

Base-transesterification process for biodiesel fuel production from spent frying oils

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ABSTRACT

The concept of converting recycled oils to clean biodiesel aims towards reducing the amount of waste oils to be treated and lowering the cost of biodiesel production. Samples of waste oils were prepared from Spent Frying oil collected from local hotels and restaurants in Khartoum, Sudan. Selected methods to achieve maximum yield of biodiesel using the waste feedstock were presented and compared. Some properties of the feedstock, such as free fatty acid content and moisture content, were measured and evaluated. Biodiesel yield recovery obtained, from Base-transesterification process about 92%. Produced Biodiesel specifications were also analyzed and discussed in Base-transesterification process. Kinematic viscosity of biodiesel was found to be $5.51 \text{ mm}^2 \cdot \text{s}^{-1}$ at 40°C , the flash point was 174.2°C and Cetane No of 48.19. Biodiesel was characterized by its physical and fuel properties according to ASTM and DIN V 51606 standards.

Keywords: Base-Transesterification; Biodiesel; Spent-Frying-Oil; Fuel

1. INTRODUCTION

The energy crises of 1979, which caused some alternative energy sources, were investigated; so Biodiesel was introduced [1-3]. The use of vegetable oils is Soybean oils and Sunflower oil as feed. Spent vegetable oil from recycled fried oil was investigated to reduce pollution of the environment [4-12]. In Sudan major vegetable oils are produced from Peanut, Sunflower, Sesame and Cottonseed oils. The consumption of Vegetable oils in Sudan is about 260,000 t/y. The spent vegetable oils from frying at Homes, Restaurants and Hotels are estimated to be 42,000 t/y.

Transesterification of a vegetable oil was conducted as early as 1853, by scientist E. Duffy and J. Patrick. Rudolf

Diesel's prime model ran on its own power for the first time in Augsburg, Germany on August 10, 1893, has been declared International Biodiesel Day. Diesel later demonstrated his engine and received the "Grand Prix" (highest prize) at the world fair in Paris, France in 1900. This engine stood as an example of Diesel's vision because it was powered by peanut oil. He believed that the utilization of biomass fuel was the real future of his engine. In 1912 speech, Rudolf Diesel said: the use of vegetable oil as engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time. During the 1920 the diesel engine manufactures altered their engines to utilize the lower viscosity of the fossil fuel (petro diesel) rather than vegetable oil, a biomass fuel. The petroleum industries were able to make inroads in fuel market because their fuel was much cheaper to produce than the biomass alternatives. The result was, for many years, a near elimination of the biomass fuel production infrastructure. Only recently there have environmental impact concerns and a decreasing cost differential made biomass fuels such as biodiesel, a growing alternative.

The International Energy Outlook (IEO) 2007 reference case projects increased world consumption of marketed energy from all sources over the 2004 to 2030 period. Worldwide fuel liquids consumption, increase from 83 million barrels per day in 2004 to 118 million barrels per day in 2030 [11-15]. Liquids fuels remain the most important fuels for transportation. Transportation accounts for 68% of the total projected increase in liquids use between 2004 and 2030, the industrial accounts for 27% in world liquids demand. The objective of this work is the management of spent frying oils.

2. MATERIALS AND METHODS

2.1. Material

2.1.1. Sampling

Spent frying oil which was produced after deep frying of food was collected and used as feed stocks of biodie-

sel production. Spent frying oil was classified to sample (A).

2.1.2. Chemicals

- Alcohol (Methanol, Ethanol).
- Base catalyst (NaOH, KOH, K_2CO_3 , etc).
- Acid catalyst (H_2SO_4).
- Drying salt (Na_2SO_4).

2.1.3. Equipments

- Stirrer hot plate,
 - Oven,
 - Filter,
 - Condenser,
 - Thermometer,
- Gas chromatography mass spectrometer.

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2.2. Methods of Samples Preparations

The sample was prepared by sedimentation the waste oils, passed through thieve about (90 micron) to filtrate the sample and the raw materials were analyzed to determine the moisture content, density and free fatty acid content.

Process of Biodiesel Fuel Production by Base-Transesterification of Sample (A)

100 g of the sample (A) were weighted and placed on a hot plate, in around bottom flask equipped with a magnetic stirrer and a thermometer. The oil was stirred and heated at (60°C to 65°C), freshly sodium meth oxide solution was prepared by mixing (25 gm methanol with 0.5% of the sample NaOH) and added into the flask, the mixture was heated and stirred for 1 hr. After this time, the flask was removed from the hot-plate and the products of reaction were allowed to settle for several hours to produce two distinct liquid phases. The top phase (crude ester) was separated from bottom phase (glycerol) by decantation, then washed for 3 times by a warm water heated in 80°C to remove the excess catalyst until the wash water become clear. The ester phase was finally dried at 100°C for 30 minutes. The final product; biodiesel was obtained as a clear, light yellow liquid. **Figure 1** shows the schematic block diagram of the biodiesel production process.

- Theoretical calculation

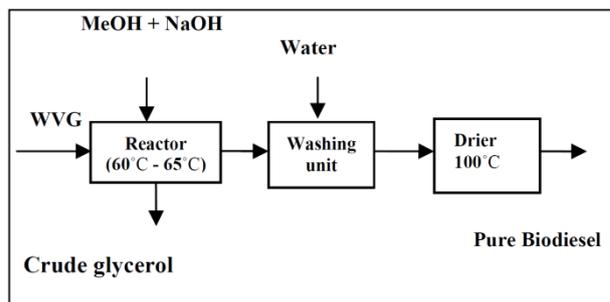
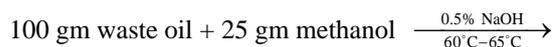
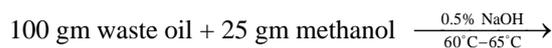


Figure 1. Block diagram of biodiesel produced by base-trans-esterification process of sample (A).



100 gm biodiesel + 25 gm glycerol

- Mass balance:



92.2 gm biodiesel + 15.3 gm glycerol

Yield percentage of biodiesel recovery is about = 92.2%

From equation:

Input = output + losses

The losses = 100 – 92.2 = 7.8

7.8% the yield losses due to triglyceride saponification and methyl ester dissolution in the glycerol phase.

Yield percentage of by product glycerol recovery is about = 15.3% with efficiency about 61.2%.

2.3. Qualitative Analysis of Biodiesel Using Gas Chromatograph-Mass

The GC serves to separate mixtures into component. The separation is based upon the retention of the analyses between two phases (the stationary liquid analyses between two phases (the stationary liquid phase and the mobile gas phase). The interface directs the effluent of the GC Column into the mass spectrometer.

The mass spectrometer consists of three components:

- 1) Ion source,
- 2) Mass filter or
- 3) Quadruple and Detector (continuous dynode electron multiplier).

All components of system are controlled via MS DOS Chem. Station. The data software Includes programs to calibrate MSD acquire data, process data and file management and Editing.

The gas chromatographic/mass spectral analyses were carried out using Gas Chromatograph Mass Spectrometer QP-2010-Shimadzu Instrument operating on EI (Electron Impact) Mode, using the followed conditions:

Helium at 1 ml/min was used as the carrier gas. Room temp: 26°C and Humidity: 31%.

Physical and Chemical properties of biodiesel product analyzed by (ASTM).

The American Society for Testing and Materials is an

international standards organization which has set the property requirements, testing criteria and quality control methods for biodiesel B100. This is known as ASTM.

Biodiesel was tested according to ASTM No: D1298, D445, D92, D130, D976, and D524.

Environmental conditions: Temp: 19.9°C and Pressure: 96.8 kPa.

3. RESULTS AND DISCUSSION

The analysis of the product showed, the results were carried out with the objective to manage spent frying oil to produce biodiesel, to help in disposal problems of used fried oil and reduced contamination of water and land resources. **Tables 1** and **2** show the results of raw materials and the biodiesel produced, respectively.

ASTM and DIN standard which are 100C minimum, copper strip corrosion rating is (1a) which is the same with Din standard and suitable when comparing with ASTM (3b max), also cetane No is about 48.19, it was higher than the ASTM standard which is 40 minimum, the viscosity @ 40°C is 5.521 mm²/s, it was a good result to flow biodiesel, when comparing with ASTM standard rang (1.9 - 6.0 mm²/s). Finally 10% distillation carbon residue is about 1.191% was v. high and not acceptable, by comparing with ASTM and Din standard.

Table 3 shows the comparison between Base-transesterification processes of biodiesel product properties with ASTM and Din standard, which was found that the process was suitable to produce pure biodiesel.

4. CONCLUSIONS AND RECOMMENDATIONS

The methyl ester was prepared from spent frying oils with methanol to produce biodiesel by base-transesterification process, and was successfully performed with a maximum biodiesel yield of 92 wt% and methyl ester purity of 100%.

Table 1. Analysis results of raw materials (spent frying oils) of sample (A).

Item	Sample A
Moisture Content %	0.29
Density, g/cm ³	0.92
Free Fatty Acid as Oleic Acid	0.48

Table 2. Yield results under select method conditions, of sample (A).

Parameter	Biodiesel Produced by Base-Transesterification
Biodiesel Yield wt%	92.2
Glycerol Yield wt%	15.3

Table 3. Comparisons of biodiesel product properties with ASTM and DIN V 51606 standard.

Item	Base-transesterification	ASTM standard	DIN V 51606 standard
Density, S.G @ 15°C g/ml	0.8873	-	0.875 - 0.900
Flash point (COC)	174.2°C	100°C min	100°C min
Copper Strip Corrosion Rating	1a	3b max	1
Cetane Index	48.190	40 min	49 min
Viscosity @ 40°C mm ² /s	5.5211	1.9 - 6.0	3.5 - 5.0
10% distillation Carbon Residue	1.19%	0.05%	0.30% max

Select methods and biodiesel yield may vary in terms of the quality of raw oils. The fuel properties of biodiesel derived from spent frying oils, all met the ASTM standard and German Biodiesel Standard.

Production of biodiesel from waste cooking oils for diesel substitute is particularly important because of the decreasing trend of economical extracted oil reserves and the environmental problems caused by the use of fossil fuel. Waste cooking oil can be an important source for biodiesel production in Sudan as there is large quantity of waste cooking oil available. Use of waste cooking oil helps to improve the biodiesel economics.

The results of the tests and calculations carried out show that the techniques employed for the process are possible to scale up this process for industrial use.

Assist the researchers to continue in this sector of alternative biofuel.

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