

## THE CHALLENGE OF BIODIESEL PRODUCTION FROM PALM PRESS FIBER OIL PRODUCED BY SMALLHOLDER IN NIGERIA

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### Abstract-

Vegetable oil have emerged as alternative source of fuel in the near future. Nigeria have choose oil palm as potential feedstock for the biodiesel industry. This study attempted the production of biodiesel from Palm Pressed Fiber (PPF), a waste by product from traditional oil palm processing in Nigeria. The Palm Pressed Fiber Oil (PPFO) produced contain free fatty acid (FFA) (19.8 to 23.6%), saponification value (190.0 to 207.0mgKOH/g), moisture content (18.15 to 28.61%), impurity level (24.25 to 38.60%), peroxide value (2.28 to 4.95 MeqO<sub>2</sub>/kg) and specific gravity (0.98 to 1.56), Crude Palm oil (CPO) produced before fermenting the palm press fiber (PPF) to produce the PPFO contain 9.98% (FFA), 205mgKOH/g(saponification value), 18.20% (moisture content), 12.54%(impurity), 1.90 MeqO<sub>2</sub>/kg (peroxide value) and specific gravity 0.955. Attempts to produce biodiesel from the PPFO and CPO failed due to the presence of high FFA, moisture and impurity. Different concentrations of H<sub>2</sub>SO<sub>4</sub> (4, 6, 8 and 10%) was used as pretreatment before transesterification using methanol and potassium hydroxide, but soap was formed instead of biodiesel except for refined vegetable oil at 4% H<sub>2</sub>SO<sub>4</sub>. The PPFO and CPO produced in Nigeria needs to be further refined and the method of processing improved to permit biodiesel production.

**Keywords-** Biodiesel; High Free Fatty Acid; Nigeria; Oil palm; Soap; Transesterification; Vegetable Oil.

### Introduction

With crude oil prices soaring, vegetable oils are fast becoming the new sources of energy. Palm oil, compared to other vegetable oil such as canola, groundnut, soybean and rapeseed. Palm oil is a cheaper raw material for biodiesel production and is the most abundantly produced vegetable oil in the world (Ramachandran, 2005). As a result, biofuel from palm oil is gaining prominence as many countries seek to substitute conventional fuel with biofuels such as biodiesel, bioethanol and biogas.

Although palm oil is still mostly used in the manufacture of food products, it is now increasingly being used as a feedstock for biodiesel for automotive use and power generation (Panapanaan et

al., 2009). Many analysts believe that biodiesel usage has the potential to becoming the biggest component of growth in vegetable oils sector. European governments are trying to promote the use of biofuel, notably biodiesel derived from vegetable oils and ethanol that can be produced from grains, sugar or biomass, and to reduce greenhouse gas emissions from fossil fuels (Ramachandran, 2005). The major oil quality parameter necessary for biodiesel production from oil palm feedstock processed in Nigeria include free Fatty Acid (FFA), moisture content, impurities and saponification level (Izah and Ohimain, 2013a). These quality indicators pose a great problem during transesterification. When an alkali catalyst such as sodium or potassium hydroxides is present, the FFA will react to form

saponified product (Atadashi et al., 2011). The saponified product formations of saturated fatty acids tend to be strengthened at ambient temperatures and the reaction mixture may gel and form a semi-solid substance that is very difficult to recover. The negative effects of excessive soap formation include consumption of the catalyst, reduction of catalyst effectiveness, difficulty in glycerol separation and prevention of crude biodiesel purification (Atadashi et al., 2011).

Biodiesel is a name applied to fuels manufactured by the transesterification of renewable oil, fats and fatty acids. It has gained importance over the years in more than 21 countries leading to commercial projects in Italy, Malaysia, Germany, France, Czech Republic, Austria, USA, Sweden and Nicaragua, and is gradually integrated into Nigerian economy. Nigeria is a tropical country with wide variations in climatic and soil conditions and therefore has a wide variety of domestic plants that produce oil (Akintayo, 2004). Biodiesel is the mono-alkyl esters of long-chain fatty acids derived from vegetable oils as well as animal fats (Alkabbashi et al., 2009). Biodiesel is synthesized from the triglycerol in vegetable oils by transesterification reaction with alcohol (methanol or ethanol). During reaction, the oil reacts with the alcohol (methanol) in a number of consecutive, reversible steps to form esters as product and glycerol as by-product (Schumacher et al., 2004). As a source of energy, biodiesel has exhibited remarkable qualities similar to and sometimes exceeding conventional fuels (Alkabbashi et al., 2009). The primary product of oil palm processing is crude palm oil (CPO), while palm press fiber oil (PPFO) is obtained from the waste fiber. Notwithstanding, there is a great potential for using CPO and PPFO for biodiesel production, but they are challenged by their low quality. PPFO and CPO can be converted after treatment into good quality biodiesel. But in Nigeria, the CPO and PPFO treatment is inhibited due to the high FFA content of the oil caused by the method of processing (i.e. traditional/smallholder processors) using rudimentary/manual equipment. The

smallholders accounts for over 80% of the oil palm processing sector in Nigeria (Ohimain and Izah, 2014; Ohimain et al., 2012a).

Though, the homogenous acid catalyzed reaction holds an important advantage over the base-catalyzed method in because the performance of acid catalysts is not adversely influenced by the presence of FFA (Moser, 2009). Actually, acids can simultaneously catalyze both esterification and transesterification (Haas et al., 2003; Demirbas, 2008). A wide range of catalysts may be used for biodiesel production, such as homogenous and heterogeneous acids and bases, sugars, extracellular hydrolytic enzymes (i.e. lipases, amylase), ion exchange resins, zeolites, and other heterogeneous materials. In general, acids are more appropriate for feedstocks high in FFA content. Homogeneously catalyzed reactions generally require less alcohol, shorter reaction times, and more complicated purification procedures than heterogeneously catalyzed transesterification reactions. Heterogeneous lipases are generally not tolerant of methanol, so production of ethyl or higher esters is more common with enzymatic method (Moser, 2009). Currently, chemical methanolysis using alkali-catalyst is the most popular commercialized process for biodiesel production that gives high yield with short reaction time. Other alcohols may also be used in the preparation of biodiesel, such as ethanol, propanol, iso-propanol, and butanol (Canacki and Van Gerpen, 2001, Kulkarni et al., 2007; Alamu et al., 2008). Studies have shown that, a large percentage of biodiesel production cost was accounted for by the feedstock price (Pizzaro and Park, 2003). However, cheap low grade feedstock often contains large amount of FFA. The inference of FFA and moisture to the alkali – catalyzed process for producing biodiesel has limited the use of recycled, inexpensive, retrograde feedstock (Ribeiro et al., 2011). It was suggested that an acid catalyst be necessarily used to perform transesterification (Harrington and D'arcy-Evans, 1985). However, the reaction rate of transesterification catalyzed by the acid catalysis is

much slower than that catalyzed by alkali catalysis and more methanol is required (Ma and Hanna, 1999).

CPO and PPFO usually contains a number of undesirable compounds such as FFA that are removed in the refining process in which other useful products for specific industrial materials are produced (Alkabbashi et al., 2009). PPFO and CPO like every other vegetable oil are triglycerides. They are high in free fatty acid. Therefore, it requires acid pretreatment using  $\text{CH}_3\text{OH}$  and  $\text{H}_2\text{SO}_4$  as catalyst in a process known as esterification before transesterifying. The fatty acid methyl ester process turns the PPFO and CPO into ester, the glycerin that is separated sinks at the bottom and the fatty acid methyl ester (FAME) floats on top which is then siphoned off (Alamu et al., 2007). PPFO is a by-product of oil palm processing and it is particularly abundant in southern Nigeria. However, this study attempt to produce biodiesel from PPFO.

## 2 MATERIALS AND METHODS

### 2.1. Field Sampling

Field visit was undertaken to smallholder oil palm processing facilities at Elele, River State Nigeria from 14th – 22nd April 2012. Four samples of PPFO produced as varying fermentation duration and CPO produced prior to the fermentation of the palm press fiber was collected. A refined vegetable oil was also bought from the market which serves as control in the experiment.

#### 2.2.1 Sample Preparation

The PPF generated during the palm oil production was further fermented to produce PPFO that was

used as feed stock for the biodiesel production as shown in Fig. 1. The extracted mixture contain water, debris and oil. The mixture were clarified by separating the water and debris from the oil in the four PPFO samples collected. In the laboratory, the resulting PPFO was further clarified resulting in the recovery of oil from the 2000ml of PPFO obtained from the PPF.

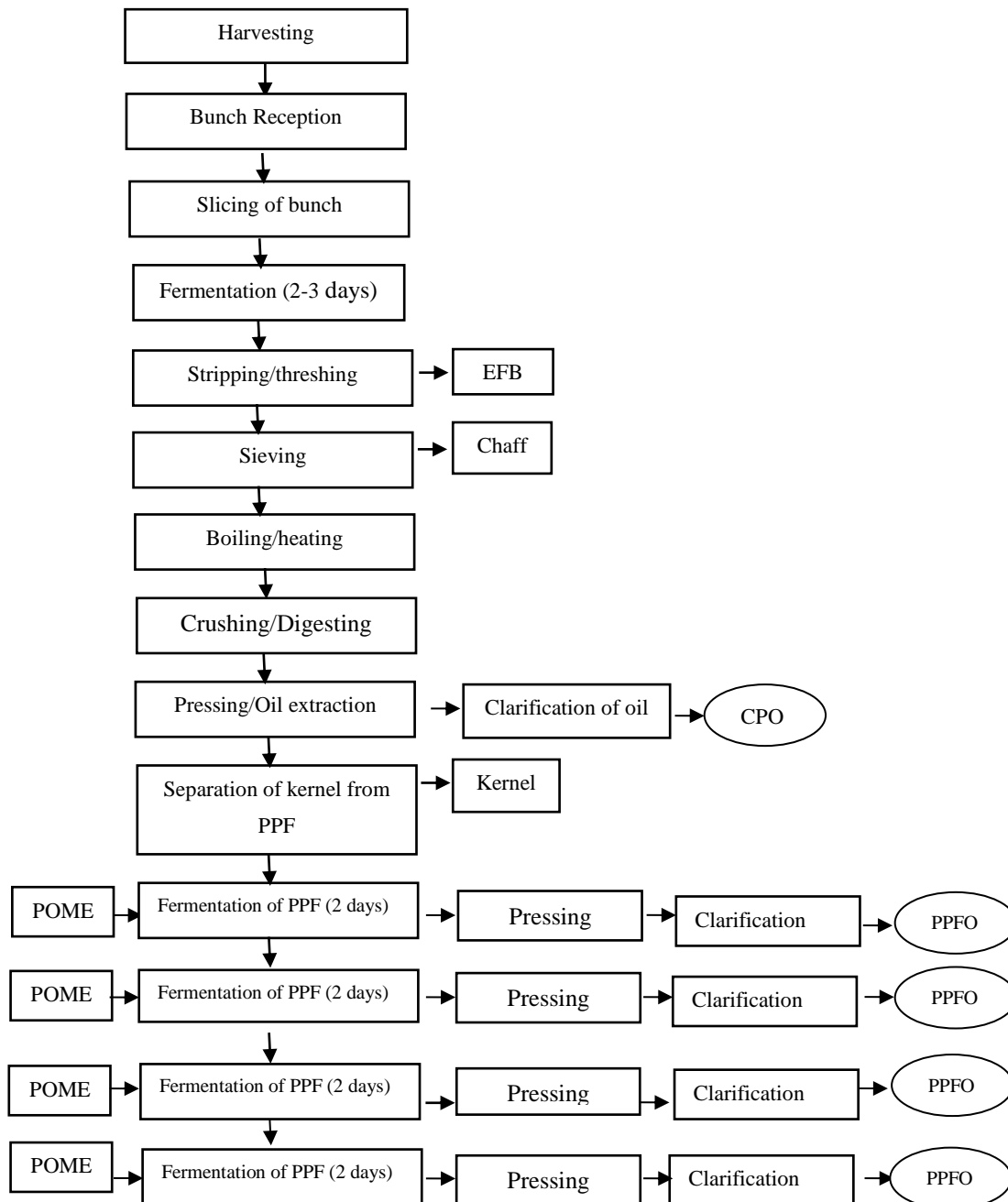


Fig. 1: A schematic chart of the traditional oil palm processing procedure in Rivers State, Southern Nigeria with emphasis on CPO and PPFO production.

### 2.2.2 Production of Potassium Methoxide

About 34ml of methanol (BDH, England) was measured into a transparent plastic container via a funnel and the screw cap of the transparent plastic

container was tightly closed. About 1.0g of KOH (BDH, England) was weight and meticulously added to the transparent plastic container containing about 34ml of methanol via another funnel, and was tightly closed. The container was stirred for 3 minutes

manually so as to homogenize the mixture of KOH and methanol to form potassium methoxide catalyst.

### 2.2.3 Esterification and Transesterification reactions

About 117ml of oil samples was measured into a beaker, it was preheated to 70°C with an oven and then the methanol-acid was poured on the preheated oil and it was allowed to esterified for 30 minutes in an oven at the same temperature, using 10ml of methanol and 1 ml, 2ml, 4ml, and 6ml of 4% H<sub>2</sub>SO<sub>4</sub>. H<sub>2</sub>SO<sub>4</sub> were used because is a common and effective catalyst for pretreatment of feedstock with high FFA content (Zhang et al., 2003) and it was then transesterified under a reaction temperature below the boiling point of methanol used (Berchmans and Hirata, 2007) by carefully removing the mixture of the acid, methanol and remains of FFA from the oil before been poured into a blender (BLG-450, Binatone, Nigeria). The prepared potassium methoxide was meticulously transferred into the esterified samples. The blender lid was tightly closed and then switched on. The mixture was allowed to blend for 30 minutes at a moderate speed before turning off the blender and the blended samples was transferred into the screw cap container for separation. These processes was repeated using 6%, 8% and 10% of H<sub>2</sub>SO<sub>4</sub>.

### 2.3.0 Chemical Analysis of CPO, PPFO and refined vegetable oil

#### Free Fatty Acid determination

The FFA concentration was determined by titrating the alcoholic solution of the oil samples with an aqueous solution of sodium hydroxide using phenolphthalein indicator (Aletor et al., 1990). About 2g of the oil samples was weighed into the conical flask (Tagoete al., 2012). About 50ml of alcohol (ethanol) was added and it was warmed in an oven to obtain a homogeneous mixture. Few drops of 1% of phenolphthalein indicator was then added and titrated with 0.1M NaOH until a fairly pink end point was obtained.

$$\% \text{ FFA as palmitic acid} = \frac{0.1 \times V \times 256}{10 \times m}$$

Where V = titre value; m= weight of oil

#### Peroxide Value determination

The peroxide value was determined by titrating chloroform/glacial acetic acid/potassium iodide solution and the oil samples with an aqueous solution of sodium thiosulphate using starch as indicator (Aletor et al., 1990). About 1g of oil samples was weighed into the 250ml conical flask. A mixture of glacial acetic acid and chloroform was added in a ratio of 3:2. About 1ml of saturated potassium iodide solution was also added. About 75ml of water was added and the mixture was properly shaken to homogenization. The solution was titrated with 0.1M sodium thiosulphate. A solution of soluble starch indicator was added to the titration process while shaking vigorously until a blue-black colour is discharged. A blank sample devoid of CPO was also analyzed using the same procedure.

$$\text{Peroxide value (Meq Peroxide/kg)} = \frac{(S - B) \times M \times 1000}{\text{Sample weight}}$$

weight

Where S = Sample titer

B = Blank

M = Molarity of thiosulphate.

#### Moisture Content determination

Gravimetric method was used for moisture determination. Two (2) g of the oil sample was weighed into crucible. It was placed in an oven and maintained at 105°C for 4hours and then cooled in desiccator and then re-weighed using analytical balance.

$$\% \text{ Moisture} = \frac{b - c}{b - a} \times 100$$

Where b = weight of crucible + sample

c = weight of crucible and dried oil

a = weight of crucible only.

*Impurity determination*

The impurities were determined by soaking filter paper in hexane and then lined in crucible. The weight of the crucible was recorded. About 2g of the oil sample was weighed into the beaker. About 20ml of hexane was added to the oil and heated to homogenize (Tagoe et al., 2012). The mixture was poured into the crucible and allowed to drain at 105°C for 40 minutes and then cooled in a desiccator and reweighed.

$$\% \text{ Impurity} = \frac{\text{Weight of dry oil}}{\text{Weight of sample}} \times 100$$

**Saponification value determination**

The saponification value was determined using the guide provided by Akinola et al.(2010).About 2g of the oil samples were weight into excess 0.5M alcoholic KOH of about 25ml. Heat was applied while swirling to saponify the fat. The treated oil samples were titrated with 0.5 M HCl using 1% phenolphthalein as indicator. A blank titration was also carried out.

$$\text{Saponification value} = \frac{(S - B) \times N \times 56.1}{\text{Sample weight (g)}}$$

S = Sample titrated, B =Blank titration, N = Normal titration of the HCl, 56.1 = The Molar weight of KOH.

*Specific gravity determination*

Specific gravity bottles were used to determine the specific gravity of all samples. The specific gravity bottles with glass stoppers were filled to the brim over flowing with the various fractions of the oil

samples (Ohimain et al., 2013a). All spillages on the body of the bottle were cleaned after the bottle had been stopped with the glass stopper. Then the specific gravity bottle is weighed on the analytical weighing balance and specific gravity is determined.

$$\text{S.G (g/ml)} = \frac{\text{Mass of SG bottle + sample}}{\text{Weight of SG}}$$

Where SG is specific gravity.

**3 Results and discussion***3.1 Oil recovery*

Table 1 shows the quantity of oil and water recovered from the different press of PPFO, while maintaining a definite time and volume of 15minutes and 2000ml respectively. The water and oil recovered from PPFO<sub>1</sub> was 8.5% and 89.9% respectively. The water and oil recovered from PPFO<sub>2</sub> was 19.1% and 79.5% respectively. The water and oil recovered from PPFO<sub>3</sub> was 29.8% and 69.2% respectively. The water and oil recovered from PPFO<sub>4</sub> was 49.8% and 49.4% respectively. About 1.6%, 1.4%, 1% and 0.8% of PPFO<sub>1</sub>, PPFO<sub>2</sub>, PPFO<sub>3</sub>, and PPFO<sub>4</sub> respectively could not be accounted for and was considered as evaporation losses. Therefore, the quantity of water recovered from PPFO<sub>1</sub>< PPFO<sub>2</sub>< PPFO<sub>3</sub>< PPFO<sub>4</sub>. This implies that, as the press continues the quantity of water generated increases, the oil reduces and the quantity of oil that could be accounted for also reduces. However, the reduction of oil recovered from the different press may be attributed to the level of crushing during digestion, quantity of sludge used prior to fermentation and duration of fermentation.

Table1: The PPFO extraction from PPF

Runs	PPFO <sub>1</sub>	PPFO <sub>2</sub>	PPFO <sub>3</sub>	PPFO <sub>4</sub>
Time allowed to boil (mins)	15	15	15	15
Quantity of oil (ml)	2000	2000	2000	2000
Water/impurities, %	8.5	19.1	29.8	49.8
Oil recovered, %	89.9	79.5	69.2	49.4
Loss, %	1.6	1.4	1.0%	0.8

### 3.2 Chemical Analysis

The FFA content of the CPO, PPFO and refined vegetable oil is 9.98%, 18.27 – 28.48% and 2.18% respectively. The FFA level of the PPFO is significantly higher than that of CPO produced by different scale of processors and sold in major markets in Nigeria as reported by Aletor et al. (1990), Akinola et al. (2010), Okechalu et al. (2011), Enemuor et al. (2012), Onwuka and Akaerue(2006), Akubor and Ogu(2012), Ohimain et al. (2012b). But the FFA level of the CPO is comparable to previous studies from traditional/smallholder oil palm processing reported by Aletor et al. (1990), Ohimain et al. (2012b). The refined vegetable oil have FFA level lower than that of PPFO and CPO, this indicating a superior quality. However, FFA content is one of the most important criterion/parameter to determine the quality of vegetable oil (Aletor et al., 1990). WHO recommended that FFA should not exceed 5% in vegetable oils (Ngando et al., 2011). Fatty acids are generally present in oils as part of triacyl glycerides (TAG) molecules. But the FFA of the CPO and PPFO is greater than that specified by WHO, unlike that of refined that is within the limit. The presence of high free fatty acids moieties in CPO and PPFO is an indication of the poor quality of the oil (Ohimain et al., 2013a). During the extraction of CPO and PPFO, the fermentation helps to build up the FFA which resulted to autocatalytic hydrolysis. As a result, the FFA acts as catalysts for the reaction between TAG and water to generate more FFA (Ngando et al., 2011). Also, the period of fermentation can significantly increase the FFA content of the CPO and PPFO due to the presence of lipolytic microorganisms that flourish in palm oil. But the high FFA level of PPFO could also be attributed to the duration of the fermentation of PPF prior to re-extraction of oil. Fermentation and re-oil extraction is carried out by smallholder processors. Ohimain et al. (2012a – c; 2013a – c), Izah and Ohimain(2013b) have variously reported that PPF are fermented for 2 - 4 days before pressing and the

resultant oil (PPFO) is being added to the CPO. As FFA levels increase, it becomes undesirable for biodiesel production due to poor quality of the oil, which results in the loss of feedstock as well as soap formation instead of biodiesel during transesterification. The soaps formed promotes the formation of stable emulsions that prevent separation of biodiesel from the glycerin during processing (Canakci and Van Gerpen, 2001).

Peroxide value in the CPO and refined vegetable oil is 1.9 and 2.2 Meq peroxide/kg respectively, while in the PPFO peroxide value ranged from 2.280 to 4.950Meq peroxide/kg, the peroxide value of PPFO is in consonance with reported of Aletor et al. (1990), Akinola et al. (2010), but higher than the values reported by Okechalu et al. (2011), Onwuka and Akaerue(2006), Akubor and Ogu (2012), Ohimain et al. (2012b). The maximum permissible limit of peroxide value in vegetable oil is 10meq O<sub>2</sub>/kg (Ngando et al., 2011). Though, Aletor et al. (1990) presented a lesser limit of 0 – 5meq/kg. Peroxide value is an indicator of the level of lipid peroxidation or oxidative degradation. According to Ohimain et al. (2013a), peroxide value indicates the amount of water and oxygen that can combine with double bond of the triglyceride. The triglycerides undergo chains of reaction involving free radicals to produce lipid peroxide which is the major determinants of rancidity. These lipids later undergo additional chain cleavage at the level of the hydroperoxide group to form secondary oxidation products such as short chain aldehydes and product bearing ketone, epoxy or alcohol groups responsible for the rancid smell and taste of the oil. Peroxide value is used to assess the stability or rancidity of fats by measuring the amount of lipid peroxide and hydroperoxide formed during the initial stage of oxidation and thus, estimate to which extent spoilage of dietary oil (expressed by the level of rancidity) has advanced (Ngando et al., 2011). Besides this visible harmful effect on the sensory quality of the oil peroxide also makes the oil dangerous for human health, as the free radicals

generated by this process are proven to be carcinogenic.

The moisture content of the CPO and refined vegetable oil is 18.20% and 5.0% respectively and that of the PPFO ranges from 18.15 - 28.61%. The moisture content of the PPFO is not in consonance with previous studies reported by Aletor et al. (1990), Enemuor et al. (2012), Onwuka and Akaerue (2006), Akubor and Ogu (2012), Ohimain et al. (2012b). The moisture and dirt content of the oil are important through their effects on acidity and bleachability. A high moisture level also favors the development of bio-deteriogens with resultant increase in FFA. The values for PPFO and CPO obtained were quite higher than the recommended limits of 0.10% (Aletor et al., 1990). The relatively high moisture content obtained for CPO and PPFO may be associated with the heating duration of the palm fruit and the quantity of water added during boiling processes (Ohimain et al., 2012b). High moisture content could affect oil storage and biodiesel production.

The specific gravity analysis conducted on the CPO and refined vegetable oil is 0.955 and 0.813 respectively, while the PPFO ranged from 0.980-1.56. The specific gravity of the PPFO is higher than the standard range of 0.898-0.907. The specific gravity values is higher than previous work reported by Akinola et al. (2010), Ohimain et al. (2013a),

Onwuka and Akaerue (2006). Therefore, it then implies that the CPO and PPFO is of poor quality and they may have been affected by the method of processing and duration of fermentation. Though specific gravity do not affect the quality of oil with regard to biodiesel production.

The saponification value obtained from CPO and refined vegetable oil is 205 and 204mgKOH/g respectively, while the PPFO values ranged from 190 – 220mgKOH/g. The saponification value of the PPFO is comparable to previous work as reported by Akinola et al. (2010), Ohimain et al. (2013a), Onwuka and Akaerue(2006), Therefore, the PPFO can easily saponify since the range is slightly above the permissible limit of 195 to 205. From these findings the PPFO is most suitable for soap production than biodiesel production.

The impurity level of the CPO and refined vegetable oil is 12.54% and 0.2% respectively, while the impurities in the PPFO ranged from 24.25 - 38.60%. These values are quite higher than the 0.01% specified limits for impurity (Aletor et al., 1990; Ngando et al., 2011) and is also higher than previous works reported by Akinola et al. (2010), Onwuka and Akaerue (2006), Ohimain et al. (2012b). The high impurity level is attributed to the method of processing, unhygienic environment and equipment used by the processors.

Table 2: Chemical qualities of PPFO, CPO that is processed traditionally in Nigeria and refined oil.

Parameters	PPFO <sub>1</sub>	PPFO <sub>2</sub>	PPFO <sub>3</sub>	PPFO <sub>4</sub>	CPO	Refined vegetable oil
Free Fatty Acid (%)	18.27	22.56	23.18	28.48	9.98	2.18
Saponification value, mgKOH/g	220	207	190	210	205	204
Peroxide value (Meq peroxide/kg)	3.45	2.28	4.95	3.86	1.90	2.2
Moisture Content (%)	22.03	18.17	28.60	21.54	18.20	5.0
Specific gravity	0.980	0.988	1.560	1.350	0.955	0.813
Impurity level (%)	38.6	24.25	28.67	32.50	12.54	0.2



### 3.3 Free Fatty Acid Reduction

In Table 3, the acid esterification is meant to remove the FFA from the PPFO, CPO and refined vegetable oil, which is mainly a pretreatment process, and it was intended to convert FFA to ester using an acid catalyst of 4% H<sub>2</sub>SO<sub>4</sub> to reduce the FFA concentration of the various oils samples. The esterification process resulted in a product with two contrasting layers. The remains of the methanol that could not be recovered is  $\leq 1.0$ ml. But at this concentration of the acid for esterification, the oil did not transesterify. The transesterification was possible only in the refined oil at after reacting 117ml of the oil, 34ml of methanol and 1.0g of KOH for 30 minutes as equivalent of gram in the recommendation by (Chitra et al., 2005). However, 6%, 8% and 10% of H<sub>2</sub>SO<sub>4</sub> was also tried in the esterification process yet; separation was not possible for CPO and PPFO after transesterification. The transesterification of the refined vegetable oil resulted in two distinct layer.

The lower layer is a mixture of FFA remains (Hasibuan et al., 2009) and glycerol formed, while the upper layer is the biodiesel formed. In the PPFO and CPO separation was not possible. Hence, it shows that the FFA and moisture content might have significant effect on the transesterification of glycerides with methanol using KOH catalyst (Goodrum, 2002). At this stage the FFA is  $> 1\%$  and resulted to the formation of soap and separation of the products were impossible (Demirbas, 2008). The refined vegetable oil could not form biodiesel due to the moisture content and the free fatty acid level which was higher than 1%. The study showed that the higher the free fatty acid the more problematic the PPFO and CPO can be in the formation of biodiesel. The palm oil produced in Nigeria is characterized by high physicochemical properties, which have been variously attributed to the method of processing. This affect the FFA, moisture and impurity which are the major indicators of biodiesel production from oil palm feedstock (Izah and Ohimain, 2013a).

Table 3: Esterification of CPO, PPFO and refined oil using 4% H<sub>2</sub>SO<sub>4</sub> followed by transesterification

	Treatments	4% H <sub>2</sub> SO <sub>4</sub>										
	VARIABLES	PPFO				CPO				Refined oil		
		1	2	3	4	1	2	3	4	1	2	3
Esterification	Reaction temperature (°C)	70	70	70	70	70	70	70	70	70	70	70
	Quantity of Methanol (ml)	10	10	10	10	10	10	10	10	10	10	10
	Quantity of H <sub>2</sub> SO <sub>4</sub> (ml)	1	2	4	6	1	2	4	6	1	2	4
	Quantity of remains of methanol and H <sub>2</sub> SO <sub>4</sub> generated (ml)*	10.6	11.6	13.4	15.5	10.4	11.6	13.6	15.7	10.5	11.7	13.4
Transesterification	Reaction temperature (°C)	60	60	60	60	60	60	60	60	60	60	60
	Methanol (ml)	34	34	34	34	34	34	34	34	34	34	34
	KOH (g)	1	1	1	1	1	1	1	1	1	1	1
	Agitation time (mins)	30	30	30	30	30	30	30	30	30	30	30

Products	60 minutes after agitation time	Saponified	saponified	Saponified	saponified	Saponified	Saponified	Saponified	saponified	saponified	Saponified	Biodiesel formed

\*Expressed as mean of triplicate.

#### 4 CONCLUSION

The aim of this study was to investigate the use of low grade oil palm feedstock (i.e. PPFO and CPO) to produce biodiesel using refined vegetable oil as control. It was discovered that PPFO, CPO and refined vegetable oil could not be separated after transesterification with the traditional alkaline catalysts that have been used with good success for biodiesel production. Then, a process was developed to use H<sub>2</sub>SO<sub>4</sub> catalyst to pretreat the PPFO, CPO and refined oil, allowing the subsequent use of alkaline catalysts like KOH to convert the triglyceride. The effect of varying concentration of the H<sub>2</sub>SO<sub>4</sub> on definite methanol level, molar ratio, and reaction time on the reduction of FFA level was tried. But the alkaline catalysts forms soap when they react with the esterified PPFO, CPO except for refined vegetable oil formed biodiesel while the PPFO and CPO could not even at increased concentration of up to 10%. The physicochemical analysis of the PPFO and CPO produced by smallholders in Nigeria indicates that the FFA, moisture and impurity level is high, which could be attributed to the challenges of forming biodiesel during transesterification. More research is therefore needed on how best to utilize oil palm processing by-products for biodiesel production for environmental sustainability.

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