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Synthesis of Biodiesel from Waste Cooking Oil and Emission Characteristics of Its blends

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Abstract. In converting different vegetable oils for the respective esters, at a minimum reaction temperature and faster rate of the fatty acids, the catalyst plays a very important role which can be changed into fatty acid esters (FAME), also known as biodiesel by transesterification reaction with methanol. Homogenous and heterogeneous catalysts have been identified as catalysts and among these catalysts. Homogeneous catalysts were chosen because it was possible to generate more biodiesel at a comparatively faster rate. As a feedstock, soybean waste cooking oil (SWCO) was used in this research work. With the help of a conventional mechanical stirrer reactor, SWCO with methanol was heated at various temperatures. As a catalyst, sodium hydroxide (NaOH) and potassium hydroxide (KOH) is used. It evaluated the effect of various parameters such as reaction temperature (60^{0}C, 70^{0}C, and 80^{0}C), the reaction time of 2 hours, and loading of the catalyst (0.5 wt. %, 0.7 wt. %, and 1 wt. % KOH and NaOH). Results show that biodiesel produced from soybean waste cooking oil was within the recommended standards of biodiesel fuel. The transesterification reaction using KOH catalyst was more effective than the NaOH catalyst. The yield and conversion of biodiesel produced from SWCO by using 0.5 wt. % KOH catalysts at 60^{0}C are 93.2 % and 96.16 % respectively while; the yield and conversion of biodiesel produced from SWCO by using 0.5 wt. % NaOH catalysts at 60^{0}C are 91.35 % and 94.5 % respectively. Blends of 10, 20, 30, 50 and 100% by volume of biodiesel derived from soybean waste cooking oil and diesel fuel were prepared as B10, B20, B30, B50 and B100. Biodiesel blends have ASTM standards that are similar to diesel fuel, and the ORSAT apparatus has used to exhaust gas.

1. Introduction

After a rise in petroleum prices, biodiesel production is, due to its environmental benefits, a very new and technical field for researchers [1]. It is an efficient alternative fuel for diesel engines developed by the sterility reaction of various feedstock products such as vegetable oils or methanol animal fats. The commodity is called biodiesel or methyl ester, a replacement for non-toxic, sustainable, biodegradable diesel fuel. It lowers global warming emissions of petroleum diesel by biodiesel [2], for example carbon dioxide. The biomass diesel weights 11% oxygen and has no aromatic and sulphur [3,4]. The key challenge in our world, in these ten years, is the price of fossil diesel, which will one day be depleted. Find an alternative way to build a diesel substitute. For human beings, biodiesel is an urgent task [4]. Biodiesel has become a growing area of concern because of the rising populations and the depletion of fossil fuel in some countries because of the rise in oil prices and environmental concerns about pollution from the gas vehicles [5,6]. With oil prices increasing and gas supplies declining, an alternative fuel source has never been required. Biodiesel is an organic energy compound which can be produced by a transesterification reaction from different triglycerides (oils), alcohol and a (acid or basic) catalyst. This is chosen because the most commonly used source of decreased carbon chains are fatty acids. In this reaction, the oil is subjected straight to alcohol transesterification that results in a molecule of biodiesel [7,8].

Some sources that can be used as raw material for biodiesel production are inedible oil, animal fats and vegetable oil [9]. However, vegetable oils from a plant used because it has similar fuel qualities to diesel fuel, not even for higher viscosity and low oxidative stability, which must be met before they are turned into organic diesel. For example, pure plant oils, straight vegetable oils (SVO) and waste vegetable cooking oils (WVCO), are the most common use of vegetable oils in the reaction to transesterification [10]. Waste vegetable oils, amongst other processed or high-quality oils, are one of the best natural sources. It is easier to collect from other business sectors (supermarket oils) than other oils [11]. Through the use of these oils as raw material, we can therefore reduce the cost of biodiesel production. Prevention of environmental contamination and low operating costs [12] are the principal advantages of using waste cooking oils for biodiesel production.

Due to its high waste disposal costs, many people dispose of waste cooking oils directly to the environment, particularly in rural areas. These oils must be treatment before they are released from the atmosphere to avoid pollution [13]. It is important to use waste cooking oils efficiently in order to reduce the costs of production of biodiesel. This study was conducted with different homogeneous catalysts in the standard mechanical stirrer reactor to conduct bio-diesel output from the SWCO. SWCO contains high FFAs so that a transesterification of alkalis is done using methanol and (KOH & NaOH) catalysts. It is also used to determine the impact on the performance and exhaust emissions of diesel engines through biodiesel mixtures B10, B20, B30, B50 and B100 with diesel fuel.

2. Materials & Methods

2.1. Materials

Raw SWCO 10 litres from the local hotels were obtained. The KOH, NaOH and Methanol grades of analytical (AR) (99.5%) were used for testing. The heating mantle with the mechanic stirrer for heating the mixture in the reaction was used for a two-liter batch reactor equipped with a water-cooled reflux condenser, and the mixture was continuously stirred in response to the traditional method transesterification. Biodiesel in all quantities is miscible with petrol. Biodiesel is often combined with diesel very frequently. The blend is commonly called B10, B20 or B50. The blend of 10% biodiesel and 90% diesel is indicated by the B10. In terms of the Cetane number [14], biodiesel is similar to diesel. The ignition quality of a fuel is this property. The combustion heat, pour point, cloud, viscosity, and oxidative stable of other characteristics showing biodiesel which are widely related to diesel [15]. Biodiesel can be contrasted with diesel in terms of both chemical and physical properties as outlined under table 1.

Table 1. Comparison by ASTM standards of the traditional properties of biodiesel with diesel

Property	Biodiesel	Diesel
Composition	FAME (C12-C22)	HC(C10-C21)
Standard	ASTM D6751	ASTM D975
Specific gravity (g/ml)	0.88	0.85
Kinetic viscosity (mm^2/s) at 40^0C	1.9-6.0	1.9-4.1
Cetane Number	48-60	40-55
Cloud point (^0C)	-3 to 12	-15 to 5
Pour point (^oC)	-15 to 16	-35 to -15
Flash point (^0C)	100-170	60-80

2.2. Systems requirements (specifications)

2.2.1. Batch Reactor

The reaction was performed in a 2-liter batch reactor consisting of an overhead mechanical stirrer, with an impeller inserted from the central opening of the reactive vial, which was fitted with a heating mantle, to allow a 2-liter batch reactor to be properly fixed. On one side of the batch reactor it is connected in order to feed the raw material (SWCO, catalyst and methanol) and to extract samples from the thermometer (up to 120^0C) along with the other side stoppers. The batch reactor specification as shown in Table 2 below.

Table 2. Specification of batch reactor for transesterification reaction

Type of reactor	Three-necked batch reactor
Material of Construction	Glass
Capacity of batch reactor	2 liters
Diameter of batch reactor (D_r)	15.6 cm
Diameter of central neck of reactor (d_1)	4 cm
Diameter of impeller (d_2)	3.15 cm

2.3. Experimental Procedure
The transesterification reaction was carried out in the three-necked batch reactor having capacity 2 liters for homogenous catalyst (KOH and NaOH) concentration i.e. 0.5 wt%, 0.7 wt % and 1 wt % at different reaction time 2 hours and at different temperature i.e. 60 ^{0}C, 70 ^{0}C, 80^{0}C and at atmospheric pressure. The experimental set-up for biodiesel production is illustrated in Figure 1.

Figure 1. Experimental setup for biodiesel production

SWCO and methanol sample was measured carefully by measuring cylinder. The amount of catalysts was weighed and taken in a batch reactor equipped with a stirrer, thermometer, and condenser. The reactor containing the mixture was kept on the water bath. The mixture was heated up to different temperature 60 ^{0}C, 70 ^{0}C, and 80^{0}C with continuous agitation for 2 hours respectively. As the boiling point of methanol is 60^{0}C at this temperature it is evaporation, then it is condensed and refluxed back to the flask. When the reaction was finished, the outlet on the lower side of the reactor was drawn from the product and pour into the separating funnel which was mounted. Biodiesel, alcohol and soap were the upper layer. The bottom layer was glycerin, alcohol in abundance, catalyst, contaminants and traces of unreacted oil. The upper layer was purified: the alcohol removal was achieved by holding the mixture at a high temperature of 80^{0}C and the saponified substance was removed-with warm water washing. The process flow diagram for SWCO development of biodiesel is shown in Figure 2.

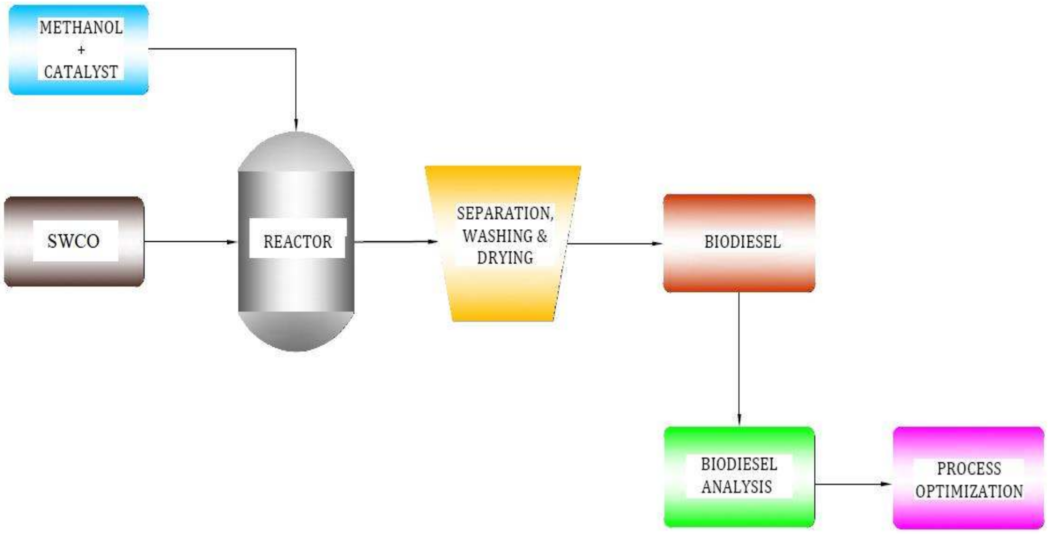

Figure 2. SWCO biodiesel development process flow diagram

3. Results and Discussions

The reaction was carried out for different homogeneous catalyst 0.5 wt%, 0.7 wt% and 1 wt % KOH and NaOH respectively at 60 ^{0}C, 70 ^{0}C, 80^{0}C. Figure-3, 4, 5 and 6, 7, 8 shows the effect of the amount of catalyst (KOH and NaOH) on the yield and conversion of SWCO respectively at 60 ^{0}C, 70 ^{0}C, 80^{0}C. The maximum yield was obtained for SWCO at 0.5wt% of KOH and NaOH catalyst respectively. It has also shown that the as amount of catalyst increases the percentage of yield and conversion decreases. Results show that the yield and conversion of biodiesel produced from SWCO by using 0.5 wt. % KOH catalysts are 93.2 % and 96.16 % respectively while; the yield and conversion of biodiesel produced from SWCO by using 0.5 wt. % NaOH catalysts are 91.35 % and 94.5 % respectively. It is possible to assume that the biodiesel production and transformation was greater than the NaOH catalyst with the use of the KOH catalyst. Acceptable operating conditions were met at 60^{0}C reaction temperature, a reaction time of 2 hours and a KOH concentration of 0.5 wt. %.

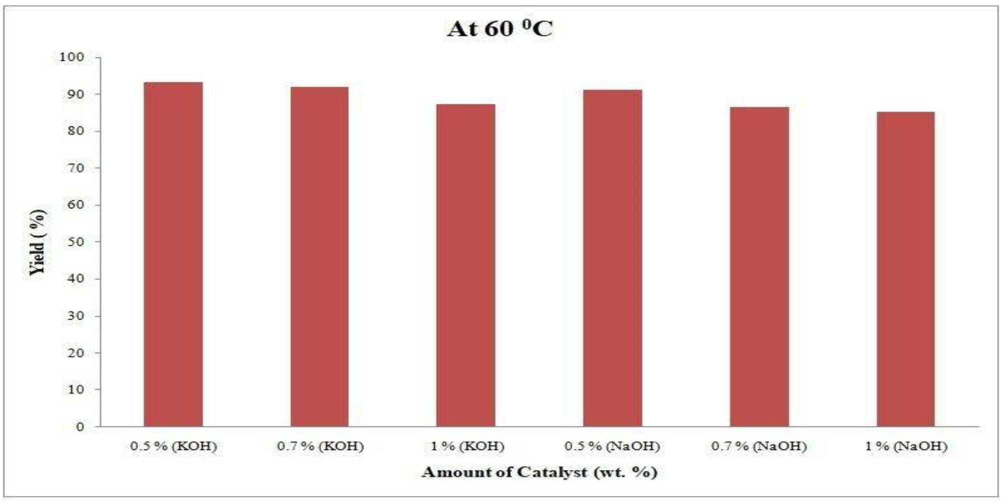

Figure 3. Yield (%) of biodiesel produced from SWCO by using KOH and NaOH catalyst at 60^{0}C

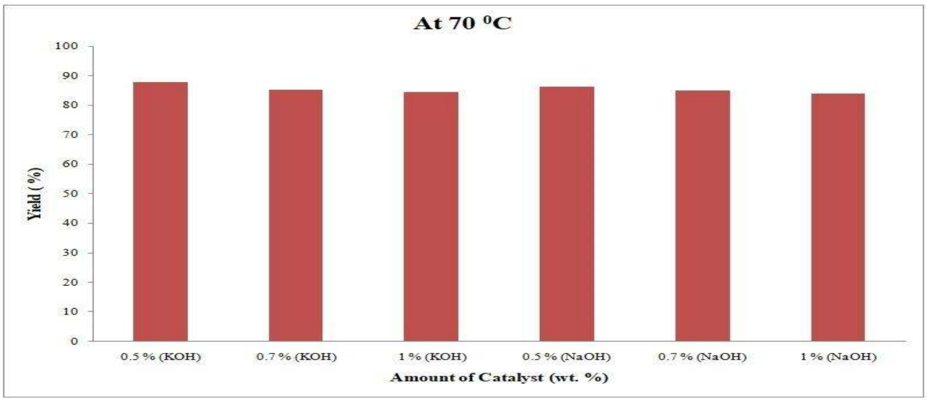

Figure 4. Yield (%) of biodiesel produced from SWCO by using KOH and NaOH catalyst at 70^0C

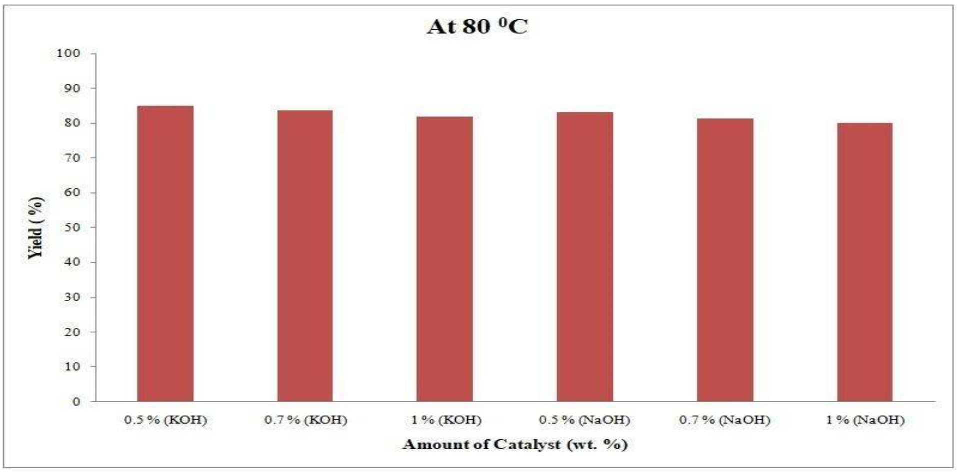

Figure 5. Yield (%) of biodiesel produced from SWCO by using KOH and NaOH catalyst at 80^0C

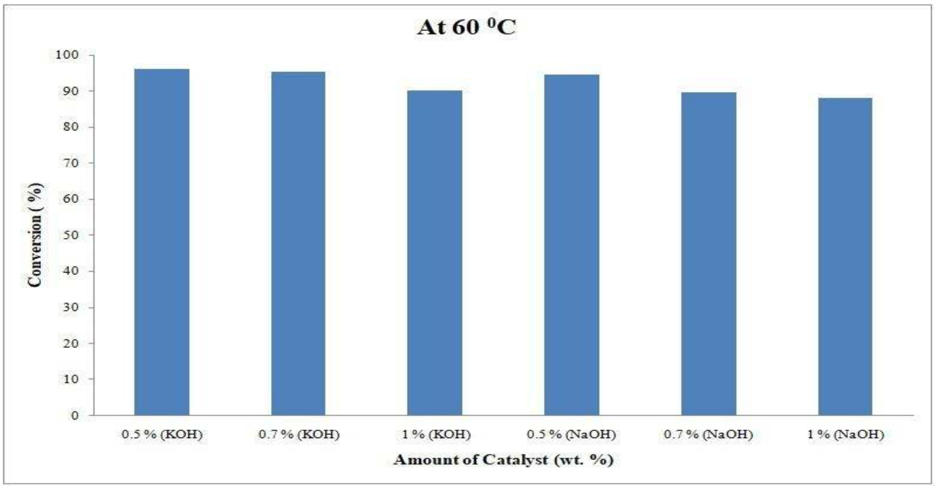

Figure 6. Conversion (%) of biodiesel produced from SWCO by using KOH and NaOH catalyst at 60^0C

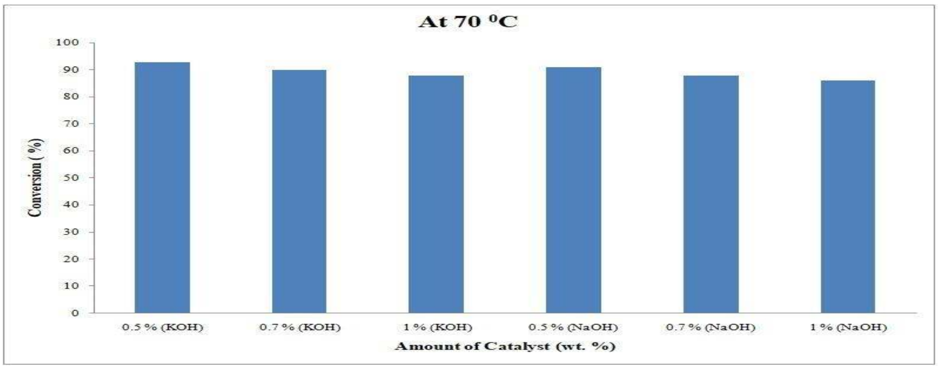

Figure 7. Conversion (%) of biodiesel produced from SWCO by using KOH and NaOH catalyst at 70^0C

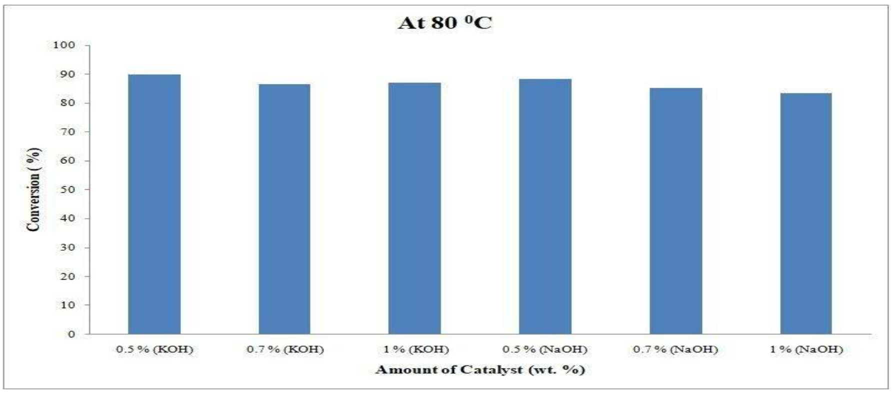

Figure 8. Conversion (%) of biodiesel produced from SWCO by using KOH and NaOH catalyst at 80^0C

The biodiesel produced from waste cooking soybean oil is used as an alternative fuel to operate diesel engines. Biodiesel blends are produced by the combination of biodiesel and oil diesel in acceptable proportions under appropriate circumstances. The tested engine provides a speed of 1500 RPM with a production ability of 3.73 kW for maximum utilization and engine specification as shown in Table 3. Biodiesel was used to measure the engine performance parameters with B10, B20, B30, B50 and B100 blends. The properties of biodiesel and its blends in comparison to diesel fuel are represented in Table 4. For measurements of exhaust gas concentrations, the ORSAT devices were used. It is found from the exhaust gas study that the CO_2 emissions of biodiesel are substantially lower than those of diesel as well as the mixture B10, B20, B30 and B50. Biodiesel has a much higher O_2 percentage than diesel and biodiesel CO is zero as shown in Table 5.

Table 3. Engine specification

Model	SF
Type	S
Serial No	11833
BHP	5
CEX No	12158
Method of starting	By using starting motor

Table 4. The properties of biodiesel and its blends in comparison to diesel fuel

Properties	**Biodiesel (B100)**	**B10**	**B20**	**B30**	**B50**	**Diesel fuel**
Density	0.940	0.65	0.78	0.82	0.82	0.84
Viscosity	3.46	1.53	2.22	2.85	3.1	3.28
Flash point	50^0C	52^0C	55^0C	56^0C	56^0C	55^0C
Fire Point	78^0C	79^0C	83^0C	85^0C	86 ^{0}C	80^0C

Table 5. ORSAT apparatus exhaust gas analysis

Sample gas (%)	**Biodiesel**	**B10**	**B20**	**B30**	**B50**	**Diesel**
O_2	18.2	8.5	9	9.2	10.4	5
CO_2	1.12	6	5	4	4	9
CO	0	1	1	1	1	1

4. Conclusion

Synthesis of biodiesel from SWCO using two homogeneous catalysts i.e. NaOH and KOH at percentages (0.5 wt %, 0.7 wt%, 1wt %) was performed. Results demonstrated that the required operative conditions at the reaction temperature of 60^0C, 2 reaction hours, and KOH concentrations at 0.5 wt. % were achieved. The yield and conversion obtained by using KOH catalyst was greater than the NaOH catalyst. It has also observed that less soap formation was obtained than with a KOH transesterification reaction. In addition, it is found that, due to the formation of soap, biodiesel derived from SWCO yield was reduced by increasing the NaOH and KOH catalyst concentration. Results also indicate that CO, CO_2 emissions for biodiesel were lower and that their mixtures were lower in comparison to diesel fuel.

References

[1] Singh A, Kumar G 2018 *J Biochem Tech* **9(1)** 17-27
[2] Abdelfatah M, Kiros Y Abu Elala R. 2017 *Petroleum & Petrochemical Engineering Journal*, **1(6)**, 1-7
[3] Xu W, Gao L, Wang S, Xiao G 2014 *Bio-resource Technology* **159** 286–291
[4] Thanh L T, Okitsu K, Boi L V, Maeda Y 2012 *Catalysts* **2** 191-222.
[5] Santos S, Gomes L N J, Puna J, Ferreira R Q, Bordado J 2019 *Energies* **12** 4670-4680
[6] Topare N S, Patil K D, Naik P, Sonawane A, Joshi P 2015 *Emerging Trends in Chemical Engineering* **2(1)** 1-8.
[7] Vasi V, Podrepsek G H, Knez Z, Leitge M 2020 *Catalysts* **10** 1-20.
[8] Thangaraj B, Solomon P, Muniyandi B, Ranganathan S, Lin L 2019 *Clean Energy* **3 (1)** 2–23.
[9] Hamamre Z A, Yamin J 2014 *Energy Conversion and Management* **79** 246-254.
[10] Diamantopoulos N, Panagiotaras D, Nikolopoulos D 2015 *Journal of Thermodynamics & Catalysis* **6 (1)** 1-8.
[11] Pandit PR, Fulekar MH 2019 *Renewable Energy* **136** 837-845.
[12] Mohamad M, Ngadi N, Lani NS 2015 *Advanced Materials Research* **1113** 518-522.
[13] Colombo K, Ender L, Barros AAC 2017 *Egyptian Journal of Petroleum* **26** 341–349.
[14] Shinde K, Kaliaguine S 2019 *ChemEngineering* **18 (3)** 1-10.
[15] Abed KA, Morsi AKE, Sayed MM, Shaib AAE, Gad MS 2018 *Egyptian Journal of Petroleum* **27** 985–989.