



PRODUCTION OF BIODIESEL USING PALM KERNEL OIL (PKO)

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Abstract

Palm kernel oil (PKO) biodiesel was produced through transesterification reaction with ethanol using sodium hydroxide as catalyst. The biodiesel was characterised as alternative fuel for diesel engine through ASTM standard fuel test. The

transesterification process using 400 g of PKO, 1200 ml of ethanol and 28 g of NaOH at 60°C temperature for five hours to yield the

KEYWORDS:

Biodiesel, PKO,
Esterification,
Transesterification,

product obtained was subjected to analytical process and the results obtained are in good agreement with published data for vegetable oil biodiesel as well as various international standards for diesel fuel.

INTRODUCTION

Biodiesel refers to a vegetable oil or animal fat – based diesel fuel consisting of long – chain alkyl (methyl, ethyl or propyl) esters. It is made by chemically reacting lipids e.g. vegetables oil, soy bean oil, animal fat with an alcohol, producing fatty acid esters. Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be used alone or blended with diesel in any proportions (Babcock, 2008).

Transesterification of vegetable oil was conducted as early as 1853 by Patrick Duffy, four decades before the first diesel engine became functional. Rudolf diesel designed his engine to run on peanut oil, the engine was constructed for using mineral oil, and was then worked on vegetable oil without any alterations being made (Hill *et al.*, 2006). In a 1912 speech, diesel said “the use of vegetable oils for engine fuels may seem insignificant today but such oils may become in the course of time as important as petroleum and the coal tar products of the present time (Energy Information Administration, 2007).

More and more biodiesel is being used all over the world in 1990 at the world fair in Paris organised by the French society for the support of the Otto engine, a small version of his diesel engine fuelled with peanut oil was demonstrated. It was a major vegetable oils unattractive as a source of fuel. Biodiesel is now available at many normal service stations across Europe. In today’s world, alternative fuels are needed more than ever (Coyle, 2007, Eidman, 2007). Conventional fuels such as coal, natural gas and fossil fuel are constantly being depleted; however the world’s dependency on these fuels is still growing. Additionally, the price on foreign fuels is ever increasing and for these reasons, the US and the world are pursuing alternative fuel source to lessen the dependency on conventional fuels. One alternative fuel is biodiesel, biodiesel can be produced from vegetable oil or animal fat and thus can be used to alleviate the foreign fuel dependency. In order for biodiesel to be viable alternative fuel source, an industrial scale production process needs to be improved. Compared to current designs and fossil fuel, the process must be cost competitive. The purpose of this study is to create awareness of the efficiency of biodiesel as an alternative fuel and also to develop an industrial process to create biodiesel using palm kernel oil. PKO has been a main fuel for some years because palm kernel can be easily grown in large scale (Agricultural Marketing Service, 2008).

The high energy demand for fossil diesel in the industrialised world and the population problems resulting from wide spread use of fossil fuel make it increasingly necessary to develop renewable energy source of limitless duration and limited environmental impact. Many researchers have

concluded that vegetable oil hold promise as alternative fuel for diesel engines. This study covers the extraction of PKO using mechanic process and the conversion of PKO to biodiesel by transesterification process (Energy Information Administration, 2007).

The possibility of using vegetable oils as fuel has been recognised since the beginning of the diesel engine. The biodiesel was developed in the 1890s for inventor Rudolph diesel, the diesel engine has become the engine of choice for power, reliability and high fuel economy (Coyle, 2007, Eidman, 2007).

The diesel engine was developed out of a desire to improve upon inefficient, cumbersome and sometimes dangerous steam engines in late 1800s. The diesel engine works on the principle of compression ignition, in which fuel is injected into the engine's cylinder after air has been compressed to a high pressure and temperature. Rudolph diesel later did extensive work on vegetable oil fuels and became a leading proponent of such a concept believing that farmers could benefit from providing their own fuel (Energy Information Administration, 2007).

Biodiesel can be used as fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulate carbon monoxide and hydrocarbons from diesel powered vehicles. Biodiesel is produced from oils or fats using transesterification.

Most transportation fuels are liquid because vehicles usually require high energy density. High energy density can also be provided by an intern combustion engine which requires clean burning fuels, the fuel that are easiest to burn clearly are typically liquid and gases. Thus liquid meet the requirement of being both energy dense and clean burning in addition liquids and gases can be pumped which mean handling is easily mechanised and thus less laborious (Coyle, 2007, Eidman, 2007). The use of biodiesel in conventional diesel engine results in substantial reduction of unburned hydrocarbon, carbon monoxide, and particulate matter compared to emission from diesel fuel biodiesel emissions have roughly 45 – 90% lower toxic emission compared to diesel (Energy Information Administration, 2007).

MATERIALS AND METHOD

Sample Collection

Palm fruit was collected from the farm and the bunch was split with cutlass it is allowed to ferment for 5 days for easy removal of the fruits from bunch. After the fruit has been detached from the bunch they are boiled for 2 – 3 hours, the pounded with mortar to remove the palm fruit. The palm kernel is allowed to dry for about 14 days, then the palm kernel cracked using palm kernel cracking machine. The seed is extracted after cracking and allowed to dry for another 14 days then the oil was extracted from the seed by either of the following method:

- a. Local Africa palm kernel extraction of PKO
- b. Mechanical method of extraction of PKO
- c. Solvent extraction method

In this study, the mechanical method of extraction was used.

Mechanical Extraction of PKO

This could be used for small scale or large scale extraction of palm kernel oil. Palm kernels are preheated by magnetic separators that remove metallic debris that might destroy the device; the kernels are sieved to remove stones, sand and other impurities before cracking with inbuilt swinging hammers. The nuts are separated from the shell after cracking and prepared by heating before screwing through a metallic path (with pores) that decreases in diameter to the exit so that the oil is forced out of the slide while the cake is collected at the tip of the screw.

There are majorly three basic steps in or processed in mechanical extraction of PKO.

- a. Kernel pre – treatment
- b. Screw – pressing
- c. Oil clarification

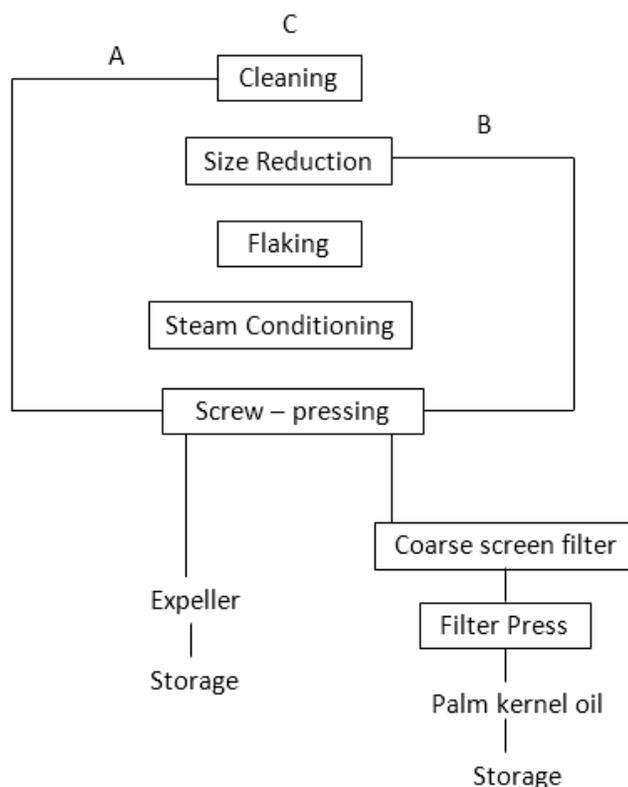


Figure 3.1: Steps in the processing of PKO
(Giampietro *et al.*, 1997)

Line A – Is for direct screw pressing without kernel pre – treatment

Line B – For partial kernel pre – treatment followed by screw pressing

Line C – Is for pre – treatment followed by screw pressing

Kernel Pre – Treatment

Proper pre – kernel treatment is necessary to efficiently extract the oil from the kernels. The feed kernels must first be cleaned of foreign materials that may cause damage to the screw – presses, increasing maintenance cost and downtime and contamination of products. Magnetic separators commonly are installed to remove metal debris while vibrating screens are used to sieve sand, stones or other undesirable materials.

A swinging hammer grinder, breaker rolls or a combination of both then breaks the kernels into small fragments. This process increases the surface

area of the kernels, thus facilitating flaking then the fragments subsequently are subjected to flaking in a roller mill.

The kernel flakes are then conveyed to a stack cooker from steaming condition, the purpose of which is to:

1. Adjust the moisture content of the meal to optimum level.
2. Rupture cell wall (initiated) by rolling reduced viscosity of oil.
3. Coagulate the protein in the meal to facilitate separation of the oil from protein materials.

The meal flows from the top compartment down the fifth compartment in series. At each stage, a mechanical stirrer agitates the meal, steam trays heat the cookers and live steam may be injected into each compartment when necessary. The important variables are temperature, retention time and moisture content. In the palm kernel the meals are normally cooked to a moisture content of 3% at 104 – 110°C.

Screw Pressing

The properly cooked meal is then fed to the screw press which consists of an intermittent helical thread which revolves within a stationary perforated cylinder called the cage or barrel. The meal is forced through the barrel by the action of the revolving worms. The volume axially feeding end to the discharge end thus compressing the meal as it passes through the barrel.

The expeller oil drains through the perforation of the lining bars of the barrel, while the de-oiled cake is discharged through all annular orifice. In order to prevent extreme temperatures that could damage the oil and cake quality the worm shaft is always cooled with air circulating water while the barrel is cooled externally by recycling some cooled oil.

Oil Clarification

The expelled oil invariably contains a certain quantity of 'fries and foots' that need to be removed. The oil from the presses is drained to a reservoir. It is then either pumped to a decanter or revolving coarse screen to remove a large part of the solid impurities. The oil is then pumped to a filter press to

remove the remaining solids and fries in order to produce clear oil prior to storage.

Production of Biodiesel

The first and very important measure was the material must be free from impurity (dirts) which was done to the palm kernel oil at first. 400ml of the PKO was then measured with a measuring cylinder and then poured in the heating dish (stainless steel bowl) and was heated to a temperature above the boiling point of water at 120°C to evaporate the liquid present in it and after than was allowed to cool for some minutes. Then sodium hydroxide was inside a desiccator and was heated in an oven to remove moisture content in it. After that 28g of the sodium hydroxide was weighted out. 120 ml of ethanol was measured, adding the 20g of sodium hydroxide slowly to the ethanol and was stirred until the sodium hydroxide dissolved in the ethanol. Furthermore, after the temperature was below the boiling point of ethanol (78°C), then the ethanol mixed with NaOH was added gently to the PKO and the mixture is heated at about 50°C to 60°C so as not to go above evaporating range of ethanol. Excess ethanol was now used to drive the reaction to completion while the mixture altogether was heated and stirred vigorously for 5 hours. The heating stopped thereafter, when the reaction was finally completed, a product was formed which is biodiesel. The necessary physical test was then carried out on the product (Biodiesel).

$$\%Yield = \frac{Volume\ of\ product}{Volume\ of\ reactant} \times 100$$

$$\%Yield = \frac{152}{400} \times 100 = 38\% \text{ by volume}$$

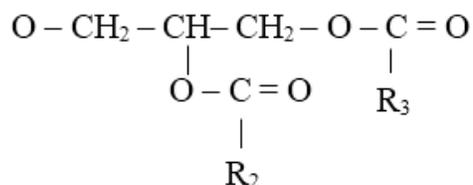
Steps in the Process

Before we can make biodiesel, the major steps required to synthesize biodiesel are as follows:

Purification

When waste vegetable is used, it should be filtered to remove dirt, charred food and other non-oil material often found. Also water can be removed

because its presence causes the triglycerides to hydrolyse to give salts of the fatty acids instead of undergoing transesterification to give biodiesel.



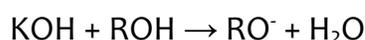
For this reaction to be more than two, more R_o groups reacts through this mechanism at the other two $\text{C} = \text{O}$ groups and this type of reaction has limiting factors. R_o has to fit the space where there is a positive reaction charges on the $\text{C} = \text{O}$. Note that as the R on R_o get bigger, reaction rates decrease this process is called (Steric hindrance) this is why methanol and ethanol are used. Care must be taken to ensure good desired reaction and most method do this by using excess of R_o .

In the process of trying to produce biodiesel these various ways are to be taken:

1. Preparation: Care must be taken to monitor the amount of free fatty acid in the incoming bio-lipid (oil or fat). If these are too much, it may result to soap formation known as saponification and the separation of glycerine by-products.
2. Then the catalyst is dissolved in alcohol using standard agitator or mixer as well.
3. The alcohol/catalyst mix is then charged into close reaction vessel and vegetable or animal oil and fat is added to it then close to prevent loss of alcohol. The reaction mix should be kept about (70°C , 158°F) to hastening the reaction and this reaction takes place at room temperature to 55°C (131°F) for safety reasons. Recommended time is about 1 – 8 hours under normal conditions, the reaction doubles with every 10°C increase in reaction temperature, excess alcohol must be used to be able to convert the fat or oil to its esters.
4. The glycerine phase is much denser than biodiesel phase, and can be separated with glycerine simply drain off the bottom of the setting vessel. Centrifuge can also be used to separate both materials faster.

5. After the separation, the excess alcohol in each phase is removed with a flash evaporation process or distillation method. In other system the alcohol is removed and the mixture neutralized before the glycerine and ester are separated. In ester case, the alcohol is reversed using convenient method of dispersing the otherwise solid catalyst into the oil and the ROH needs to be very dry because any water in the process promotes the saponification reaction and inhibits the transesterification reaction.

A word on methoxide production claims that methoxide is produced by the reaction:



Is incorrect as the reaction constant is on the order $K_{\log} - 15$, that is the reaction equilibrium is far to left while KOH and NaOH are strong base methoxide can only be produced by reacting sodium metal in alcohol. However, the following reactions using methoxide as an example are common the literature as methoxide is an excellent base catalyst for their reaction.

Neutralization of Free Fatty Acids

To neutralize the free fatty acid content, a sample of the cleaned oil is titrated against a standard solution of base in order to determine the concentration of free fatty acids (RCOOH) present in the waste vegetable oil sample the quantity (in moles of base required to neutralize the acid is calculated.

Transesterification

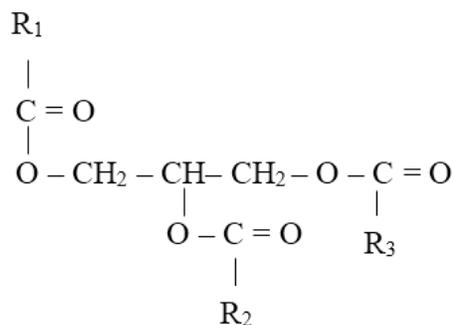
While adding the base, a slight excess is factored in to provide the catalyst for the transesterification, the calculated quantity of base (usually sodium hydroxide) is added to the alcohol and it is stored until it dissolves. Sufficient alcohol is added to make up three full equivalent of the tryglycircle and an excess to drive the reaction to completion.

The solution of sodium hydroxide in the alcohol is then added to warm solution of the waste oil, and the mixture is heated (typically 50°C) for

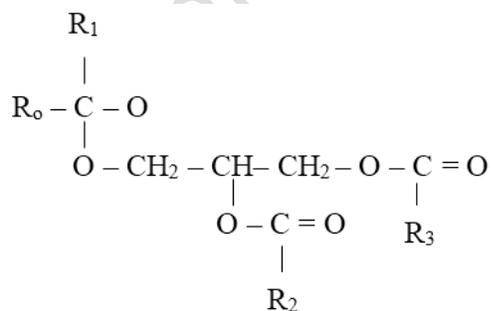
several hours (4 to 8 hours) to allow the transesterification to proceed. A condenser may be used to prevent the evaporation losses of alcohol, care must be taken not to create a closed system which can explode.

Separation of Product/By-Product

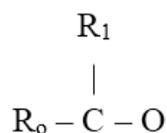
Once the reaction is completed, the glycerol should sink when ethanol is used, it is reported that emulsion often forms this emulsion can be broken by standing, configuration or the addition of a low boiling (easily removed non polar solvent decanting and distilling. The top layer a mixture of biodiesel and alcohol decanted. The excess alcohol can be distilled off if latter, the bio diesel should be dried by distillation or drying agent.



This yields a transition state that a pair of electrons from the C = O bond now located in the oxygen that was in the C = O bond.



These electrons can fall back to the carbon and push off the glycol forming the ester.



At home, this can often be accomplished by heating the filtered oil to approximately 120°C. At this point dissolved or suspended water will loose off. When the water boils, it spatters (Chemists refer to this as bumping). To prevent during this operation should be done in a sufficiently large container (at most two third full), which is closed but not sealed.

In the laboratory, the crude oil may be stirred with a drying agent such as Magnesium sulphate to remove the water in the form of water of crystallization. The drying can be separated by decanting filtration. However, the viscosity of the oil may not allow the drying agent to mix thoroughly.

RESULTS AND DISCUSSION

The product obtained for the production process and esterification reaction is known as biodiesel. This product is the subjected to analytical process such as:

- Test for viscosity
- Test of cloud point
- Test for cetane number
- Test for specific gravity
- Test for pour point

The result gotten from the analysis is summarized in the table below

Table 4.1: Physical characteristics of palm kernel oil (PKO)

PARAMETER	VALUE
Viscosity mm ² /s	33
Cloud point (°C)	28
Pour point (°C)	21

Table 4.2: Physical characteristics of biodiesel

PARAMETER	VALUE
Viscosity mm ² /s	9.40
Specific Gravity	0.86
Cloud point (oC)	14
Cetane number	48
Flash point (oC)	160
Pour point (oC)	8

Due to the tests carried out in the product obtained from the production, which is now a biodiesel shows that the product is compatible with an engine diesel machine used in powering or carrying out heavy duty works as well.

Discussion

The physical characteristics of PKO was analysed by determining the viscosity in millimetre square/seconds. Cloud point at degree Celsius and pour point in degree Celsius. The viscosity of PKO was found to be 33 mm²/s, the viscosity of water was used as a standard, and the viscosity of water is 4.75 mm²/s. comparing this value of the PKO which is 33 mm²/s to that of water which is 4.75 mm²/s. it was observed that PKO is more viscous than water. The flash point of PKO was analysed to be 21°C using a thermometer of about 360°C range. The temperature of flash point of the PKO is not easily ignitable. The cloud point is analysed to be 28°C therefore PKO is not readily volatile.

The physical characteristics of biodiesel

The viscosity of biodiesel was analysed to be 9.40 mm²/s, this shows that biodiesel is a less viscous liquid compared to PKO, cloud point of 14°C this biodiesel is readily volatile. Flash point of 160°C thus it is highly flammable cetane number of 48 therefore it reacts readily with less combustion. Specific gravity of 0.86 and pour point of 8°C.

The previous test of biodiesel to the American society of testing material (ASTM) was 38°C compared to this present 14°C test shows that it has 24°C higher than this present test due to the free fatty acid (FFA) than virgin oil. Biodiesel has a flash point of 160°C (Previous test) compared to 100°C for

petrol diesel show that it has 10°C difference which is higher than petrol diesel.

Biodiesel is still considered the safer fuel than petro diesel. Most important is the Cetane number which is 48 approximately high due to the fact that it reacts more rapidly in chamber with less combustion occur without plug.

CONCLUSION

Based on the evidence that this production has met the ASTM standard of the production of biodiesel with the various test that were carried out to check the efficiency and standard show that it should be embraced and the production steps known as transesterification reaction must be well followed and see the importance and benefit of this product so that the future will be better than today.

The production of biodiesel is a very rich and good business, which will enhance the economic benefits of the country. This kind of production can only be practiced in a place where there are sufficient vegetable oil produce like palm oil and other oil trees so as to improve on transportation and power heavy duty machines which includes diesel engines.

From the above analysis, it has been seen that biodiesel is an environmental friendly and alternative source of energy to PMS and diesel; therefore the production and use of biodiesel should be encouraged so as to reduce environmental pollution and create a sustainable development, fix scarcity of PMS as energy sources and reduce cost.

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