A One – step Catalytic Production of Biodiesel from Waste Cooking Oil

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Abstract-In this study, biodiesel was synthesized from Waste Cooking Oil (WCO) by one-step method, trans esterification of WCO. The raw oil containing 0.253% Free Fatty Acid (FFA) , 0.526(mg KOH / g) acid value, 9 °C cloud point and 0.91g/ml density. WCO was collected from local ----- shop. In the trans esterification reaction method, NaOH was used due to low FFA content in WCO. Various reaction parameters such as oil to methanol volume ratio and catalyst concentration were optimized. The reaction time, reaction temperature and stirring rate were two hours , 60 °C and 250 rpm respectively. Finally various properties of biodiesel such as FFA, kinematic viscosity, specific gravity ,moisture cntent, cetane index, pour point, flesh point , cloud point, saponification value, iodine value and yield % of optimized biodiesel were measured and compared with petro- diesel standard. The yield of biodiesel was 90%.The fuel consumption of produced biodiesel was tested with 20hp single cylinder diesel engine by blending with prtro-diesel in the ratio of 1:4 ,1:1, 4;1 and compared fuel consumption of with petro – diesel only.

Keywords: Waste Cooking Oil, Biodiesel, Trans esterification, Base Catalyst, Fuel Consumption

1. INTRODUCTION

Recent developments in life style and significant growth of population have gradually increased fossil fuel consumptions. Excessive demand for fossil fuel reserves, rising prices and increasing environmental concerns due to rising greenhouse gas emissions such as carbon monoxide, carbon dioxide, sulphur dioxides, heavy metals, polycyclic aromatic hydrocarbons and volatile organic compounds. Several studied have been carried out in order to find new renewable and sustainable energy sources to substitute the fossil fuel [1 – 4]. Among all alternatives the characteristics of biodiesel makes it attractive for scientists because it is environment-friendly and completely economical. The biodiesel is a mono alkyl ester of fatty acids that is produced from vegetable oils and animal fats. Therefore, they need some modification and adjustment before using in the diesel engines. The dilution, thermal cracking (pyrolysis), trans esterification, and micro emusification are different methods for modification of vegetable oils. A large number of scientists reported that transesterification reaction is the best method for biodiesel production [5].

The Methyl esters produced by transesterification of vegetable oil have low viscosity and improved combustion properties compared to those of fossil fuels and crude vegetable oil [6, 7]. Transesterification or alcoholysis is the displacement of acohol from an ester by another in a process similar to hydrolysis, except than alcohol is used instead of water [Srivatava and Prasad, 2000].The process has been widely used to reduce the high viscosity of triglycerides. The transesterification reaction is represented by the general equation as in the following equation. Transesterification is one of the reversible reactions and proceeds essentially by mixing the reactants. However, the presence of a catalyst (a strong acid or base) will accelerate the conversion.**** processes paper

$$\text{Triglycerdes} + \text{Methanol} \rightleftharpoons \text{Glycerol} + \text{Methyl Ester}$$

In addition, the obtained glycerol can be used as byproduct in developed applications in terms of animal feed, carbon feedstock in fermentations, polymers, surfactants, intermediates and lubricants [8].

2. MATERIALS AND METHODS

2.1. Materials

WCO was collected from vegetable fried shop . Sodium hydroxide (NaOH), methanol, acetic acid, distilled water and diesel were purchased from local chemical store. All the chemicals and reagents used in this experiment were commercial grade.

2.2. Transesterification Reaction

` The transesterification reaction performed at different volumetric ratio of oil to methanol, varying volumetric ratio of oil to methanol, varyingfrom 3:1,4:1,5:1 and 6:1 at 60 ˚ C and 250rpm.The reaction time was kept constant at 2 hours for all experimentsNaOH catalyst has been used at a range of 0.25 to 0.55g.After transesterification reaction, the biodiesel was separated from glycerol using separating funnel and finally washed with (1:10 acetic acid to warm water) solution one time and after that washed until with warm water to get pH-7 of warm water.

3. RESULTS AND DISCUSSIONS

3.1. Physico - chemical Properties of Raw Material

Before producing biodiesel from waste cooking oil, WCO was purified by filtration with cloth and determined the physic-chemical properties to choose the reaction of process. The results were shown in table (1).

According to the physic-chemical properties of WCO, the value of FFA is < 1 so only transesterification reaction was carried out. Methanol is preferably used for the transesterification due to its low cost and advantages in physical and chemical properties, i.e., polarity and small molecule [11].

Table-1 Physico- chemical properties of WCO

No	Properties	Data
1.	Free Fatty Acid(%)	0.253
2.	Acid Value(mgKOH/g)	0.526
3.	Peroxide Value(meq/kg)	12.77
4.	Cloud Point (˚ C)	9.00
5.	Density(g/ cm^3)	0.91

3.2. Effect of methanol content and NaOH content

According to the physic-chemical properties of WCO, the value of FFA is < 1 so only transesterification reaction was carried out. Methanol is preferably used for the transesterification due to its low cost and advantages in physical and chemical properties, i.e., polarity and small molecule [11]. (Sanli and Canakci,2008) . Methanol is an important reagent used in the process of transesterification of fatty acids; it react with triglycerides and FFA to form methyl ester. Pretreated WCO was considered as the reactant for the transesterification process; where TG is converted to FAME using an alkaline catalyst. The larger the methonal content , the greater is the yield of biodiesel and 0.45g of NaOH is the optimum amount for highest yield % and the optimized ratio of oil to methanol was 3:1 according to result of yield % and properties of biodiesel .The properties and yield (%) of biodiesel from different methanol content and different NaOH content were shown in table (2) and Fig(1) and Fig(2).

Table – 2 Properties of Biodiesel

Properties	Biodiesel (1:5 oil to MeOH)		Biodiesel (1:4 oil to MeOH)		Biodiesel (1: 3 oil to MeOH)	
Wt. % NaOH	0.45	0.55	0.45	0.55	0.45	0.55
Free Fatty Acid as (Oleic acid)	0.245	0.245	0.204	0.256	0.205	0.245
Acid Value (mg KOH / g)	0.448	0.428	0.406	0.509	0.407	0.488
Iodine Value (Wijs)	53.05	64	51.80	53.62	53.85	53.05
Saponification Value (mg KOH/g)	142.31	143.06	146.98	141.06	142.40	143.88
Cloud Point (˚C)	2	2.2	2.2	1.8	0	1.8
Moisture (%)	1.8	1.92	1.92	2.1	0.7	1.01
Density	0.872	0.875	0.875	0.87	0.86	0.87
Kinematic Viscosity (mm^2/s)	6.0185	6.7958	6.6928	5.1261	4.5	5.1
Yield (%)	86	85	77	81	90	81

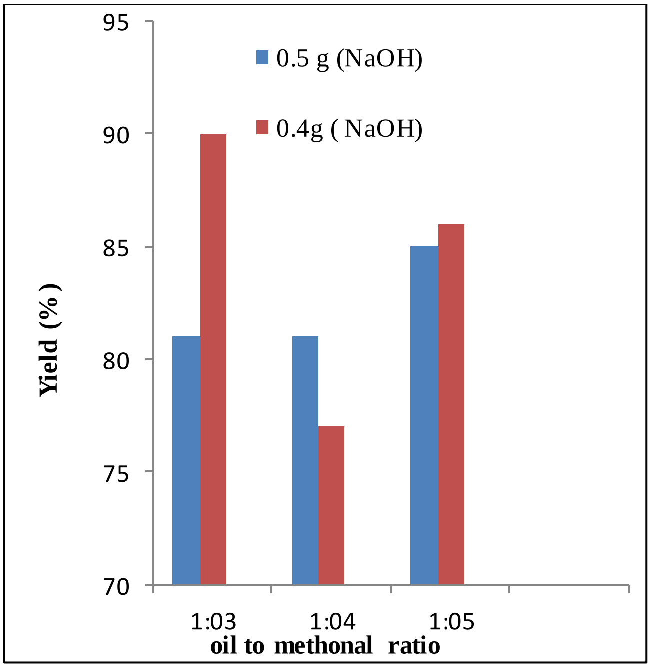

Figure –1 . Relation between oil to methanol ratio, NaOH amount and yield%

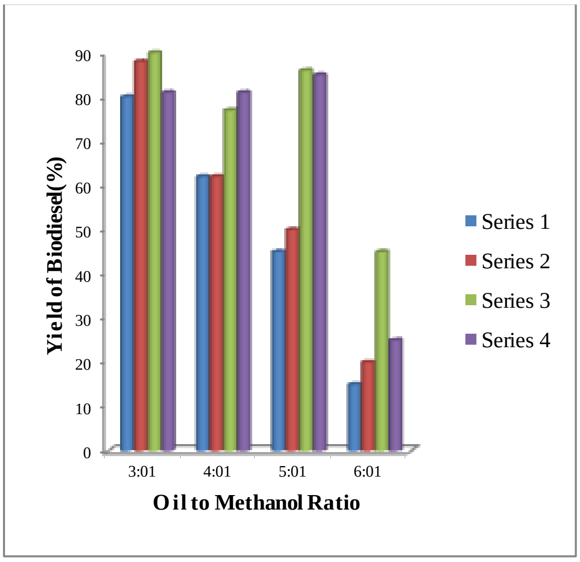

Figure -2 . Oil to methonal ratio and Yield

3.4. FTIR Spectrum of Biodiesel

The produced biodiesel with highest yield was determined the Fourier Transform Infrared spectrum and compared with FTIR spectrum of standard spectrum was shown in figure (3) and assignment of band interpretation was table (3).

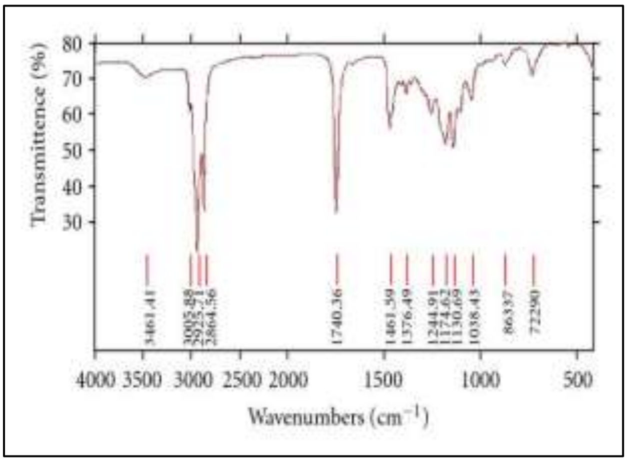

Figure-3 FTIR spectrum of standard biodiesel

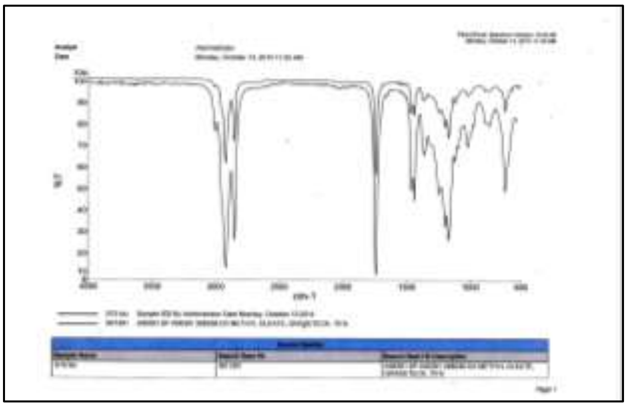

Figure-4 FTIR spectrum of produced biodiesel

Table(3) Assignment for FTIR spectrum of produced biodiesel

No	Wave number (cm^{-1})	Description
1.	2923.1-2853.8	- Asymmetric and symmetric strong stretching vibration of carboxyl group ester group
2.	1742.3	- -C=O - ester group strong stretching
3.	1169.56	- -C -O group combined with carboxylic group, ester group strongly stretching
4.	1464.47	- C-H stretching of alkane group
5.	1169.56-1014.73-722.24	- C-H bending of alkane group

3.5. Comparing the Properties of Produced Biodiesel with Standard Biodiesel and Standard Diesel

Specification of biodiesel produced from WCO was compared with specification of standard biodiesel and standard diesel. Specifications of produced biodiesel were in the range of standard. The results were shown in table (4).

Table -4 Specification of Produced Biodiesel, standard biodiesel and Standard Diesel

Properties	Produced biodiesel	Standard biodiesel	Standard diesel
Specific gravity at 25 ˚C	0.876	0.88	0.85
Kinematic Viscosity (mm2/s)at 40 ˚C	4.5	1.9 – 6.0	1.3 – 4.1
FFA content (wt%)	0.164		
Moisture content(%)	0.05-0.1	0.05% max	0.161
Sponification value(mg KOH/g)	156.21		
Flash point (˚C)	160	100-170	60-80
Cetain index	51	47(min)	
Iodine value	51.69		
Cloud point (˚C)	0	-3 to 12	-15 to 5
Pour point (˚C)	6	-15 to 12	-35 to -15
Yield (%)	90	-	-

3.6 Blending with Diesel and Consumption in Diesel Engine

We carried B-100, B-80, B-50 and B-20 by blending with diesel. There are four standard biodiesel blending methods: *Splash blending*, *in-tank blending*, in-line blending, and rack injection. We used the Splash method[13]. With splash blending, Biodiesel and diesel fuel are loaded into a tank separately. Product mixing occurs as the fuel is agitated during the transportation and delivery of the Biodiesel blend to the end user. Being slightly heavier than conventional distillates, we recommend that Biodiesel be loaded second on top. This eliminates the possibility of Biodiesel settling at the bottom of the container. In the case of bottom loading, adequate fuel flow ensures no negative consequences will result from the minor viscosity differences between diesel and biodiesel[14].

After that B-100(no blended) and blended biodiesel(B-20, B-50 and B-80) were applied in 20hp single cylinder diesel to know the the engine performance. Testing duration and engine revolution 30 minutes and 1800rpm) respectively were fixed. According to the results of fuel consumption per hours, B-80 is the best performance but B-20 and B-50 were nearly the same as B-80.So that our prepared biodiesel has the same evaluation as diesel. The resuls of fule consumptions were shown in table (5).

No.	Fuel	Testing duration (min)	Engine revolution (rpm)	Fuel Consumption (kg/hr)
1	Diesel	30	1800	0.78
2	Biodiesel B-20 (20: 80)	30	1800	0.766
3	Biodiesel B-50 (50:50)	30	1800	0.766
4	Biodiesel B-80 (80:20)	30	1800	0.80

4. CONCLUSION

According to the analysis results, biodiesel obtained from the 1:3 ratio of oil to methanol and 0.45g of NaOH is the best condition for yield % and relevant properties of biodiesel . Thus why it has biodiesel properties and it is suitable to use blending with diesel in the diesel engine.

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