 4℃. The ASTM standard for cloud point of biodiesel is 13℃[9].

3.3.6 Pour point

The pour point of biodiesel was found be approximately -1℃. There is no standard value for pour point on the ASTM standards list of biodiesel. Heikal et al (2017)[7] determined the pour point of biodiesel produced from Jatropha oilat-3℃. Therefore, the pour points of two different oil-based biodiesels are comparable.

3.3.7 Calorific value

The calorific value for biodiesel was found to be11175.20 Btu/lb. The ASTM standard for calorific value of biodiesel is 10907.4 Btu/lb[1]. The calorific value of the biodiesel produced is less than diesel (19706Btu/lb)[10]. However, biodiesel is economically efficient and environmentally sound than diesel.

Table 2: Properties of biodiesel derived from beef tallow.

Specifications	Beef Method	ASTM Standards	
		Results	Methods
Density at 25℃ (g/cm^3)	0.875	0.86-0.90	ASTMD-1298
Dynamic Viscosity at 40℃ (cP)	4.98	4.698	ASTMD-445
Kinematic Viscosity at 40℃ (cSt)	5.70	1.9-6.0	ASTMD-445
Flash Point (℃)	162	>130	ASTMD-93
Cloud Point (℃)	4	13	ASTMD-5773
Pour Point (℃)	-1	------	ASTMD-97
Calorific Value (Btu/lb)	11175.20	10907.4	ASTMD-240

3.4 Effect of temperature on dynamic viscosity of biodiesel

The effect of temperature on the dynamic viscosity properties of the biodiesel is shown below (Figure2). The figure shows that with increasing temperature, the dynamic viscosity of the biodiesel decreases.

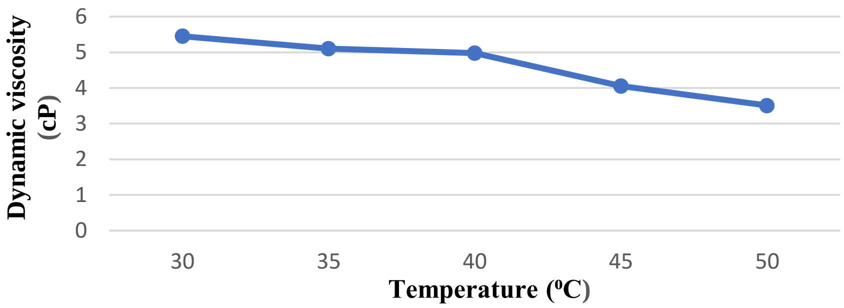

Figure2: Behavior of dynamic viscosity of biodiesel with the changes of temperature.

3.5 Effect of temperature on kinematic viscosity of biodiesel

The effect of temperature on the kinematic viscosity properties of the biodiesel is shown below (Figure 3). According to the figure, with increasing temperature, the kinematic viscosity of the biodiesel decreases.

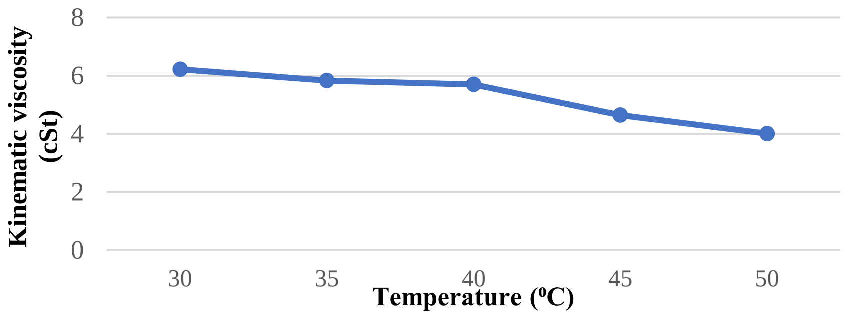

Figure 3: Behavior of kinematic viscosity of biodiesel with the changes of temperature.

3.6 Fourier-transform infrared spectroscopy (FTIR) analysis for biodiesel

To investigate the chemical composites of the biodiesel (beef tallow methyl ester) produced, fourier transform infrared spectroscopy (FTIR) test was performed, the result of which is shown below (Figure 4). The FTIR spectrum of biodiesel clearly shows the absorption band in the region of 2855–3000 cm^{-1} and 1350–1480 cm^{-1} due to C–H stretching vibration. This indicates identical functional group of alkane in their molecular structure[7] as the absorption band for petroleum diesel, which is in the region of 2855–3000 cm^{-1} and 1350–1480 cm^{-1}, indicating the presence of C–H functional group. Besides, the FTIR spectrum of biodiesel shows new absorption bands in the region of 1670–1820 cm^{-1}, which indicates the presence of the C=O functional group. The other sharp peak at 1170.79 cm^{-1} indicates the presence of oxygen in the biodiesel produced. These peaks indicate that the biodiesel transesterification reaction was close to completion.

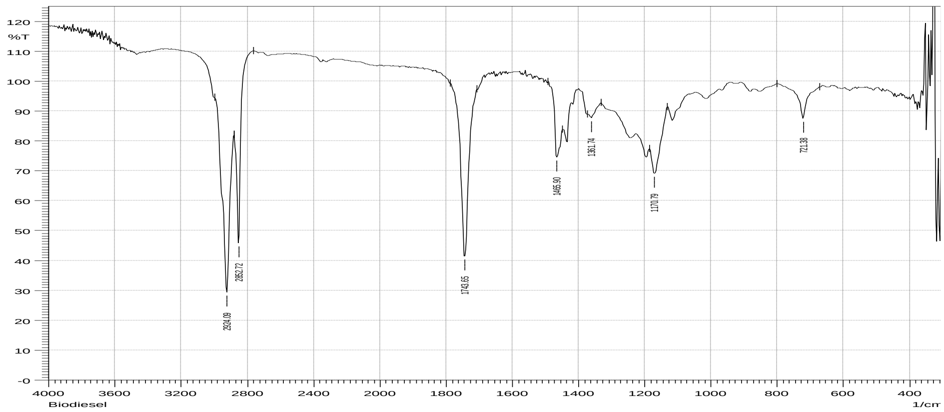

Figure 4: IR spectra of biodiesel (beef tallow methyl ester).

4. Conclusion

In terms of availability and low cost, compared to virgin vegetable oils, animal fat wastes (AFW) have been proven to be potential feedstocks for good quality biodiesel production. The use of AFWs as biodiesel feed stock reduces production costs and environmental damage. Combustion of animal fat-based biodiesel has been shown to produce lesser NOx emission than vegetable oil-based biodiesel. Over the last years, meat production has increased significantly attaining 237.7 million tons in 2010, of which 42.7%, 33.4%, 23.9% correspond to pork, poultry and beef, respectively[6]. As a result, large volumes of residues from animal processing-plants is generated in countries with intensive livestock production. Within the agro-industrial residues, lipid sources may be used to solve inappropriate environmental disposal of the animal wastes, besides contributing to energy supply. Biodiesel has a higher flash point than fossil diesel and is safer in the event of crash. Besides, other biodiesel properties such as density, viscosity, cloud point, pour point, calorific value are comparable to commercial industrial oil.

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