Production and characterization of biodiesel from the traditional tannery fleshing wastes

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ABSTRACT

The possibility of biodiesel production from traditional tannery fleshing wastes was investigated with respect to fuel properties. Based on worldwide standard procedures (ASTM specification), the biodiesel fuel properties such as iodine value, moisture content, free fatty acid, saponification value, acid value, viscosity, density, cetane number, higher heating value, and percentage yield were evaluated. The fleshing oil, which was investigated experimentally, had high acid value of 26.37 mg KOH/g and FFA level of 13.18%. As a result, acid pretreatment followed by base-catalyzed transesterification reaction was carried out to produce biodiesel. At the pretreatment stage, the acid value and FFA level were reduced to 3.93 mg KOH/g and 1.96%, respectively through sulfuric acid catalyzed esterification reaction.

Key words: Animal fat, biodiesel, catalyst, renewable energy, transesterification

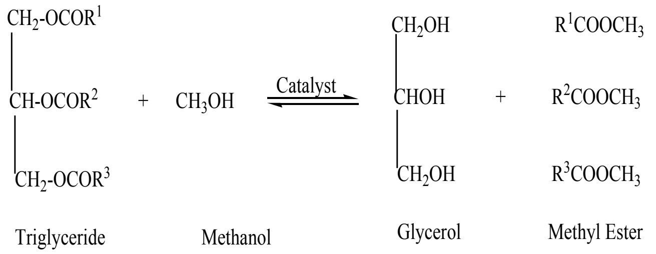
INTRODUCTION

Currently, the main energy source of our globe is mainly based on fossil fuels. However, it is associated with problems to be sustainable in the future energy scenario, particularly the rise of its price, depletion of fossil fuel and petroleum reserves and emitting of air pollutants and greenhouse gases as a byproduct which have a significant adverse impact on the environment (Sossina Haile, 2003; Martinelli and Filoso, 2008; Junhong-Chen, 2009). The large and increasing energy demand of the world is the major problem in the next 50 years. This is because, energy can affect all kinds of development in the world, like environment, livelihoods, population levels, health, access to water, agricultural productivity, and education. Additionally, energy cost and supplies also affect economic and social development (Eisenberg and Nocera, 2005; Junhong-Chen, 2009).

Due to the depletion of fossil fuel resources, increasing energy demands, unpredictability of fossil oil production, and increasing concerns of rising greenhouse gas emissions; the governments, research communities, and private organizations around the world are looking for alternative and renewable energy sources. These renewable energy sources should be technically feasible, competitive in price compared with the existing source of energy, environmentally friendly, abundantly available, and sustainable. One promising renewable energy source is biodiesel, a green fuel that has various advantages compared with fossil fuel in terms of renewability, non-toxicity and biodegradability (Mittelbach and Remschmidt, 2004).

Biodiesel is a renewable source of energy which can be used as a car fuel substituting fossil fuel and petroleum and hence lowering the issue of global warming. Such a renewable source of energy, which can be generated easily from wastes, serves as a clean energy source besides reduction of environmental pollution (Vivek and Gupta, 2004).

Biodiesel fuels can be obtained by the transesterification of oils in a batch reactor which involves an alcohol in the presence of a catalyst. The most common catalysts used for biodiesel production are homogeneous liquid catalysts, such as NaOH and KOH. The universal reaction equation for the transesterification of triglycerides with methanol for the production of biodiesel is shown in Scheme 1 (Budiman, 2012; Upadhyay and Sharma, 2013).



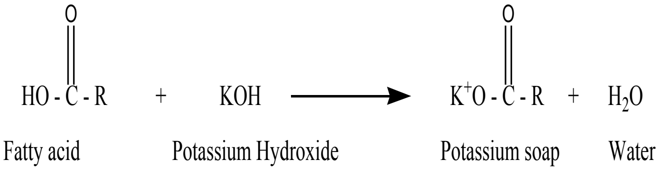
Scheme 1 Transesterification reaction of vegetable oils or fats.

The feedstocks for biodiesel production are vegetable oils, animal fats and short chain alcohols. The oils used for global biodiesel production are rapeseed, soybean, palm, and sunflower, though others such as peanut, linseed, safflower, vegetable oils, and animal fats are used. Methanol is the commonly used alcohol in the production of biodiesel to be reacted with the fat or oil in the presence of catalyst though ethanol can also be used (Romano *et al*., 2006; Kywe and Oo, 2009; Budiman, 2012; Upadhyay and Sharma, 2013).

Besides, the low cost of non-edible oils as raw materials for biodiesel production, the utilization of these oils does not affect the food chain of mankind (Romano *et al*., 2006; Kywe and Oo, 2009). These reasons have led to medium and large scale biodiesel production assessments from non-edible oils such as castor oil, tung, cotton, jojoba and jatropha in numerous countries. Although animal fats such as the fats from cattle, pork, poultry, and fish are solids which need preliminary action, they are also fascinating options especially in countries with prosperity of livestock resources like Ethiopia (Romano *et al*., 2006; Kywe and Oo, 2009).

In this study, traditional tannery fleshing wastes (fleshing cattle fat wastes) from Bahir Dar, Ethiopia was the raw materials used for the production of biodiesel in an environmentally friendly and cost effective way. Because, disposal of these wastes to the environment may harbor pathogenic microorganisms resulting in environmental pollution and health risks. Therefore, especial attention is given to these wastes on handling and converting to value added materials.

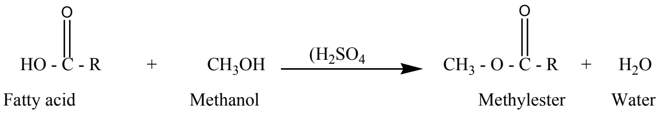
Vegetable oil usually contains unsaturated fatty acids in the range 2 to 7% while animal fat containing 5 to 30%. During transesterification of a feedstock with high free fatty acid (FFA) content, soap formation (saponification) could take part leading to reduction of the biodiesel quality. Besides, the feedstock with higher free fatty acid makes the product separation difficult (Scheme 2). To minimize the aforementioned problems, it is already recommended to conduct an esterification step as a pretreatment step (Gerpen, 2005; Alptekin *et al*., 2012; Plšek and Vašek, 2012; Eshetu Getahun and Niguse Gabiyye, 2013) so that the free fatty acids could be converted to esters than to soap (Scheme 2).



$$HO-\overset{\overset{O}{\|}}{C}-R + KOH \longrightarrow K^{+}O-\overset{\overset{O}{\|}}{C}-R + H_2O$$

Scheme 2 Saponification reaction of free fatty acids.

The pretreatment step is esterification of the free fatty acids in the oil with methanol in the presence of sulfuric acid as a catalyst (Scheme 3). After the esterification reaction, the treated fat can be transesterified intending to convert the triglycerides in the fat to methyl esters under an alkali catalyst (Gerpen, 2005; Eshetu Getahun and Niguse Gabiyye, 2013) (scheme 3):



$$HO-\overset{\overset{O}{\|}}{C}-R + CH_3OH \xrightarrow{(H_2SO_4} CH_3-O-\overset{\overset{O}{\|}}{C}-R + H_2O$$

Scheme 3 Esterification reaction of free fatty acids.

The objective of this study was to characterize the biodiesel obtained by the alkali catalyzed transesterification of traditional tannery wastes in Bahir Dar city, Ethiopia.

EXPERIMENTAL

Materials

Enough amount of fleshing cattle fat wastes (1.5 kg) were collected from Bahir Dar Traditional Tannery found in Bahir Dar, Ethiopia as main raw materials.

Chemicals and Reagents

Analytical grade ethanol (99%, Aldrich), was used for the reaction, KOH (92%) as catalyst, toluene (99%), sulfuric acid (98%), potassium iodide, Phenolphthalein, diethyl-ether, iodine, toluene (99%), bromine liquid, sodium thiosulphate, and hydrochloric acid were used for raw material treatment and biodiesel characterization.

Instruments

Oven, pH meter, Hydrometer, Pycnometer, Viscometer, Thermometer, Heating mantel, Hot plate magnetic stirrer, Electrical Balance (ae ADAM, PW 124), Separator funnel, Distillation flask, and Reflux condenser.

Preparation of raw materials

1.5 kg of fleshing cattle fat wastes was collected from traditional tannery found in Bahir Dar, Ethiopia, and then triplicate batches were prepared to undertake extraction process. The batch samples were prepared from solid waste fleshing sample mixed with sufficient water. In order to break the fat-protein bond in the fleshing material, the mixture was heated at a temperature of 70 – 90 °C for 2 hrs. Three different phases; solid phase, liquid fat phase (upper layer) and liquid impurity (protein) phase (lower layer) were formed. After the separation of the solid phase by decantation, the fat phase (fleshing oil) was separated from the impurity (protein) using a separator funnel.

Esterification reaction (Pretreatment of fleshing oil)

The free fatty acid of fleshing oil was 13.18%, which may suppress production of biodiesel due to soap formation and makes the product separation difficult. As a result, before the transesterification step, an esterification pretreatment step of the fleshing oil with ethanol was conducted. Sulfuric acid (98 %) and ethanol (99%) were used as catalyst and alcohol, respectively for the pretreatment of fleshing oil at ethanol to oil ratio of 6:1 and then the mixture was heated at 65 °C for 1 hr (Eshetu Getahun and Niguse Gabiyye, 2013; Mebrahtu Haile *et al*., 2013; Mata *et al*., 2014). Finally, the pretreated oil was characterized in order to confirm whether these parameters met international standard or not to proceed to the next (transesterfication) step.

The physicochemical characteristics of the fleshing oil, pretreated oil, and the produced biodiesel were determined experimentally. For each physicochemical characterization the mean of the triplicate samples was taken as final value for calculation. The experimental outcome of physicochemical characterization of fleshing oil, pretreated oil, and the produced biodiesel were calculated by their respective formula shown below.

Transesterification reaction of the pretreated oil

The transesterification reaction was carried following the procedure reported by Eshetu Getahun and Niguse Gabiyye (2013). Molar ratio between alcohol (ethanol) and pretreated oil mixture was selected at 6:1, which is the best ratio as reported elsewhere (Eshetu Getahun and Niguse Gabiyye, 2013, Mebrahtu Haile *et al*., 2013; Mata *et al*., 2014). The reaction temperature was selected to be 65 °C, in 1 hr reaction time. Before transesterification reaction, the ethoxide was prepared by reacting 1% catalyst (Potassium hydroxide) with ethanol using magnetic stirrer for 20-30 min. When particles of potassium hydroxide were completely dissolved, then the ethoxide was added to the pretreated oil followed by heating at 65 °C for 1 hr. When the pretreated oil and ethoxide was contacted the alkali-catalyzed transesterification reaction was started. The mixture was allowed to cool overnight at ambient temperature. It was observed that the resulting mixture from the reaction had settled into two separate layers with the glycerol layer at the bottom and the crude ethyl esters over it (Figure

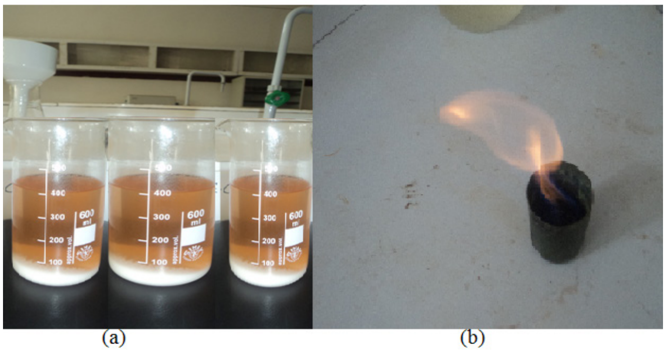


Figure 1. (a) biodiesel products before separation of glycerol and (b) flame of biodiesel

1 (a)). The ester phase was collected and excess ethanol was removed by boiling at 75 °C for 1 hr. The crude biodiesel was washed with hot water several times in order to remove out the remnants; catalyst, soap, suspended glycerol and other impurities. Finally, the product was characterized based on international standards (ASTM).

Determination of Physico-Chemical properties of fleshing oil, pretreated oil and the produced biodiesel

Determination of density

Density was determined using Pycnometer (50 mL, KW 14/23) (Sivaramakrishnan and Ravikumar, 2012; Abdullah *et al*., 2013). A 50 mL volume Pycnometer (V_p) was washed, dried and its mass was recorded as mass of Pycnometer (M_p). The Pycnometer was filled with the fleshing oil up to the marked level and was recorded as mass of the oil and Pycnometer (M_{sp}). Then, the density (g/mL) of the fleshing oil was calculated using Equation 1. The same producer was followed for the determination of pretreated oil and the produced biodiesel.

$$Density = \frac{M_{sp} - M_p}{V_p} \qquad (1)$$

Where V_{P} is the volume of Pycnometer (mL) which is equal to the volume of the fleshing oil.

Determination of viscosity and moisture content

The viscosity and moisture content of the fleshing oil were calculated using the method described elsewhere (ASTM, 1998). The viscometer (falling ball viscometer) was cleaned and filled with the fleshing oil. After that, the ball with known diameter (D_b) was introduced at one end and allowed to move to the other end of the viscometer by gravitational force. This step was repeated and then the time taken by the ball to travel between two marks within the viscometer was recorded (T_b) for each measurement and the average value was taken for calculation. Finally, a ball constant (K) and viscosity of fleshing oil, was calculated using Equation 2 and 3, respectively. This producer was employed to determine the viscosity of the pretreated oil and the produced biodiesel.

$$K = \frac{2}{9} r^2 \frac{g}{s} \qquad (2)$$

$$Viscosity = \frac{K(SGB - SGS)t}{(1 + 2.4\frac{r}{R})(1 + 3.3\frac{r}{L})} \qquad (3)$$

Where: SGB, SGS, K, R, L, r, t, g and s are, specific gravity of ball, specific gravity of sample, ball constant, inner radius of the cylinder (cm), total length of cylinder (cm), radius of a ball (cm), falling time of the ball (sec), gravitational acceleration (m/s^2), falling distance covered by the ball or distance between two marks (cm), respectively.

To measure the moisture content, the weight of a small beaker containing 30 mL of flesh oil was measured and recorded as W_{in} (Sirisomboon and Kitchaiya, 2009; Mebrahtu Hail *et al*., 2013). The beaker containing the flesh oil was dried at 110 ^{o}C in an oven and the weight was measured at every 2 hrs interval until constant weight was obtained. The constant weight was recorded as W_f and the percentage moisture content of fleshing oil was calculated using Equation 4. The moisture content of pretreated oil and the produced biodiesel were determination following the same producer.

$$\text{Moisture content (\%)} = \frac{W_{in} - W_f}{W_{in}} 100\% \qquad (4)$$

Determination of Acid Value and Free Fatty Acid Value

Acid value (AV) and free fatty acid (FFA) value were determined following the procedures reported (ASTM, 1998; Nahak *et al*., 2010). Toluene and ethanol, each 25 mL were mixed in a beaker to which 2 g of fleshing oil and 3 drops of phenolphthalein were added. The mixture was then titrated against 0.1 M potassium hydroxide under a continuous swirling until deep pink color persists. The total volume of potassium hydroxide consumed was recorded (V_{KOH}). Titration was repeated in the same manner and the average volume of KOH was taken for calculations. Finally, acid value and percentage of free fatty acid value were calculated using Equation 5 and 6, respectively. The acid and free fatty acid values of pretreated oil were achieved with the same producer.

$$\text{Acid value (AV)} = \frac{V_{KOH} C M_w}{W_s} \qquad (5)$$

$$\text{Free fatty acid (\%FFA) value} = \frac{1}{200} \text{AV } 100\% \qquad (6)$$

Where: M_W, Ws and C are the molecular weights of potassium hydroxide (g), weight of fleshing oil sample (g), and concentration of potassium hydroxide (M), respectively.

Determination of Saponification Value

Saponification value (SV) of biodiesel was determined by using standard methods (ASTM, 1998; Nahak *et al*., 2010; Eshetu Getahun and Niguse Gabiyye, 2013). 1 g of biodiesel sample and 25 mL of 0.5 M potassium hydroxide was mixed in beaker, 4 mL of ethanol-ether solution was added, and then the mixture was refluxed for 30 minutes using hot plate heat magnetic stirrer followed by cooling. 3 drops of phenolphthalein was added to the mixture and then the mixture was titrated against 0.5 M hydrochloric acid while regular swirling until faint pink color permanently vanishes, and the consumed volume by the sample was recorded as V_a. The blank titration was also carried out using the same procedure in the absence of biodiesel sample, and then the consumed volume by blank solution was recorded as V_b. Finally, the Saponification value of biodiesel was calculated by using Equation 7.

$$\text{Saponification Value (SV)} = \frac{Mw_{KOH} M (V_b - V_a)}{W_s} \quad (7)$$

Where: M, Mw_{KOH} and Ws are concentration of hydrochloric acid (M), molecular weight of potassium hydroxide (g) and weight of biodiesel sample (g), respectively.

Determination of Iodine Value

The iodine value (IV) of the biodiesel was determined by the method described in (Eshetu Getahun and Niguse Gabiyye, 2013; Leal *et al.*, 2008). It was performed by mixing 1 g biodiesel sample together with 10 mL chloroform and 25 mL of hanus solution, and allowed to keep in dark place for 30 minutes. Onwards, 10 mL of 15% potassium iodide solution was added to the mixture and then the mixture was titrated against standardized sodium thiosulphate. Consequently, the volume of titrant (sodium thiosulphate) solution consumed by sample was recorded as V_t. The blank titration was carried out through the same procedure in the absence of biodiesel sample, and then the volume of titrant solution consumed by the blank solution was recorded as V_b. These titrations were repeated in the same manner and the average values of titrant volume were taken for calculation. Finally the iodine value of biodiesel was calculated as follow.

$$\text{Iodine value (IV)} = \frac{Mw_{KOH} C_t (V_b - V_t)}{W_s} \quad (8)$$

Where: C_t, Mw_{iodine} and Ws are concentration of standardized sodium thiosulphate (N), molecular weight of iodine (g) and weight of biodiesel sample (g), respectively.

Determination of Cetane Number and Higher Heating Value

The Cetane number (CN) and higher heating value (HHV) (MJ/Kg of oil) of the biodiesel was determined using ASTM D 613 standard procedures through the following empirical formula as described in (Cocks and Vanrede, 1984; Eshetu Getahun and Niguse Gabiyye, 2013). The calculation was based on the results from saponification value (SV) and iodine value (IV) of oil.

$$\text{Cetane number(CN)=}\ 46.3 + \left(\frac{5458}{SV}\right) - (0.225IV) \quad (9)$$

$$\text{HHV} = 49.43 - \left[\frac{(0.041SV) + (0.015IV)}{W_s}\right] \quad (10)$$

Determination of Percentage Yield

The percentage yield of biodiesel was determined using ASTM D 613 standard procedures using Equation 11 as stated elsewhere (Cocks and Vanrede, 1984; Eshetu Getahun and Niguse Gabiyye, 2013). It was calculated based on the weight of glycerol obtained with 90% purity as noted by (Addison, 2009).

$$\%\text{Yield} = \frac{0.9(W_{glyserol})\dfrac{Mw_{FAEE}}{Mw_{glyserol}}}{W_{initial}}100 \qquad (11)$$

Where: $W_{initial}$, $W_{glycerol}$, $Mw_{glycerol}$ and Mw_{FAEE} are weight of fleshing initially used (g), weight of glycerol produced (g), molecular weight of glycerol (g) and molecular weight of fatty acid ethyl ester (g), respectively.

Each experimental fuel properties for the determination of biodiesel, replicate samples were treated and their average value was taken as final value of measurement for calculation. In this study, the physicochemical properties of the fleshing oil, pretreated oil, and the produced biodiesel were determined so that the fuel quality can be compared against the standards set by ASTM international standard specification for biodiesel.

RESULTS AND DISCUSSION

Biodiesel was produced from traditional tannery waste fleshing by alkali-catalyzed transesterification reaction. In the production of the biodiesel, three steps; oil extrication step, oil pretreatment or esterification step and biodiesel production step were carried. At the end of this fleshing oil extraction process, 0.5 L fleshing oil was obtained from 1.5 Kg waste fleshing fat raw material. After that, the extracted fleshing oil was characterized experimentally.

Physicochemical Characteristics of the Fleshing Oil, Pretreated Oil, and the produced Biodiesel

The density of the fleshing oil was reduced to 895 kg/m^3, viscosity to 8.25 mm^2/s, acid value to 3. 93 mg KOH /g, free fatty acid to 1.96 %, at the oil pretreatment stage. The experimental results of the physicochemical characteristics of fleshing oil and pretreated oil are shown in Table 1. The quality control standards for biodiesel production were covered under ASTM D 6751 (ASTM, 1998; ASTM, 2002). These standards descried the fuel properties of conventional biodiesel fuel, in other word; they list out fuel properties that biodiesel must have in order to use as diesel fuel. The experimental outcome of the physicochemical characterization over ethyl ester product was discussed as follows.

Determination of Density

The density of biodiesel or ethyl ester produced was measured by Pycnometer and the result of the experiment was 873 kg/m^3. According to quality control standards for biodiesel production, the density of biodiesel had to lie down on the range of 850 to 880 $\frac{kg}{m^3}$ (Demirbas, 2006). The experimental result confirm the density of the product was found within standard value range and also it shows that the higher density of extracted fleshing oil; 900 kg/m^3, was reduced to 895 kg/m^3 after esterification reaction, this result was further reduced to 873 kg/m^3 through alkali-catalyzed transesterification reaction.

Many scholars have studied the properties of biodiesel and was achieved density of 903.17 kg/m^3 from *Jatropha curcas* oil Seed (Akbar *et al*., 2009), 922.8 kg/m^3 when waste coffee ground was used as a substrates (Mebrahtu Haile *et al*., 2013), 883, 870, 872, and 886 kg/m^3 from chicken fat, beef tallow, pork lard, and sardine oil, respectively (Mata *et al*., 2014). Hence, the current study has a good agreement with the standard specification as compared to the densities of *Jatropha curcas* oil Seed and waste coffee ground values.

Determination of Viscosity

During the experiment, the higher viscosity value (35.75 mm^2/s) of fleshing oil was diminished to lower accepted value through esterification reaction followed by alkali-catalyzed transesterification reaction. After that, the viscosity of biodiesel was measured by falling ball viscometer and using Equation 2 for calculation, the viscosity of biodiesel was found to be 4.15 mm^2/s. As mentioned by the quality control standards for biodiesel production (ASTM specification), biodiesel can be used as diesel fuel only if its viscosity value lies down on the range of 1.9 mm^2/s to 4.1 $\frac{mm^2}{s}$ (Demirbas, 2006). The viscosity obtained from babassu, rapeseed, soyabean, sunflower, peanut, and palm was 3.6, 4.2, 4.5, 4.5, 4.9, and 5.7 mm^2/sec, respectively as reported in (Sivaramakrishnan and Ravikumar, 2012). The viscosity (4.15 mm^2/s) obtained in of this study shows that the produced biodiesel had almost the acceptable viscosity.

Determination of Saponification Value (SV)

Saponification value depends on the kind of fatty acid enclosed in the fat. It measures the average molecular weight (chain length) of all fatty acids present. As the majority of the mass of a fat is in the free fatty acids, it allocates for evaluation of the average fatty acid chain length. The experimental saponification value measurement was done according to the ASTM D 5558 standard procedure and Equation 7

Table 1. Physicochemical properties of fleshing oil and pretreated/esterified oil.

No	Property	Unit	Fleshing oil	Pretreated oil
1	Moisture content @ 383.15 K	% mass	0.10	0.03
2	Density @ 298.15 K	kg / m^3	900	895
3	Viscosity @ 313.15 K	mm^2 /s	35.75	28.25
4	Acid value	mg KOH /g	26.37	3.93
5	Free fatty acid value	%	13.18	1.96

was used for calculation (ASTM, 1998; Nahak *et al.*, 2010; Eshetu Getahun and Niguse Gabiyye, 2013). The saponification values of *Jatropha Curcas* oil seed, leather industry fleshing wastes, corn germ oil, and Jatropha (*Jatropha curcas* and *Jatropha gossipyfolia*) were 193.55±0.61 mg KOH/g (Akbar *et al*., 2009), 185.2 mg KOH/g (Eshetu Getahun. and Niguse Gabiyye, 2013), and 193.7 mg KOH/g (Giwa *et al*., 2012), and 193 mg KOH/g (Nahak *et al*., 2010), respectively. However, the saponification value of this study was 173.8 mg KOH/g oil, which is in good agreement with the reported works. This result means that 173.8 mg of potassium hydroxide was needed to saponify one gram of fat.

Determination of Iodine Value

The experimental determination of iodine value of biodiesel was carried out according to the ASTM D 5558 and EN 14214 standard procedure and Equation 8 was used for calculation (ASTM, 1998; Demirbas, 2009; Eshetu Getahun and Niguse Gabiyye, 2013). Then, the experimental outcome shows that iodine value of the produced biodiesel was 55.6 g I_2/100 mL of oil. The outcome of the experimental work indicates 55.6 gm of iodine was absorbed by 100 mL of oil. Iodine value higher than 50 g I_2/100 mL may result engine life decrement, however, it gives better viscosity characteristics in cooler situations (Leal *et al*., 2008). According to the international standard method (EN 14214) the upper limit of iodine value is 120 g I_2/100 mL (Demirbas, 2009). Therefore, the produced biodiesel from fleshing oil could not show viscosity problem in engine performance because the experimental result showed that its iodine value is larger than 50 g I_2/100 mL and less than 120 g I_2/100 mL. Several researchers have investigated on the fuel properties of biodiesel, and achieved the iodine values of waste groundnut oil 106 g I_2/100 mL (Anitha and Dawn, 2010), Jatropha oil 100.1 g I_2/100 mL (Kywe and Oo, 2009). All are lay down on the international standard range as stated by EN 14214 method.

The Cetane numbers of babassu, rapeseed, soyabean, sunflower, peanut, and palm were 63, 54, 45, 49, 54, and 62, respectively (Sivaramakrishnan and Ravikumar, 2012), while the high heating value and percentage yield of chicken fat, beef tallow, pork lard, and sardine oil are 39.4, 40, 39.9, 39.7 MJ/kg and 76.8, 90.8, 91.4, 89.5 %, respectively (Mata *et al*., 2014). The Cetane number, higher heating value and percentage yield of this study are 65, 43.13 MJ/kg, and 93 %, respectively (Table 2). The experimental results of the physicochemical characteristics of biodiesel are shown in Table 2.

CONCLUSION

The biodiesel production from traditional tannery wastes was investigated, and the fuel properties of the produced biodiesel were studied based on the conventional standards. Many studies have been done worldwide after releasing the implication of biodiesel. The result obtained is quite positive

Table 2. Physicochemical properties of Biodiesel

No	Property	Unit	Biodiesel
1	Density @ 298.15 K	kg / m^3	873
2	Viscosity @ 313.15 K	mm^2 / s	4.15
3	Moisture content	% mass	0.03
4	Iodine value	g I_2/100 ml of oil	55.60
5	Saponification Value	mg KOH/g oil	173.80
6	Cetane number (*CN*)	_	65
7	Higher heating value (*HHV*)	MJ/kg	43.13
8	Percentage yield	%	93

for further investigation because the process of esterification is restricted to eco-friendly alkali-catalyzed transesterification.

Because of the high level of FFA content in this study, two-step reaction was favored to process left over fleshing oil, that is, acid pretreatment followed by alkali-catalyzed transesterification. The first acid-catalyzed esterification step, carried out at 65 ^{o}C for 1 hr, reduced the FFA level from about 13.18% to 1.96%. The second alkali-catalyzed transesterification step transformed the esterified fleshing oil into biodiesel under the conditions reaction of 6:1 molar ratio of ethanol to oil; 1 % potassium hydroxide; 65 ^{o}C, and obtained a percentage yield of 93% at the transestrification stage in1 hr. Analytical method based on the ASTM specification standard confirmed the production of better class biodiesel from traditional tannery fleshing wastes. The biodiesel obtained from traditional tannery fleshing wastes has fuel properties that met the ASTM D 6751 standard. Therefore, as an economical feedstock and minimization of environmental pollution, traditional tannery fleshing wastes can be potentially used as a raw material for biodiesel production on a marketable scale.

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