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Production of biodiesel from waste cooking oil issued from restaurants of Adrar city in Algeria

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***Abstract*— Biodiesel is a promising biofuel and has a lot of great prospective and could become an alternative to fossil fuels. To diversify energy sources ,dispensing of fossil fuels and significant disadvantages of using diesel, such as global warming issues, air pollution and the security of energy are the main concerns that have directed interests to green and sustainable energy. In this work, biodiesel (ethyl ester) was prepared from waste cooking oil (WCO) collected from a local restaurant in Adrar city (Algeria) at the laboratory scale. This paper is focused on determination of optimum conditions of the reactant and catalyst concentration for the production of biodiesel. The effect of alcohol type is studied. The free fatty acid value of WCO was found to be 0.6%, rendering the one step alkaline transesterification method for converting WCO to their ethyl esters possible. The optimum production parameters: catalyst amount, alcohol amount, temperature were optimised and found to be: 1.0 wt% catalyst amount, alcohol to oil molar ratio 6:1, and 40 °C reaction temperature.**

***Keywords*— Biodiesel, Waste cooking oil, Transesterification.**

I. Introduction

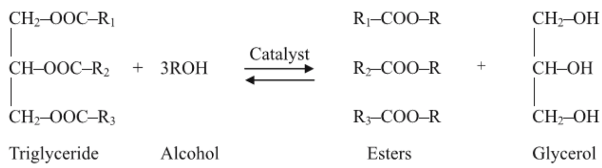
The instability oil prices and its impact in the environment have provided an impetus for research into the production of biofuels. Biodiesel is one of most attractive biofuel [1] because its biodegradability reduced production of most regulated exhaust emission [2], higher flash point and contributes to sustainability [2] and [3].

Biodiesel which is accepted as attractive is prepared by transestrification of vegetable oils and animal fats with an alcohol in presence of catalyst. It is possible to manufacture biodiesel using a waste vegetable oil found in restaurant. So the waste cooking oil is a promising alternative because a cheaper raw material and is one of most economical to produce biodiesel. In recent work, Claudia Sheinbaum-Pardo and all, show that the potential of biodiesel from WCO is between 7.8 PJ and 17.7 PJ that represent between 1.5% and 3.3% of petro-diesel consumption for the road transport sector and can reduce between 0.51 and 1.02 Mt of CO_2, (1.0%-2.7% of CO_2-associated emissions), depending on the recovery ratio of WCO from vegetable oil consumption for cooking and considering CO_2 emissions for biodiesel production and methanol emissions during production and combustion in the blend. Biodiesel costs are similar to petro-diesel costs if WCO is free [7].

II. TRANSESTERIFICATION

One of the most common methods used to reduce oil viscosity in the biodiesel industry is called transesterification [4].

The transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerin. The transesterification is represented as:



A catalyst is usually used to improve the reaction rate and yield.

III. MATERIALS AND METHODS

The chemicals used were of an analytical reagent grade, that is, Potassium hydroxide (85% pure), Sodium hydroxide (85% pure), Methanol (99.8% pure) and Ethanol (99.8% pure) were obtained from SIGMA-ALDRICH (Germany).

Waste cooking oil (WCO) was collected from local restaurants in Adrar city (Algeria).

WCO oil properties were determined before the optimization process. The said oil was found to possess a free fatty acid content of 0.60% utilising the simple laboratory titration method [5] using potassium hydroxide solution and a phenolphthalein indicator. Its acid number was estimated from the free fatty acid value to be 1.194 mg KOH/g. This acid value is below 1% which does not require a two step transesterification procedure [5], [6]. The properties of the WCO oil are shown in Table 1.

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FIXED PARAMETER	**VARIABLE PARAMETER**
Alcohol to oil: 6:1 molar ratio Type of catalyst :NaOH Amount of catalyst: 1%	Type of alcohol - Methanol - Ethanol
Ethanol to oil : 6:1 molar ratio Type of alcohol : Ethanol Type of catalyst : NaOH	Amount of catalyst 0.25% 0.5% 0.75% 1%
Ethanol to oil : 6:1 molar ratio Type of alcohol : Ethanol Type of catalyst :NaOH Amount of catalyst: 1%	Temperature (°C) 40 50 60

TABLE I
WCO OIL PROPERTIES.

Property	**value**
Density	0.907
Dynamics viscosity (cP) at 20 °C	-
Acid value (mg KOH/g)	1.194
Free fatty acid (FFA) (%)	0.6
Saponification number	192.3

The properties of the final biodiesel product, including density, kinematic viscosity, acid value and cetane number were determined in order to evaluate its suitability as a diesel fuel substitute. Its density was determined by a density bottle while its kinematic viscosity was determined by a viscometer according to the ASTM D445 method. The acid value (AV) was calculated according to the ASTM D644 method, cetane number was calculated according to ASTM D86 method and the flash point according to ASTM D 93.

A. *Production method*

Waste cooking oil was collected from a local restaurant in Adrar city in Algeria. The waste cooking oil was filtered by filter paper to remove bits of food residues. The filtered clean cooking oil was then collected in a clean conical flask and used for experiments. The transesterfication is carried out in basic medium and to achieve it, NaOH is used as a catalyst. Catalyst is dissolved in alcohol.

The filtered oil was heated at specified temperature in water bath using a heating plate and a magnetic stirrer. At this time catalyst and alcohol were added to the heated oil, The mixture was agitated for one hour and stirred continuously, 6:1 mole ratio of alcohol to oil was used [8]. Two phases are formed as a result of transesterfication. Separation is done using a separating funnel. Upper layer consists of biodiesel, alcohol and some soap. Lower layer consists of glycerin, excess alcohol, catalyst, impurities and traces of unreacted oil. Further purification of the biodiesel was carried out using distilled water to wash the biodiesel in the separating funnel. Variable and fixed parameters used in this paper are summarized in Table 2.

TABLE II

FIXED AND VARIABLE PARAMETER

IV. RESULTS AND DISCUSSIONS

A. *The effect of temperature*

Fig. 2 shows the effect of the reaction temperature on the biodiesel yield.

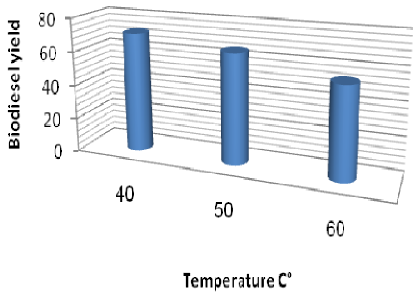

Fig. 2 The effect of temperature on biodiesel yield

the result showed that the experiment conducted at 40°C was produced higher yield of Biodiesel. Further increase in temperature lowered the biodiesel yield due to the evaporation alcohol. This result was also observed by other researchers [5].

B. *The effect of catalyst concentration*

The experiment was done at temperature 40°C, ethanol to oil molar ratio 6:1 and reaction time one hour. The research was done in catalyst concentration 0.25, 0.5, 0.75, 1 %. Figure3 shows biodiesel yield using different concentrations of NaOH as a catalyst. From the results, the optimum yield of biodiesel can be obtained at 1.0% of NaOH concentration. It reached 82% of the biodiesel yield. Of course when we use 1.5 % of catalyst the result showed that there is not separation between the biodiesel and glycerine, in the same time a soap formation was observed after washing. This is because higher amount of catalyst cause soap formation [6] .with a concentration catalyst of 0.25 % there is no biodiesel formation because of insufficient catalyst concentration.

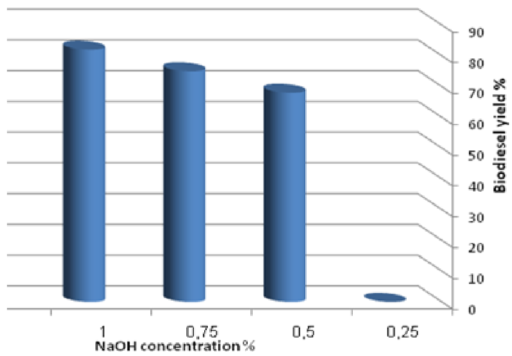

Fig. 3 Effect of catalyst concentration on biodiesel yield

C. The effect of alcohol nature

Yield of biodiesel can be influence by type of alcohol used in the reaction. In this experiment tow types of alcohol were used, they were methanol and ethanol. The reaction were carried out by using 1% of NaOH , 6:1 alcohol to oil molar ratio for 1 hour at 40 ± 2°C. The results show that methanol is better results compared to ethanol below these work conditions. Methanol gave 83.13% of biodiesel yield whereas only 71 % obtained using ethanol as alcohol.

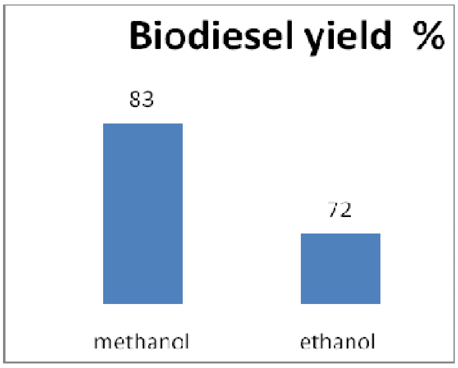

Fig.4 The effect alcohol type on biodiesel yield

D. Properties of WCO methyl ester

The properties of the WCO methyl esters (WCOME) are summarised in Table 3. As can be seen in Table 3, biodiesel produced in this work has higher cetane number. However, it is not in the range defined in ASTM D6751-02 because the minimum value should be 47. But, while biodiesel is blended to diesel, the predicted cetane number gives better value, and can be acceptable to use in diesel engine [8].
The viscosity of WCOME was determined to be 4.91 mm^2/s; thus it meets the requirements of the ASTM D6751 biodiesel standards, which prescribe that the viscosity ranges should lie between 1.9–6.0 mm^2/s. Density of our product was determined to be 881.1 kg/m^3 , in recent work Alptekin and all were observed that the density of biodiesel is very closed to the density of methanol and oil [9] and [10]. The flashpoint temperature of the WCOME is 140 °C. This value is higher than the minimum requirements of the ASTM D6751 biodiesel standards. The high flashpoint temperature of the WCOME is a beneficial safety feature, as this fuel can safely be stored at room temperature [8].

TABLE III
. PROPERTIES OF WCO ETHYLE ESTER

PROPERTY	UNIT	VALUE	ASTM D6751
Cetane number		46.7	>47
Kinematic viscosity at 40 °C	mm2/s	4.41	1.9–6.0
Acid value	mg KOH/g	0.56	<0.80
Density at 15 °C	kg/m^3	881.1	Not specified
Flash point	°C	140	130 min

V. CONCLUSIONS

In this work, the transestrification was carried out with waste oil cooking by varying parameters such as, catalyst concentration and temperature. The experimental results show that the production of biodiesel with 1 % of catalyst NaOH, alcohol to oil molar ratio 6:1 under 40 ±2°C are an optimum conditions for economical production. Results show also that the methanol gave a higher yield compared to the ethanol, and this in the same optimal conditions.
The properties of the WCO methyl esters as fuel are very close to the ASTM D6751-02 except for cetane number which present a value under the range defined in ASTM D6751-02 because the minimum value should be 47, But, while biodiesel is blended to diesel, the predicted cetane number gives better value, and can be acceptable to use in diesel engine.

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