Production of Biodiesel from Used Groundnut Oil from Bosso Market, Minna, Niger State, Nigeria

Alabadan B.A.
Department of Agricultural and Bioresources Engineering, Federal University, Oye – Ekiti.

Ajayi E.S.
Department of Agricultural and Bioresources Engineering, Federal University, Oye – Ekiti.

Godwin J.A.
Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State.

Abstract

The transesterification of used cooking oil with short-chain alcohols, in the presence of base catalyst sodium hydroxide (NaOH) and methanol as solvent, by means of single step batch transesterification process in order to obtain biodiesel fuel was studied using a reaction ratio of 6:1 for alcohol to oil ratio. The oil was heated in a water bath.

The process variables that were investigated are catalyst concentration and reaction time. The variable that was fixed throughout the whole experiment was quantity of used vegetable oil, mixing degree of mechanical stirrer at 1300 rpm and alcohol to oil ratio. The oil was divided into three samples namely, 1, 2, and 3.

Abstract Cont'd

The biodiesel yield for the samples are 58ml, 79ml and 70ml respectively while the glycerine yield for the samples were 19ml, 19ml and 20ml respectively. The reaction times for the three samples are 60, 90 and 120 minutes respectively.

The best result for highest yield and highest purity is at 90 minutes reaction time and 1.5g catalyst concentration.

Sample 2 was found to have the highest cetane rating closer to the ASTM standard which implies that sample 2 will be a more efficient fuel than the other two samples, guarantee smooth running of the engine as well as burn cleaner.

Introduction

- **Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to American Society for Testing and Materials, ASTM D6751 specifications for use in diesel engines.**
- **It is a clean burning alternative fuel, produced from domestic and renewable resources.**
- **Biodiesel can be blended at any level with diesel to create a biodiesel blend.**

Advantages of Biodiesel

- **Biodiesel is simple to use,**
- **Biodegradable (*biodegrades as fast as sugar*)**
- **Nontoxic**
- **Essentially free of sulphur and aromatics.**
- **Much cleaner than fossil-fuel diesel.**
- **Diesel engines run better and last longer with biodiesel.**
- **Better for the environment because it is made from renewable resources and has lower emissions compared to petroleum diesel (Ramadhas et al., 2005).**

- **Biodiesel is made through a chemical process called transesterification .**

- **The process leaves behind two products:**
  ***(i)* methyl esters or biodiesel and**
  ***(ii)* glycerine.**

Using biodiesel in a usual diesel engine substantially reduces emissions of unburned *hydrocarbons, carbon monoxide, sulphates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter*

- **In many European countries, a 5% biodiesel blend, B_5 is widely used and is available at thousands of gas stations.**

- **The majority of vehicle manufacturers limit their recommendations to 15% biodiesel blended with mineral diesel.**

- **Diesel blends containing up to 20% biodiesel called B_{20} can be used in nearly all diesels powered equipment, and higher-level blends and pure biodiesel.**

- **B_{100} can be used in many engines with little or no modification.**

- **Lower-level blends are compatible with most storage and distribution equipment, but special handling is required for higher-level blends**

Table 1. Chemical properties and fatty acid composition (%) of UCO

Property		% Fatty Acid Composition UCO
Palmitic acid	**C16:0**	16
Stearic acid	**C18:0**	5.21
Oleic acid	**C18:1**	34.28
Linoleic acid	**C18:2**	40.76
Specific gravity		0.92

UCO – Used Cooking Oil

Table 2. Specifications of biodiesel fuels

Properties	REF	UCO
Density at 15 ^{0}C (Kg/m^3)	834	887
Kinematic viscosity at 40 ^{0}C (cSt)	2.72	5.16
Gross heating value (MJ/kg)	45.54	39.26
Lower heating value (MJ/kg)$_a$	42.49	36.59
Acid Number (mg KOH/g)	0.10	0.55
% C (wt.)	86.13	76.95$_b$
% H (wt.)	13.87	10.91$_b$
% O (wt.)	0	12.14$_b$
Sulphur Content (ppm wt.)	34	0$_b$
Water Content (ppm wt.)	57	466
IBP (^{0}C)	172	320
T10 (^{0}C)	211	325
T50 (^{0}C)	270	333
T90 (^{0}C)	340	356
Molecular weight	211.7$_c$	293.2$_b$
Stoichiometric fuel/air ratio	1/14.67	1/12.55
CFPP (^{0}C)	-18	-6
Iodine Number	-	97.46
Renewable fraction	0	90.11$_d$

a- Calculated from composition and gross heating value. ***c-*** Calculated by Aspen-Advisor software.
b- Calculated from speciation. ***d-*** Calculated from used cooking oil composition.

Materials, Chemical Reagents and Equipment

These include used vegetable oil, Sodium hydroxide, Methanol, Pipette and Pycnometer bottle. Others are Electric weighing balance, Beaker, Measuring cylinder, Magnetic hot plate and Water bath.

Methanol (manufactured by Aldrich Chemicals Co. Ltd, England) having a boiling point of 65°C and 99.5% purity and sodium hydroxide was used as catalyst

The used groundnut oil was sourced from local bean-cake sellers at Bosso market, Minna. Nigeria.

Experimental Procedure

- **Characterization of used vegetable oil**
- **Filtration**
- **Transesterification**
- **Settling**
- **Separation**
- **Characterization of Biodiesel produced**

Experimental Procedure

- **Characterization of used vegetable oil**

Properties	Used Vegetable Oil
Acid value	17.391 mgOH/g
FFA	8.70 mg/g
Iodine value	119g
Peroxide value	10
Saponification value	191.388mg/g
Specific gravity	0.912
Refractive index	1.463

Filtration

The used vegetable oil collected from the bean-cake fryers was first properly filtered using a filter paper and transferred into a clean beaker so as to remove completely every food particle present in the oil and obtain a very clean, clear and particle free oil which will guarantee a good and acceptable result.

Transesterification Process

Three samples of the used vegetable oil were put in three different beakers to produce the biodiesel at varying temperature, time and quantity of catalyst

Sample 1

1.0g of NaoH crystals was put into a beaker and 100ml of methanol was used to dissolve the NaoH crystals by heating it on a magnetic hot plate with a magnetic stirrer inside the mixture to obtain a meth oxide solution.

100ml of the used vegetable oil was measured, poured into a separate beaker & was purified by heating in a water bath at a temperature of 45 ^{0}C for 60 minutes.

25ml of the meth oxide solution was then mixed with the 100ml of purified oil and the mixture was heated for 30 minutes on the magnetic hot plate with a magnetic stirrer inside the mixture.

Sample 2

- **1.5g** of NaoH crystals was put into a beaker and 100ml of methanol was used to dissolve the NaoH crystals by heating it on a magnetic hot plate with a magnetic stirrer inside the mixture to obtain a meth oxide solution.

- **100ml** of the used vegetable oil was measured, poured into a separate beaker & was purified by heating in a water bath at a temperature of 65 ^{0}C for 90 minutes to remove the free fatty acid content which may alter the result.

- **25ml** of the meth oxide solution was then mixed with the 100ml of purified oil and the mixture was heated for 30 minutes on the magnetic hot plate with a magnetic stirrer inside the mixture.

Sample 3

2.0g of NaOH crystals was put into a beaker and **100ml** of methanol was used to dissolve the NaOH crystals by heating it on a magnetic hot plate with a magnetic stirrer inside the mixture to obtain a meth oxide solution.

100ml of the used vegetable oil was measured and poured into a separate beaker and was purified by heating in a water bath at a temperature of **70 ^{0}C** for **120** minutes remove the free fatty acid content which may alter the result.

25ml of the meth oxide solution was then mixed with the **100ml** of purified oil and the mixture was heated for **30** minutes on the magnetic hot plate with a magnetic stirrer inside the mixture

Settling

The resulting samples were kept in desiccators for 48 hours to allow for separation of the biodiesel from glycerine after which the biodiesel gotten was separated by a decantation process and was washed with water and heated to obtain pure biodiesel.

Characterisation of the Biodiesel Produced

The biodiesel produced was characterized based on the following parameters:

- Specific Gravity by Hydrometer Method (ASTM D1298)
- Flash Point by Pensky-Martens Closed Cup Tester (ASTM D 93)
- Cloud point (ASTM D 2500)
- Kinematic viscosity (ASTM D 445)
- Pour point (ASTM D 97)
- Cetane Number of Diesel Fuel Oil ASTM D 613
- Acid Number of Petroleum Products by Titration ASTM D 664

Results and Discussion

Table 4. Biodiesel produced and its yield

	Quantity of oil (ml)	Quantity of catalyst (g)	Temp. (^{0}C)	Time (Minutes)	Biodiesel Produced (ml)	Glycerine Produced (ml)
Sample 1	**100**	0.5	45	60	58	19
Sample 2	**100**	1.5	65	90	79	19
Sample 3	**100**	2.0	70	120	70	25

Table 5. Characterization of Biodiesel produced (Sample 1)

TEST	UNIT	TEST METHOD		LIMIT	RESULT
		IP	ASTM		
Specific gravity	kg/l	160	D1298	0.95 max.	0.88
Total sulphur	% wt	107	D4294	0.5 max.	0.006
Flash point	^{0}C	54	D93	150 min.	ND
Pour point	^{0}C	219	D97	70 max.	ND
Kinematic viscosity	c.s.t	71	D445	26 max.	4.65
Diesel index	^{0}C	21	-	47 min.	18.0
Cetane number		-	D975	40 min.	52.5
Free Glycerine	% mass	-	-	0.02	0.019
Total Glycerine	% mass	-	-	0.24	0.17
Cloud point	^{0}C	219	D2600	40 max.	20
Water by Distillation	% vol.	53	D95	0.5 max.	Trace
Acid value	mgKOH/g	65	D108	0.5 max.	0.43

Table 6. Characterization of Biodiesel produced (Sample 2)

TEST	UNIT	TEST METHOD		LIMIT	RESULT
		IP	ASTM		
Specific gravity	kg/l	160	D1298	0.95 max.	0.89
Total sulphur	% wt	107	D4294	0.5 max.	0.006
Flash point	^{0}C	54	D93	150 min.	ND
Pour point	^{0}C	219	D97	70 max.	ND
Kinematic viscosity	c.s.t	71	D445	26 max.	4.65
Diesel index	^{0}C	21	-	47 min.	19.0
Cetane number		-	D975	40 min.	53.5
Free Glycerine	% mass	-	-	0.02	0.019
Total Glycerine	% mass	-	-	0.24	0.18
Cloud point	^{0}C	219	D2600	40 max.	20
Water by Distillation	% vol.	53	D95	0.5 max.	Trace
Acid value	mgKOH/g	65	D108	0.5 max.	0.46

Table 7. Characterization of Biodiesel produced (Sample 3)

TEST	UNIT	TEST METHOD		LIMIT	RESULT
		IP	ASTM		
Specific gravity	kg/l	160	D1298	0.95 max.	0.88
Total sulphur	% wt	107	D4294	0.5 max.	0.006
Flash point	^{0}C	54	D93	150 min.	ND
Pour point	^{0}C	219	D97	70 max.	ND
Kinematic viscosity	c.s.t	71	D445	26 max.	4.65
Diesel index	^{0}C	21	-	47 min.	19.0
Cetane number		-	D975	40 min.	53.1
Free Glycerine	% mass	-	-	0.02	0.019
Total Glycerine	% mass	-	-	0.24	0.17
Cloud point	^{0}C	219	D2600	40 max.	20
Water by Distillation	% vol.	53	D95	0.5 max.	Trace
Acid value	mgKOH/g	65	D108	0.5 max.	0.45

Effect of Catalyst concentration on purity

The purity of the biodiesel obtained from sample 1 did not conform to the acceptable standard because the *viscosity* of the diesel, *cetane rating* among other properties is below the recommended value and this could lead to *excessive use* of the diesel by automobiles and *smoky exhaust*.

Effect of Catalyst Concentration on Yield

The yield of the first sample was the smallest of the three. The second sample produced more biodiesel because of the reaction ratio of the oil sample to the catalyst.

From this, It can be deduced that a biodiesel produced using this ratio will yield more product and less glycerine.

Effect of Reaction Time on Purity

- **The reaction time of** 90 **minutes produced the biodiesel that is in its purest state than the other two at** 60 **minutes and** 120 **minutes.**

- **This implies that at a either lower reaction or higher reaction time than** 90 **minutes, the biodiesel produced may likely be of low quality as well as contain some form of impurities.**

- **This can be checked by ensuring that diesel produced at acceptable reaction ratio is allowed to completely react at corresponding time, which will enhance the purity of the diesel produced.**

Effect of Reaction Time on Yield

- **The result obtained shows that the highest quantity of biodiesel produced was at a reaction time of** 90 **minutes**.

- **This implies that the biodiesel produced at** 60 **minutes and** 120 **minutes have lower yield and which suggest that with a reaction time of** 90 **minutes, the second sample produced more biodiesel with good combustion properties and less glycerine than the other two**.

Conclusion

- **High yield of quality biodiesel can be produced using used vegetable oil as feedstock with a good reaction ratio, appropriate concentration of catalyst, temperature and time of heating.**

Recommendations

- The use of renewable energy should be encouraged due to its environmental friendly nature and reduce over-dependence on energy from fossil fuel.

- In further research work, the free fatty acid present in the used vegetable oil should be removed so as to obtain a higher yield of biodiesel as its presence affects the yield of biodiesel.