# Quantitative Analysis of fatty acids on Biodiesel fuel derived from Virgin Coconut Oil

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**Abstract -** *Biodiesel has become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. The cost of diesel is increasing tremendously, also the amount of fossil fuel from our earth gets decreases day by day. In this current situation, we need an alternative fuel instead of diesel fuel. Many of the researchers have successfully worked on generating energy from several alternative sources including solar and biological sources such as the conversion of some renewable agricultural products into fuel. One of the biggest challenges for developing countries in relation to energy consumption is to develop and implement technologies that help to reduce the emissions of gases and particulate matters. In order to avoid environmental impacts, emissions are reduced or eliminated by introducing renewable energy resources.*

*This work includes the use of crude coconut oil for the production of renewable biodiesel fuel as an alternative to conventional diesel fuel. The preliminary results of using a homogenous catalyst ($KNO_3$) for crude coconut oil transesterification with methanol. It was found that, from the experimental investigation, the catalysts (homogenous) called $KNO_3$ with methanol shows much higher activity than that of the heterogeneous catalysts and it shows more similar properties with diesel fuel. The results obtained from the chemical test and physicochemical properties clearly prove the above-mentioned statement. The chemical tests such as GCMS and FT-IR clearly shows the volatile components and functional groups present in the oil respectively. Finally, physicochemical properties include, Fire point, Flashpoint, density, and viscosity were analyzed. It was found to be, the transesterified crude virgin coconut oil biodiesel has properties similar to that of the diesel fuel, which was analytically determined through some basic properties of biofuel. Since the obtained transesterified biofuel can be used as an alternative fuel for diesel engines. The several reports and find outs depict the efficiency of the transesterified biofuel mainly depends upon the amount of catalyst adding and type of catalyst present, whether it is homogenous or heterogeneous with methanol. Finally, a comparison is made with the diesel fuel, to determine the optimum blend percentage of catalyst for better and efficient one.*

***Key Words***: *Transesterification process, biodiesel, virgin coconut oil, homogenous, heterogeneous, catalysts, chemical properties, FTIR, GCMS*

## 1. INTRODUCTION

Biodiesel, an alternative diesel fuel, is made from renewable biological sources such as vegetable oils and animal fats. It is biodegradable and non-toxic, has low emission profiles and so is environmentally beneficial [1]. One hundred years ago, Rudolf Diesel tested vegetable oil as fuel for his engine [2]. With the advent of cheap petroleum, appropriate crude oil fractions were refined to serve as fuel, and diesel fuels and diesel engines evolved together. In the 1930s and 1940s vegetable oils were used as diesel fuels from time to time, but usually only in emergency situations. Recently, because of increases in crude oil prices, limited resources of fossil oil, and environmental concerns, there has been a renewed focus on vegetable oils and animal fats to make biodiesel fuels. Continued and increasing use of petroleum will intensify local air pollution and magnify the global warming problems caused by CO2. In a particular case, such as the emission of pollutants in the closed environments of underground mines, biodiesel fuel has the potential to reduce the level of pollutants and the level of potential or probable carcinogens [3].

The use of oils from coconut, soybean, sunflower, safflower, peanut, linseed, rapeseed, and palm oil amongst others have been attempted. The long term use of vegetable oils led to injector coking and the thickening of crankcase oil which resulted in piston ring sticking. Therefore, vegetable oils are not used in diesel engines because of endurance issues [1, 2]. To overcome this problem, various modifications of vegetable oils have been employed such as transesterification, micro-emulsion formation and the use of viscosity reducers. Among these, transesterification was considered the most suitable modification because the technical properties of esters are nearly similar to diesel. Through transesterification, these vegetable oils are converted to the alkyl esters of the fatty acids present in the vegetable oil [3-5]. These esters are commonly referred to as biodiesel. Biodiesel is an alternative fuel that is renewable in the sense that its primary feedstock has a sustainable source. Some other feedstocks that can be converted to biodiesel are waste restaurant grease and animal fat [6, 7]. These sources are less expensive than vegetable oil.

Natural vegetable oils and animal fats are extracted or pressed to obtain crude oil or fat. These usually contain free fatty acids, phospholipids, sterols, water, odorants, and other impurities. Even refined oils and fats contain small amounts of free fatty acids and water. The free fatty acid and water contents have significant effects on the transesterification of glycerides with alcohols using alkaline or acid catalysts. They also interfere with the separation of fatty acid esters and glycerol [1]. Some natural glycerides contain higher levels of unsaturated fatty acids. They are liquids at room temperature. Their direct uses as biodiesel fuel are precluded by high viscosities. Fats, however, contain more saturated fatty acids. They are solid at room temperature and cannot be used as fuel in a diesel engine in their original form. Because of the problems, such as carbon deposits in the engine, engine durability, and lubricating oil contamination, associated with the use of oils and fats as diesel fuels, they must be derivative to be compatible with existing engines.

In view of the current instability in oil prices, biodiesel stands as an attractive source of alternative energy. By adopting and increasing the use of biodiesel, Nigeria will also be free from her over-dependence on crude oil reserves [8]. Besides, conventional fossil fuel has been reported as being finite. While it is worthy to note that biodiesel will not completely displace petroleum diesel, biodiesel has its place as an alternative fuel and can be a source of lubricity as an additive to diesel fuel. The emissions produced from biodiesel are cleaner compared to petroleum-based diesel fuel. Particulate emissions, soot, and carbon monoxide are lower since biodiesel is an oxygenated fuel.

Currently, four primary production methodologies for producing biodiesel. This paper reviews the technology with an emphasis on the current process of choice, called transesterification. This work is therefore aimed at producing biodiesel from ethyl esters of coconut oil and comparing some properties of the produced biodiesel with ASTM standards.

## 1.1 Transesterification Process

Transesterification (also called alcoholysis) is the reaction of a fat or oil with an alcohol to form esters and glycerol. The reaction is shown in Fig. 1.1, catalyst is usually used to improve the reaction rate and yield. Because the reaction is reversible, excess alcohol is used to shift the equilibrium to the products side.

Alcohols are primary and secondary monohydric aliphatic alcohols having 1±8 carbon atoms [9]. Among the alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are used most frequently, especially methanol because of its low cost and its physical and chemical advantages (polar and shortest chain alcohol). It can quickly react with triglycerides and NaOH is easily dissolved in it. To complete a transesterification stoichiometrically, a 3:1 molar ratio of alcohol to triglycerides is needed. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield. The reaction can be catalyzed by alkalis, acids, or enzymes. The alkalis include NaOH, KOH, carbonates and corresponding sodium and potassium alkoxides such as sodium methoxide, sodium ethoxide, sodium propoxide and sodium butoxide. Sulfuric acid, sulfonic acids and hydrochloric acid are usually used as acid catalysts [10]. After transesterification of triglycerides, the products are a mixture of esters, glycerol, alcohol, catalyst and tri-, di- and monoglycerides. Obtaining pure esters was not easy, since there were impurities in the esters, such as di- and monoglycerides [3]. The co-product, glycerol, needs to be recovered because of its value as an industrial chemical such as CP glycerol, USP glycerol and dynamite glycerol. Glycerol is separated by gravitational settling or centrifuging. Transesterification is the process used to make biodiesel fuel as it is defined in Europe and in the USA [11].

## 1.2 Composition of Coconut Oil

The different compositions in the coconut oil [12]. From these reference itself we get a clear idea about the properties of coconut oil is showing similarities with the acidic properties and biodiesel. The contents have acidic property, on behalf of that the experimental can proceed for the transesterification process.

Tab 1.1 Composition of Coconut oil

| Fatty Acids (Type) | Name | Chemical Formulae | Percentage |
|---|---|---|---|
| Saturated fatty acids | Lauric acid | $C_{12}H_{24}O_2$ | (45%-52%) |
| | Myristic acid | $C_{14}H_{28}O_2$ | (16%-21%) |
| | Caprylic acid | $C_8H_{16}O_2$ | (5%-10%) |
| | Capric acid | $C_{10}H_{20}O_2$ | (4%-8%) |
| | Caproic acid | $C_6H_{12}O_2$ | (0.5%-1%) |
| | Palmitic acid | $C_{16}H_{32}O_2$ | (7%-10%) |
| | Stearic acid | $C_{16}H_{36}O_2$ | (2%-4%) |
| Unsaturated fatty acids | Oleic acid | $C_{18}H_{34}O_2$ | (5%-8%) |
| | Linoleic acid | $C_{18}H_{32}O_2$ | (1%-3%) |
| | Linolenic acid | $C_{18}H_{30}O_2$ | (0-0.2%) |

Saturated fatty acid do not contain any double bonds, they are highly heat stable, and as coconut oil is about 90% saturated fat, the quality of the oil itself is not affected very much by the processing. Interestingly enough, some sellers even advertise their product as being both "made without heat processing" and as being heat stable. The main difference between these two oils is the amount of extra nutrients that may remain in the unrefined oil, and the taste which in the refined oil is nearly non-existent [14]. Coconut oil is currently used as a fuel for transport and electricity generation in the Philippines and India while research is being carried out in the islands of the Pacific. Coconut oil has been used widely because it is believed to have benefits compared to coconut oil, made through a heating process, and palm oil. Virgin coconut oil is useful against microbes, bacteria and viruses, and is useful for helping one lose weight in terms of metabolism [13].

### 1.3 Properties of Coconut Oil

Coconut oil is a fat consisting of about 90% saturated fat. The oil contains predominantly medium chain triglycerides, [1] with 86.5% saturated fatty acids, 5.8% monounsaturated fatty acids, and 1.8% polyunsaturated fatty acids. Of the saturated fatty acids, coconut oil is primarily 44.6% lauric acid, 16.8% myristic acid and 8.2% palmitic acid, although it contains seven different saturated fatty acids in total. Its only monounsaturated fatty acid is oleic acid while its only polyunsaturated fatty acid is linoleic acid [11].

## 2. MATERIALS AND METHODOLOGY

The method being described here is for making FAMEs biodiesel. The reaction is called transesterification, and the process takes place in four steps. The first step is to mix the alcohol for reaction with the catalyst, typically a strong base such as NaOH. The alcohol/catalyst is then reacted with the fatty acid so that the transesterification reaction takes place. Figure 2.1 shows the preparation of the catalyst with the alcohol.

$$\text{Triglyceride} + \text{Alcohol} \xrightleftharpoons{\text{Catalyst}} \underbrace{\text{Ester}}_{\text{Biodiesel}} + \text{Glycerol}$$

Fig. 2.1 Transesterification of triglycerides with alcohol.

Once the catalyst is prepared, the triglyceride will react with 3 mols of methanol, so excess methanol has to be used in the reaction to ensure complete reaction. The three attached carbons with hydrogen react with OH ions and form glycerine, while the CH group reacts with the free fatty acid to form the fatty acid methyl ester.

Figure 2.1 is a graphic of the necessary amounts of chemicals needed to make the reaction happen and the overall yield of biodiesel and glycerine. The amount of methanol added is almost double the required amount so the reaction goes to completion. With 100 gms of fat (virgin coconut oil) and 16-20 gms of alcohol (and 1 gms. of catalyst), the reaction will produce 100 gms of biodiesel and 10 gms of glycerine. The reaction typically takes place at between 40-65°C. As the reaction temperature goes higher, the rate of reaction will increase, typically 1-2 hours at 60 °C versus 2-4 hours at 40°C. If the reaction is higher than 65°C, a pressure vessel is required because methanol will boil at 65°C. It also helps to increase the methanol to oil ratio.

Glycerol is formed and has to be separated from the biodiesel. Both the glycerol and biodiesel need to have alcohol removed and recycled in the process. Water is added to both the biodiesel and glycerol to remove unwanted side products, particularly glycerol, that may remain in the biodiesel. The wash water is separated out similar to solvent extraction (it contains some glycerol), and the trace water is evaporated out of the biodiesel. Acid is added to the glycerol in order to provide neutralized glycerol [16].

## 3. EXPERIMENTAL WORK

Transesterification Process was adopted for the production of the biodiesel. So, 0.5 g of sodium hydroxide pellet was mixed with 30 ml of methanol inside a strong heat resistance glass beaker. The mixture was stirred vigorously until sodium hydroxide pellets dissolved and formed a strong base known as methoxide ($NaOH_3$). 100 ml of the treated coconut oil was poured into the reactor and heated gently at 65°C, in line with the work of Igbokwe and Nwafor [21] and the methoxide was added and the mixture was stirred vigorously for 1 hour in order to obtain a homogeneous mixture. The pictorial representation of the experimental work is shown in Fig. 3.1

The mixture was poured into a separating funnel and made to settle for 24 hours. The mixture separated into two layers with the biodiesel floating on top and glycerine at the bottom so the biodiesel was decanted The raw biodiesel was washed with water to remove some traces of soap and other contaminants and the water was allowed to settle down before removing it by draining. The washed biodiesel was collected into a beaker and gently heated in an oven at 105°c to evaporate the excess water and methanol in the biodiesel.

Fig. a Heating and stirring the coconut oil with catalyst
Fig.b Cooling the Content using water Steam Bath
Fig.c Separation of Biodiesel and Glycerol content using Separating funnel
Fig. 3.1 Severe Steps of Transesterification Process

## 4. RESULTS

The biodiesel obtained through transesterification process was characterized to know the fuel properties. Chemical tests include Gas chromatography – mass spectrometry (GCMS) and Fourier-transform infrared spectroscopy (FTIR), to find the fatty acid contents and functional groups present in the oil. Density, viscosity, Flash test, Fire point Test and calorific values were determined using the same method for the characterization of the degummed extracted coconut oil. Flash point and fire point were determined by using Pensky-Martins apparatus by ASTM D93 method. The calorific value was determined by using Hewlett Adiabatic bomb calorimeter model 1242. Cetane number was obtained numerically by the relation enunciated by Bunkyakiat et al. [16].

### 4.1 Chemical Results

### 4.1.1 GCMS test Results

Gas chromatography–mass spectrometry is an analytical method that combines the features of gas-chromatography and mass spectrometry to identify different substances within a test sample. Analysis of FAME was performed on a GC-MS QP 2010 by Shimadzu equipped with a split/split less injector. Separations were achieved using a fused silica Zebron ZB-FFAP capillary column (60 m × 0.25 mm ID, 0.25 µm film thickness). Helium was used as the carrier gas at flow rates of 1.99 mL/min and a split ratio of 1:10. The injector temperature was 250°C. The oven temperature was programmed at 140°C for a hold of 10 min and increased to 250°C at a rate of 7°C/min and hold a the final temperature for 10 min. FAME peaks were identified by comparing their retention time and equivalent chain length with respect to standard FAME.

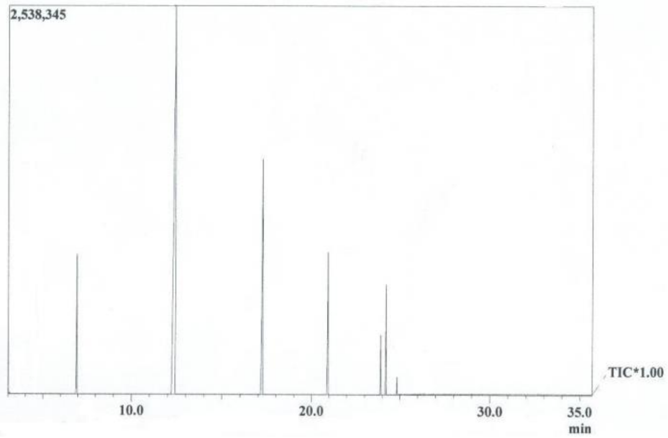


Fig.4.1 GCMS test results of Virgin Coconut Oil

Gas-chromatography coupled with mass spectrometry (GC-MS) was used to identify and measure the composition of fatty acids present in walnut and coconut oils. In the oils samples was tested MUFAs: caproic acid (C6:0), caprylic acid (C8:0), capric acid (C10:0), lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0), arachidic acid (C20:0), oleic acid (C18:1) and PUFAs: linoleic acid (C18:2) and linolenic acid (C18:3). Gas chromatography, revealed that total MUFAs in walnut oil is 9.5% and PUFAs with 63.3% had the highest level. The unsaturated: saturated ratio was 1:6.6. Linoleic acid is the major fatty acid of walnut oil followed by oleic, linolenic, palmitic and stearic acids.

This was observed in our study, but the percentages vary. Thus, with 54.8% the linoleic acid had the highest quantity followed by oleic acid with 24.2%, linolenic acid with 7.5%, and palmitic acid with 6.3% and stearic acid with 3.0%. These results are comparable with the data previously reported in literature. The predominant fatty acid composition in walnut oil obtained from Romanian walnut kernels is the linoleic acid ranging between 56.57% and 58%. The chromatographic profile of these fatty acid showed that the coconut oil is rich in saturated fatty acids, with high proportions of lauric and myristic acids. From Table 2, it can be seen that coconut oil has 87.2% saturated fatty acid and only 8.4% unsaturated fatty acid, mostly composed of oleic acid (5.5%). The saturated: unsaturated ratio was 1:10.3. The presence of lauric acid (44.6%) was found in coconut oil. This result is in line with Gregorio and Gopala et al., they reported that coconut oil is major source of lauric acid, with significant food and non-food uses.

### 4.1.2 FT-IR test Results

The results by FTIR shows that the two functional groups of fatty acid ethyl esters (C=O, 1733 cm-1 and C-O, 1154 cm-1) and at 3400 cm-1, the OH wide band group of glycerol.

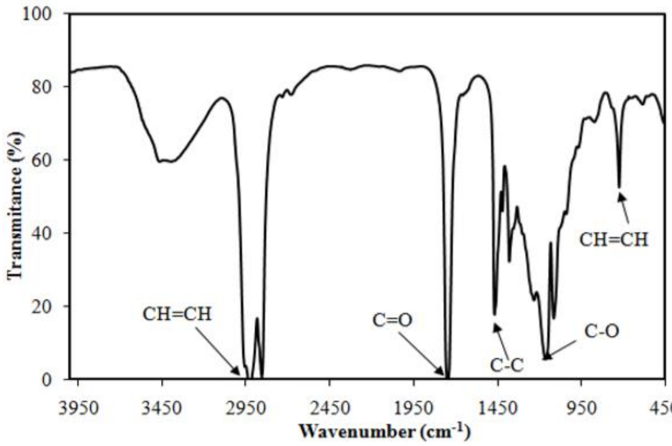


Fig. 4.2 FT-IR results of transesterfied coconut oil.

The results by FTIR for washed biodiesel (Figure 5) indicated the two main functional groups of fatty acid ethyl esters (C=O, 1733 cm-1 and C-O, 1154 cm-1]. In addition is important to say that the colour of crude glycerol was brownish and is necessary to improve this reaction. On the other hand biodiesel was a transparent liquid similar to petrodiesel, suggesting an acceptable quality. The 3500-3450 cm-1 band is attributed to the presence of small quantity of remnant water used during washing of crude biodiesel.

## 4.2 Physiochemical Properties

The flash and fire points of a liquid fuel specimen are the indicators of its flammability. In general, flash point is the lowest temperature of the test specimen, corrected to a barometric pressure of 101.3 kPa, at which the application of an ignition source causes the vapour of the test specimen to ignite momentarily and the flame to propagate across the surface of the liquid under the specified conditions of test [18]. It is important to realize that the value of the flash point is not a physical constant but is the result of a flash point test and is dependent on the apparatus and procedure used. Fire point may be considered as the lowest temperature of the liquid at which vapour combustion and burning commences. A fire point happens when an ignition source is applied and the heat produced is self-sustaining, as it supplies enough vapors to combine with air and burn even after the removal of the ignition source [17].

### 4.2.1 Flash Point and Fire Point test results

Flash point is the minimum temperature at which a fuel gives off sufficient vapors which can be mixed with air and will ignite momentarily. Determination of flash point is needed for every type of biodiesel to classify it as non-hazardous under the National Fire Protection Association (NFPA).

Tab. 4.1 Flashpoint and fire point of biodiesel samples

| Samples | Flash Point (*C) | Fire Point (*C) |
|---|---|---|
| Diesel | 73 | 76 |
| Biodiesel (Sample 1) | 62 | 68 |
| Biodiesel (Sample 2) | 66 | 72 |
| Biodiesel (Sample 3) | 70 | 78 |

Flash point is the lowest temperature of the sample; corrected to a barometric pressure of 101.3 kPa, application of a test flame causes the vapour of the fuel to ignite. It measures the response of the sample to heat and flame under controlled conditions. It is an essential property, which must be considered in assessing the overall flammability hazard of fuel. The flash point obtained for the bio-fuel is 62 $^{0}$C and that of the petrol diesel is between 59–66 $^{0}$C. The flash point of the bio-fuel falls within the range of petrol diesel. However, the results of this test may be used as elements of a fire risk assessment, which takes into account all factors that are pertinent to an assessment of the fire hazard. Flash point can indicate the possible presence of highly flammable and volatile materials in a relatively non-flammable material.

### 4.2.2 Viscosity and density of Biodiesel

The proper operation of the equipment depends upon the kinematics viscosity of the liquid fuel. Thus, the accurate measurement of kinematics viscosity is essential to the bio-fuel produced. The kinematics viscosity of fuel is of great importance in the flow of fuel through pipelines, injection nozzles, and orifices. Viscosity is the measure of this friction.

Tab. 4.2 Sample results of biodiesel fuel

| Fuel Property | Unit | Diesel | Biodiesel (Journal) | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|---|---|---|
| Fuel Standard | | ASTM D975 | ASTM PS 121 | | | |
| Fuel Composition | | C10-C21 HC | C12-C22 FAME | | | |
| Viscosity | mm2/sec | 1.3-4.1 | 1.9-6.0 | 2.4 | 2.7 | 3.1 |
| Density | Kg/m3 | 707.9 | 732.8 | 795.3 | 879.3 | 631 |

The value of kinematic viscosity obtained for bio-fuel produced from coconut oil is 2.4 – 3.1 at 40 $^{0}$C. It could be deduced from these results that the higher the temperature the lower the kinematic viscosity of a liquid fuel. When these results are compared with those of petrol diesel, which has a range of 1.3 – 4.1 at 40 $^{0}$C, respectively, it can be observed that the kinematics viscosity of bio-diesel is seems to be within the limit of petrol diesel.

### 4.2.3 Characterisation of Biodiesel Fuel

As shown in Table 4.3 below, the lauric acid content of VCO is the highest with 54.06%. In contrast, coconut oil contains only 2.81%. There are two types of fatty acid contents in VCO; 54.06% lauric acid and 12.06% stearic acid, and no (0%) palmitic acid.

Tab.4.3 Characterisation of Biodiesel Fuel

| Type of the Oil | Fatty Acids | % | Acid Number | Saponification number | %FFA | iodine Number | pH | Water Content (%) |
|---|---|---|---|---|---|---|---|---|
| VCO (A) | Lauric Acid (C12:0) | 54.06 | 1.01 | 348 | 0.26 | 5.32 | 6.5 | 0.11 |
| | Palmitic Acid | | | | | | | |
| | Stearic Acid(C18:0) | 12.03 | | | | | | |
| VCO (B) | Lauric Acid (C12:0) | 53.9 | 1.03 | 345.7 | 0.25 | 5.24 | 6.4 | 0.12 |
| | Palmitic Acid | | | | | | | |
| | Stearic Acid(C18:0) | 12.01 | | | | | | |
| VCO © | Lauric Acid (C12:0) | 53.7 | 1.02 | 346.64 | 0.26 | 5.25 | 6.5 | 0.11 |
| | Palmitic Acid | | | | | | | |
| | Stearic Acid(C18:0) | 11.9 | | | | | | |
| Coconut oi | Lauric Acid (C12:0) | 2.81 | 0.39 | 269.62 | 0.28 | 7.02 | 6.9 | 0.11 |
| | Palmitic Acid | 2.31 | | | | | | |
| | Stearic Acid(C18:0) | 2.65 | | | | | | |

From Table 4.3 above it can be said that VCO has an acid number of 1.0165, which is higher than coconut milk (acid number of 0.39695). VCO water content is similar to coconut oil, which is 0.11%, whereas coconut oil processed through heating has a lower water content of 0.10%. However, the water content of the three samples still meet the limit standard of cooking oil 2177 SNI 3741 2013. In other words, the smaller number of the three samples' water content simplifies the heating process so the three samples can be used as biodiesels, in accordance with current guidelines.

The analysis result of %FFA contains 0.264 VCO, 0.281 coconut oil and 0.51 palm oil. It shows that VCO heating process is much better than other oil samples according to the study of the VCO saponification number being 348.003, whereas coconut milk has a saponification number of 269.6266. The high saponification number reflects the number of the fatty acid molecules.

The bigger the saponification number, the smaller the molecules, or consisting of smaller fatty acid molecules or shorter chains, and vice versa. Hence, the higher saponification number of the VCO is because it consists of medium chain triglyceride fatty acids. The higher saponification number compared to palm and coconut oils mean that the saponification occurring in VCO is greater, even though still within tolerable limits.

## 5. CONCLUSIONS

The following conclusions are derived on the basis of the synthesis processes carried out for preparation biodiesel from crude coconut oil using methanol as alcohol and potassium hydroxide as catalyst. Based on the experimental analysis some find outs are derived.

They are:

- This work is focused on the production of bio-fuel from coconut oil.
- Results obtained in this work show that bio-fuel obtained from coconut oil has properties close to petrol diesel.
- Through transesterfication process using methanol as alcohol and Potassium hydroxide as catalyst, by

considering several factors such as temperature, stirring time were playing a crucial role in the yield and efficiency of biodiesel.

- The values obtained by testing the biodiesel is 40% more efficient than the Biodiesel produced as per the referred journal.
- As per GCMS test results, Coconut oil contains high quantities of saturated fatty acids, with a high proportion of lauric acid (44.6%). Thus obtained transesterified oil consist of volatile components and use as an alternative fuel for diesel.
- FTIR spectrum of biodiesel for the KOH catalyst shows asymmetric and symmetric strong stretching vibrations of the carboxyl group, and On the other hand biodiesel was a transparent liquid similar to petrodiesel, suggesting an acceptable quality.
- The coconut oil has the advantage that it is non-polluting source of energy; hence, it can help in reducing the emission of greenhouse gases and other emissions that are toxic and cacogenic.

### 5.1 Findings

- Presence (Type) of catalyst influences the production, yield and efficiency of the Biodiesel.
- The heating time, temperature and several factors including in the production of biodiesel (through transesterification process) influences the production.

The transition is experienced by the global energy sources from wood to hay to coal and nuclear to oil and hydrocarbon to natural gas then to non-polluting energy sources. Based on this transition, it was believed that a time will be reached in the future when demand for non-polluting and efficient energy sources will be met by other sources than fossil fuel globally. It is on this basis that this work is focused on the production of bio-fuel from coconut oil. Results obtained in this work show that bio-fuel obtained from coconut oil has properties close to petrol diesel. Therefore, it can be used as a substitute for diesel oil. The coconut oil has the advantage that it is non-polluting source of energy; hence, it can help in reducing the emission of greenhouse gases and other emissions that are toxic and cacogenic.

## 6. FUTURE WORKS

➢ Bio-diesel Production (by different solid catalysts)

- Currently biodiesel produced using transesterification process with potassium hydroxide as catalyst. On next level the work reports on the preliminary results of using several acidic and basic solids, such as ZrO2, ZnO, SO4 2−/SnO2, SO4 2−/ZrO2, KNO3/KL zeolite and KNO3/ZrO2 as heterogeneous catalysts for crude palm kernel oil (PKO) and crude coconut oil (CCO) transesterification with methanol.
- Efficient Fuel - Bio-diesel Production (Adding nanoparticle and blend with diesel fuel)
- Currently biodiesel produced using transesterification process, thus some of the researchers from fuel processing field explained about the addition of nanoparticles into the fuel improves the efficiency and reduces the pollution.

➢ Testing Process

- Compare with diesel oil (DO). The test diesel engine performance such as power (Ne), torque (Me), specific fuel consumption (ge) and thermal efficiency (ηe) is determined, calculated and evaluated while using JOME, preheated PCO and compared to DO.
- Also the work focuses on the production of liquid bio-fuel produced from coconut oil. Analytical determinations of some properties of bio-fuel were carried out to confirm the quality and purity as well as the identification of bio-fuel.

➢ Adding nanolubricants

The present work focuses on the synthesis of stable suspension of cerium zirconium mixed oxide nanoparticles in diesel and also on the effect of these nanoparticles on fuel properties, diesel engine performance and exhaust smoke. Cerium zirconium mixed oxide nanoparticle was synthesized by co precipitation method and characterized using Transmission electron microscope and Dynamic light scattering techniques. Catalytic activity of mixed oxide nanoparticles was compared by means of Temperature programmed reduction technique. Nanofluid was prepared by two step method, employing an ultrasonic shaker and oleic acid was used as surfactant to improve the stability of nanoparticle in diesel.

➢ As Lubricant

Synthesis of nanoparticles using other established methods and to check the credibility of various classes of metal, metal oxide nanoparticles as efficient lubricant additives and to develop an eco-friendly and bio-degradable lubricant using vegetable oil as base oil with nanoparticle additives.

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