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RESEARCH ARTICLE

FUEL QUALITY ASSESSMENT OF BIODIESEL PRODUCED FROM COMBINATION OF DIFFERENT ANIMAL FATS AND VEGETABLE OILS

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ABSTRACT

Animal fat (chicken and beef fat) and vegetable oil (ground nut oil and palm oil) were gotten commercially, treated, combined to know their characteristic physico-chemical properties, ASTM and AOCS methods were used. Parameters with highest results for raw oils include GOCF- Acid Value (15.70±0.01mgKOH/g), GOCF- Free Fatty Acid (7.90±0.07%), PO- Saponification Value (208.40±0.06 mgKOH/g), POCF- Peroxide Value (52.00±0.35mEq/Kg), GOPO- Iodine Value (64.50±0.03 gI_2/100g), GOPO- Relative Density (0.93±0.01), GOCF- Flash Point (242.80±0.12^{o}C), GOPO- Pour Point (5.70±0.10^{o}C), CFBF- Kinematic Viscosity (5.70±0.04mm^2/s) GOBF- Cloud point (7.50±0.10^{o}C). The transesterification products with highest values were PO- Acid Value (2.90±0.02mgKOH/g), PO- Free Fatty Acid (1.50±0.07%), POBF- Saponification Value (259.10±0.24 mgKOH/g), POBF- Peroxide Value (18.00±0.35mEq/Kg), GO- Iodine Value (41.20±0.01gI2/100g), GOPO and GOCF - Relative Density (0.89±0.00), GOPO- Flash Point (158.80±0.31^{o}C), CF- Pour Point (4.4±0.17^{o}C), GOCF- Kinematic Viscosity (4.40±0.15mm^2/s), GO- Cloud point (8.7±0.21^{o}C). Transesterification of combined oils and fats is a new trend in the production of biodiesel, percentage yield of biodiesel were significant, with GOCF giving a high yield of 82.40% among the combinations. The availability and sustainability of sufficient supplies of less expensive feed stocks will be a crucial determinant in delivering a competitive biodiesel for commercial uses.

INTRODUCTION

BIODIESEL

Nowadays, majority of the world's energy needs are gotten from petrochemicals sources. All these sources are limited and at current usage rates will be consumed shortly. The high energy demand in the industrialized world as well as the pollution problems caused due to the use of fossil fuels make it increasingly necessary to develop a new renewable energy source. Biodiesel refers to a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl) esters. Vegetable oil is also seen as a promising alternative because it has several advantages. It is renewable, biodegradable, environmentally-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy (Boehman, 2005; Shaheed and Swain, 1998). Biodiesel as an alternative fuel has numerous advantage over conventional fossil fuel such as biodegradability, renewability, low sulphur content, high combustion efficiency and low aromatic content. The commercial method used for the biodiesel production is the transesterification (also called alcoholysis). The transesterification consists on the reaction of oils or fats (triglycerides between 15 and 23 atoms, being the most common with 18) with an alcohol of low molecular weight (usually ethanol or methanol) with the presence of an alkaline catalyst (usually NaOH or KOH) to produce esters and glycerol. Long chain fatty acids are in obvious rejection to the biodiesel industry as it increases the viscosity of the biodiesel in cold weather (Knothe *et al*., 2002). The appropriate fats and oils are selected through accessing their physical and chemical properties.

The use of biodiesel has grown dramatically during the last few years. However, feedstock costs account for a large percent of the direct biodiesel production costs, including capital cost and return (Bozbas, 2008). The major byproduct of biodiesel production is glycerol, its uses is enormous. Glycerol can be thermochemically converted into propylene glycol, 1,3-propanediol, can also be dehydrated with sulphuric acid to give acrolein (a polymer), lipids and several other chemicals (Kumar and Sharma, 2008). Among lipids, it was shown that glycerol can be used to produce docosahexaenoic acid (DHA) through fermentation of the alga *Schizochytrium limacinum*. It also finds useful application as key ingredient in the manufacture of explosives (Solomon, 1996).

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Abdulkareem *et al*. (2012) successfully produced biodiesel from refined groundnut oil via alkali catalysed transesterification using methanol, in the presence of NaOH. The produced biodiesel was characterized and from the results obtained, the methyl ester produced could be effectively used in a diesel engine since it meets the requirements of ASTM D 6751. Refined groundnut oil has also been proved to be a good feedstock for biodiesel as an optimum yield of 99% was obtained, and the obtained fuel properties such as kinematic viscosity (5.86 mm2/s), flash point (170^{o}F), cetane number (49.56), total sulphur content (0.025 wt%), e.t.c. after detailed characterization of the produced methyl esters of the oil were within the standard ascribed by ASTM. Ayodele *et al*. (2011) extracted oil from Jatropha curcas seeds and palm fruits fronds (Elaeis guineesis). Upon extraction, the oils were characterized using standard methods. The percentage oil yields were 60.4% and 35.1% respectively for *jatropha carcus* seeds and palm fruits. Two steps homogeneous base catalyzed transesterification process was adopted for the production of the biodiesels.

Bello and Agge (2012) in their study concluded from their conversion of groundnut oil to biodiesel that groundnut oil can be converted to methyl esters and the properties are within the limits for biodiesel. The pour point is -6^{o}C which means it cannot be used when temperature falls below this value. The cetane number is just above the maximum for biodiesel. In view of the similarity of the properties to those of diesel fuel, it can hence be used as alternative fuel for diesel engine. Darunde and Deshmukh (2012) carried out a review on the production of biodiesel from animal fats and its impact on the diesel engine with ethanol-diesel blends, then concluded that the production of biodiesel from animal fats is a new option for vegetable oil biodiesel and can be efficiently used in diesel engine and animal fats biodiesel can be used as solvent or properties improver in alcohol and diesel blends.

Ibeto *et al*. (2011) carried out a study on production of biodiesel from methyl ester of groundnut oil and blend with petro diesel, and then compared the fuel quality of the biodiesel and its blend with ASTM standards (American Society for Testing and materials Standards). Also stated, that there were very little changes in the parameters in the biodiesel when it was blended with petro diesel except for the flash point that was only slightly below the recommended minimum ASTM value of 130^{o}C. They indicated that the biodiesel could be blended with petro diesel to give satisfactory properties not too different from the biodiesel produced.

Research shows that biodiesel has always been produced from vegetable oils and animal fats. The use of combination of animal fat and vegetable fat to produce biodiesel is scarce in literature which is one of the aims of this research work.

Aim

This study aimed to evaluate and compare the fuel qualities of the biodiesels produced from animal fats (chicken and beef fat), vegetable oils (groundnut oil and palm oil) and their respective combinations and also to determine whether their physico-chemical characteristics conform to the ASTM D6751.

METHODOLOGY

Sampling procedures

The palm oil and groundnut oil (unbranded) were purchased at Ipetumodu market, Osun State, Nigeria and were stored in plastic bottles. The chicken fat and beef fat were gotten from Jankara market, and Ita Faaji market Lagos Island, Lagos State, Nigeria respectively and were stored in plastic bags.

Sample preparation

The fats were washed and cleaned with deionized water and freed from skin and flesh. The fats were melted at around 65^{o}C, filtered, mixed vigorously and decanted to remove other suspended particles. The oils were also filtered to remove suspended particles. Samples were then combined, the combination of the oils and fat were done by missing the oils and fats in 1:1 as shown in Table 1 below :

Table 1. Combination of the specific oils and fats

Combination	Composites
Chicken fat and beef fat	CFBF
Ground nut oil and beef fat	GOBF
Palm oil and chicken fat	POCF
Palm oil and beef fat	POBF
Ground nut oil and palm oil	GOPO
Ground nut oil and chicken fat	GOCF

Biodiesel production

The procedures were modification of Ayodele *et al.* (2011) and Ojolo *et al.* (2012). 200mL of groundnut oil (GO), palm oil (PO), melted beef fat (BF), melted chicken fat (CF), groundnut oil and palm oil (GOPO), groundnut oil and melted beef fat (GOBF), groundnut oil and melted chicken fat (GOCF), melted beef fat and melted chicken fat (BFCF), melted beef fat and palm oil (POBF) and melted chicken fat plus palm oil (POCF) were measured. 40mL of methanol was measured separately and then poured into separate beakers. 0.7g KOH pellet was weighed and then added to the methanol mixture. The content of the beaker was stirred vigorously until the KOH dissolves completely to form a solution of potassium methoxide.

The oils, fats and composites were pre-heated to a steady temperature of 60^{o}C using a magnetic heater-stirrer after which the methoxides was poured into the conical flask containing the preheated oils, fats and their composites. The content of the conical flask was stirred with the magnetic stirrer at a steady speed and kept at a temperature of 60^{o}C. Then heating and stirring was stopped after 2 hours and the products were poured into separating funnels mounted on a retort stand. The mixtures were allowed to stand overnight so as to separate. The separating funnels were freed at the bottom allowing the glycerin at the bottom to run off the following morning after which the biodiesel were collected in beakers, washed three times with distilled water to remove excess methanol, KOH, glycerol and soap that could have been formed, and then poured into containers for storage.

Physicochemical Characteristics of products

Flame test

Flame test was carried out on the biodiesels to determine how they burn in flame and compare them with the normal petrol diesel. 2mL of the biodiesels and petro diesel respectively were poured on different papers and was lighted and was left to burn for minutes till the paper was burnt to ashes and observations were recorded.

Characterization of the fats and oils and their respective biodiesels

Determination of peroxide value

5 g of sample was weighed into a 250 mL stoppered flask and 30 mL of acetic acid- chloroform solution (with volume ratio 2:1) was added. The flask was swirled until the sample completely dissolved (slight warming was done for the fats). 0.5 mL saturated potassium iodide was added, the flask was stopped and swirled for exactly one minute, 30 mL of distilled water was added and then mixed vigorously to liberate the iodine from the chloroform layer. 1mL of starch solution was added as indicator after which it was titrated with 0.1N sodium thiosulphate until the blue grey colour disappeared in the aqueous layer. The volume of titrant in was accurately recorded. The same method was used to prepare the blank except the addition of the oil or fat (AOCS, 1980). The peroxide value was calculated using the equation below

Peroxide value = (S − B) X N thiosulfate X 1000 Weight of sample

S = volume of titrant used for sample B = volume of titrant used for blank

Determination of acid value and free fatty acid

25mL of diethyl ether was added to 25mL of alcohol and 1mL of phenolphthalein solution. This was carefully neutralized with 0.1M of sodium hydroxide; 5g sample was dissolved in the neutral solvent and titrated with 0.1M sodium hydroxide solution with constant shaking until a constant pink colour which persisted for 15 seconds was obtained (Pearson, 1976). The acid value was calculated using the equation below:

Acid value = titration (mL) X 5.61 weight of sample used

Free fatty acid = 0.503 X Acid value (Akubugwo *et al.*, 2008)

Determination of Saponification Value

40g of potassium hydroxide was dissolved in 20mL of water and diluted to 1L with 95% alcohol and allowed to stand overnight. The clear liquid was decanted, 2g of the sample was weighed into a conical flask and 25mL of the alcoholic potassium hydroxide solution was added, then the flask was heated in boiling water for 30 minutes with the aid of a reflux condenser shaking it frequently. 1mL of phenolphthalein (1%) indicator was added and titrated hot with 0.5M HCl. A blank titration was also carried out using the same procedures (Pearson, 1976). The saponification value was calculated using the equation below:

Saponification value = (b – a) x 28.05 weight in g of sample
a = volume of titrant used for sample
b = volume of titrant used for blank

Determination of iodine value

The method of Wij was used. Wijs' solution was first prepared by dissolving 8g of iodine trichloride in 200mL glacial acetic acid and 9g iodine in 300mL carbon tetrachloride, the two solutions were mixed and diluted to 1000mL with glacial acetic acid, 2.5g of sample was weighed into a 250mL flask after which 10mL of carbon tetrachloride was added into the sample to dissolve, 20mL of Wijs' solution was then added. A stopper moistened with potassium iodide solution was used for the flask and was allowed to stand in the dark for 30 minutes after which 10mL of potassium iodide solution (10%) and 100mL of distilled water was added and then mixed. The solution was titrated using 0.1M sodium thiosulphate solution just before the end point, starch solution was used as indicator, the same procedure was used to prepare the blank (Pearson,1976). The iodine value was calculated using the equation below:

Iodine value = (b – a) X 1.269weight in g of sample
b = volume of titrant used for blank
a = volume of titrant used for sample

Determination of flash point

The flash point temperature of diesel fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility (Ayodele *et al.*, 2011). The analysis was done using ASTM D93 method using Pensky-Martens closed cup apparatus with thermometer.

Determination of cloud point

The cloud point is the temperature limit at which oils and biodiesels could be used as fuel. The oils and biodiesel would not be suitable for usage as fuel in region where the temperature is lower than their cloud points because they start waxing or solidifying below these temperatures. The cloud point analysis was done using the ASTM D2500 method.

50mL of sample was measured into a glass bottle containing a thermometer and immersed together in a water bath after which the water bath and the content were cooled in a refrigerator with continuous stirring of the sample, the temperature at which the thermometer was no longer visible was recorded as the cloud point.

Determination of pour point

Pour point refers to the temperature at which the oil in solid form starts to melt or pour. The pour point was done using the ASTM D97 method. 5mL of sample was drawn into a capillary tube tied to a thermometer, placed in a 250mL beaker containing distilled water and immersed together in a water bath for controlled heating. The temperature at which the sample starts to move downward the capillary due to its weight was recorded as the pour point.

Determination of relative density

Relative density or specific gravity is the measure of the ratio of the density (Mass per unit volume) of the oil to the density of water. This is done with the aid of a Specific Gravity Bottle following the ASTM D 445 method.

Determination of kinematic viscosity

This is the measure of the resistance of an oil to flow. The viscosity was done using the ASTM D78 method using Herzog GmbH MP-480 viscometer.

Kinematic viscosity = $Dynamic\ viscosity\ relative\ density$

Statistical analysis

Two way analysis of variance test (ANOVA) was used to determine the significance difference and principal component analysis was used to determine the relation of the component, this was done using SAS 9.13 version.

RESULTS AND DISCUSSION

Biodiesel Yield

Transesterification of fats and oils was done with methanol in the presence of KOH at 60^{o}C. Plate 1 below shows the picture of biodiesel produced.

Plate 1. Picture of the biodiesel produced; from left to right GO, GOCF, CF, POCF and GOPO

The results obtained from the transesterification of all the oils and fats gave high yield of CF 87.5% but lower than 95.2% reported by Ilaravesi *et al.* (2011). For CF, GO 86% and GOCF 82.4% were both higher than 79% reported by Ibeto *et al.* (2011). For GO, GOCF 82.4%, GOPO 76.35% and POCF 73.5% and tends to give a lower yield compared to the others, but from literatures no work has been found to have combined several oils and fats for the production of biodiesel. Despite the fact that oils, fats and composites were not pre-treated using acid transesterification, these indicates that chicken fat and groundnut oil are good feedstocks for the production of biodiesel and may not always require the long process pretreatment which involves the acid transesterification before the normal base transesterification. The fact that groundnut oil usage can compete with food shortage because of it edibility makes chicken fat a better option for the production of biodiesel more so it is good to consume it due to health issue.

Fats and oils were transesterified under the same condition of time, amount of catalyst, temperature and stirring speed but some which include; BF, CFBF, POBF, PO and GOBF all formed a waxy substance which separates itself from the added methanol, these substances were suspected to be soap because they formed lather with water, this must have been as a result of the oils and fats having a high percentage of free fatty acids, high moisture contents, high saponification value and poor agitation which is in line with the report of Ibeto *et al.* (2011). The case of the palm oil might be because it was obtained commercially and over 80% of palm oil mills are processed by smallholders who typically make use of manual and /or traditional techniques for processing which basically increases the FFA of the palm oil. Storage also increases the FFA content of palm oil. Besides, palm oil produced locally in Nigeria often solidifies even at ambient tropical climatic conditions as reported by Izah and Ohimain (2013).

Table 3. Flame test results of biodiesels and petro-diesel

Sample	Observation
Petro-diesel	Highly flammable and sooty flame
GO	Moderately flammable and soot-less flame
GOCF	Slightly flammable and soot-less flame
GOPO	Less flammable and soot-less flame
CF	Moderately flammable and soot-less flame
GOCF	Less flammable and soot-less

Flame test was carried out on biodiesel produced so as to determine how best they burn in diesel engines, their environmental impact and how well they can be handled to prevent fire outbreak. According to the analysis, petro-diesel was highly flammable which is not safe for keeping at home and also gave a very sooty flame which was as a result of incomplete combustion of the hydrocarbon content of the diesel which could result into the degradation of the environment and it's ecology, all biodiesels were not very flammable which indicates that they are safe for handling in

Table 2. Percentage yields of the biodiesels

Fats or Oils	GO	PO	CF	BF	GOCF	GOPO	POCF	CFBF	POBF	GOBF
% yield	86%	FS	87.5%	FS	82.4%	76.35%	73.5%	FS	FS	FS

FS- formed soap

% yield = $volume\ of\ biodeisel\ producedvolume\ of\ oils\ or\ fats\ used \times 100$

homes, the biodiesels also gave soot-less flames which was due to the presence of fatty acid methyl esters which undergo complete combustion these makes the biodiesels environmentally friendly since they do not cause any environmental and health degradation.

Physico-chemical characteristics of products formed

Table 4 below shows the statistical analysis of the results of the physico chemical parameters of the oils, fats and composites while Table 5 below shows the statistical analysis of the result of the physico chemical parameters of the transesterification products of each oils, fats and composites.

GO (245.30±0.12 mgKOH/g) has the highest saponification value but not significantly different (P<0.05) from GOPO (232.50±0.11 mgKOH/g) and BF (234.60±0.01 mgKOH/g) which are significantly different from the other oil types. PO (208.40±0.10 mgKOH/g) tends to have the highest saponification value, even higher than 207.00 mgKOH/g reported by Ayodele *et al.* (2011) which makes it liable to form soap, as well as POBF (201.30±0.50 mgKOH/g), the GO (194.10±0.06 mgKOH/g) was higher than 148.67 mgKOH/g reported by Ibeto *et al.* (2011). CF (186.20±0.40 mgKOH/g) has the lowest saponification value which makes it a good feed stocks for biodiesel. POBF (259.10±0.24 mgKOH/g) has the highest saponification value which could have resulted from the combination of both fat and oil. The saponification value of all other transesterification products were significantly different from each other. The peroxide value in all the oil types were significantly (P<0.05) different from each other except CF (48.00±0.58 m/Eqkg) and GOBF (47.00±0.42 m/Eqkg) which were not significantly different from each other. POCF (52.00±0.35 m/Eqkg) had the highest value followed by CF (48.00±0.58 m/Eqkg), GO (22.40±0.05 m/Eqkg) was higher than 18 m/Eqkg reported by Bello and Agge, (2012) for GO. The peroxide value in all the biodiesel products were significantly (P<0.05) different from each other except GOBF (14.0±0.17 m/Eqkg) and PO (14.00±0.06 m/Eqkg) which were not significantly different from each other and did not form biodiesel. All biodiesel formed have least values which indicates that they are less rancid.

The iodine value in all the biodiesel products were significantly (P<0.05) different from each other except GOBF (27.20±0.62 gI2/100g) and GOCF (27.70±0.13 gI2/100g) which were not significantly different from each other. GO (60.40±0.17 gI2/100g) which was lower than 89.46 gI2/100g reported by Ibeto *et al.* (2011) and GOPO (64.50±0.03 gI2/100g) both have the highest values which shows how unsaturated they are, CF (20.20±0.09 gI2/100g) and BF (15.10±0.01 gI2/100g) both have low iodine values which implies that they are highly saturated, their level of saturation affects their cloud points. The iodine value of the transesterification products were significantly (P<0.05) different from each other, but GO (41.20±0.01 gI2/100g) and CF (41.20±0.01 gI2/100g); PO (39.8±0.01 gI2/100g), BF (40.30±0.01 gI2/100g), CFBF (40.40±0.23 gI2/100g), POCF (40.40±0.10 gI2/100g) and GOCF (40.40±0.25 gI2/100g) were not significantly (P<0.05) different from each other. Relative density, cloud point, flash point, pour point as well as kinematic viscosity were not determined in the oils or fats that formed soap during the process of transesterification since it was outside the scope of this research.

The relative density of all the oil samples were not significantly (P<0.05) different from each other. The relative density of GO (0.85±0.01) is significantly different from CF (0.87±0.02), GOCF (0.89±0.02), GOPO (0.89±0.01) and POCF (0.86±0.01). All biodiesel formed conformed with the ASTM standard (0.86-0.90) for relative density, biodiesel from GO (0.85±0.01) was lower than the 0.88 reported by Ibeto *et al.* (2011), biodiesel from CF (0.87±0.02) was similar to 0.87 reported by Ilaravesi *et al*. (2011). GOCF(0.89±0.02), GOPO(0.89±0.01) seems higher this may be as a result high moisture content arising from combining the oils and fats in the biodiesel this could be eradicated by passing the biodiesel through anhydrous Na_2SO_4 to help remove moist as reported as reported by Bello and Agge (2012).

CFBF (5.70±0.04 mm^2/sec) had the highest kinematic viscosity value which is significantly greater than the kinematic viscosity value of other oil types but not significantly different from POCF (5.60±0.03 mm^2/sec). GOCF (4.40±0.15 mm2/sec) had the highest kinematic viscosity value which is significantly greater than the kinematic viscosity value of GO (3.40±0.21 mm^2/sec) which was the lowest value of all but not significantly greater that the viscosity of the other oil and fats sample. All biodiesels conformed with the ASTM standard of kinematic viscosity which makes them a good fuel for engines, because highly viscose fuels have an adverse effect if used in engines as reported by Ayodele *et al.* (2011). The biodiesel from GO (3.40±0.21 mm2/sec) recorded was lower than 6.6 mm^2/sec reported by Bello and Agge (2012) and 7.65 mm^2/sec reported by Ojolo *et al.* (2012) but did conformed to the ASTM standard which makes a good fuel. There was no significant different in the pour point value of GO (3.80±0.21^{o}C) and GOBF (3.70±0.06^{o}C). GOPO (5.70±0.10^{o}C) had significantly higher pour point value than the other oil types while GOBF (3.70±0.06^{o}C) had the least value.

The pour point value of CF (4.40±0.20^{o}C) was significantly higher than the pour point value of GO (3.50±0.15^{o}C) and GOCF (3.90±0.12^{o}C), GOPO (4.10±0.17^{o}C) and POCF (3.70±0.12^{o}C) which were not significantly different from each other. All biodiesels conform to the ASTM standards for pour point which has no limit, biodiesel from GO (3.50±0.15^{o}C) tends to be the highest, followed by the biodiesel from GOCF (3.90±0.12^{o}C), all pour points tends to be lower than the 8 reported by Ayodele *et al.* (2011) for biodiesel from jatropha oil, which indicates that GO and GOCF biodiesels when solidified would melt easily, these makes them a better fuel than others when pour point is the most important property of fuel needed to consider. The flash point of all oil samples were significantly (P<0.05) different from each other but the flash point of PO (214.80±0.23^{o}C) and BF (213.80±0.12^{o}C) were not significantly different from each other. The flash point of all the biodiesel produced were significantly (P<0.05) different from each other, biodiesel from CF (116.80±0.35^{o}C) tends to be the lowest of all flash points while GOPO (158.80±0.31^{o}C) was the highest which indicates that it a better fuel among all when flash point is considered, all biodiesels flash point were lower than 202^{o}C reported by Ibeto *et al.* (2011).

Table 4. Physico chemical parameters of raw oils, fats and composites

S.No	PARAMETER	OIL TYPES									
		Groundnut oil (GO)	Palm oil (PO)	Chicken fat (CF)	Beef fat (BF)	Chicken fat + beef fat (CFBF)	Groundnut oil+ beef fat (GOBF)	Ground nut oil + chicken fat (GOCF)	Ground nut oil + palm oil (GOPO)	Palm oil + chicken fat (POCF)	Palm oil +beef fat (POBF)
1	Acid value (mgKOH/g)	5.90±0.01f	3.00±0.01i	5.90±0.02f	6.70±0.01d	6.60±0.08e	5.60±0.00h	15.70±0.01a	5.70±0.02g	11.50±0.12c	14.00±0.01a
2	Free fatty acid (%)	3.00±0.01f	1.50±0.01h	3.00±0.01f	3.40±0.01d	3.20±0.04e	2.80±0.02g	7.90±0.07a	2.80±0.06g	5.80±0.02c	7.10±0.02b
3	Saponification value (mgKOH/g)	194.10±0.06ef	208.40±0.10a	186.20±0.40i	193.20±0.29g	198.50±0.29c	197.20±0.21d	192.10±0.26h	193.40±0.23gf	194.60±0.25e	201.30±0.50b
4	Peroxide value (mEq/kg)	22.40±0.05g	38.0±0.29c	48.00±0.58b	19.00±0.23h	35.00±1.15d	47.00±0.42b	33.00±0.56e	48.00±0.40c	52.00±0.35a	28.90±0.61f
5	Iodine value (gI2/100g)	60.40±0.17b	54.30±0.06c	20.20±0.09h	15.10±0.01i	24.50±0.38g	27.20±0.62f	27.70±0.13f	64.50±0.03a	29.20±0.04e	30.50±0.02d
6	Relative density	0.92±0.01a	0.90±0.00a	0.90±0.02a	0.90±0.01a	0.91±0.02a	0.92±0.02a	0.93±0.02a	0.93±0.01a	0.90±0.01a	0.90±0.01a
7	Flash point (oC)	197.40±0.20i	214.80±0.23f	202.80±0.12h	213.80±0.12f	237.60±0.21b	209.00±0.40g	242.80±0.12a	233.40±0.10c	227.40±0.24e	229.40±0.09d
8	Pour point (oC)	3.80±0.21f	5.50±0.10ab	5.00±0.10cde	5.20±0.17bcd	4.60±0.15e	3.70±0.06f	5.40±0.15abc	5.70±0.10a	4.80±0.15de	4.80±0.15de
9	kinematic viscosity (mm2/sec)	4.40±0.12f	4.70±0.03ef	5.20±0.08bdc	5.00±0.32cde	5.70±0.04a	5.50±0.06ab	5.30±0.06abc	4.90±0.07ed	5.60±0.03a	5.40±0.03ab
10	Cloud point (oC)	7.20±0.15ab	5.20±0.12g	5.60±0.10gf	5.90±0.20ef	6.90±0.17bc	7.50±0.10a	6.60±0.12cd	6.40±0.15d	6.30±0.06de	5.40±0.15g

a, b, c, d, e, f, g..: means within each row with different superscript are significantly different (P< 0.05)

Table 5. Statistical analysis of physico chemical parameters of transesterification products of each oils, fats and composites.

S.No.	PARAMETER	OIL TYPES										
		Groundnut Oil (GO)	Palm Oil (PO)	Chicken Fat (CF)	Beef Fat (BF)	Chicken Fat + Beef Fat (CFBF)	Groundnut Oil+ Beef Fat (GOBF)	Ground nut Oil + Chicken Fat (GOCF)	Ground nut Oil + Palm Oil (GOPO)	Palm Oil + Chicken Fat (POCF)	Palm Oil +Beef Fat (POBF)	ASTM
1	Acid value (mgKOH/g)	1.00±0.02e	2.90±0.02a	1.50±0.03d	0.50±0.02f	0.90±0.09e	0.90±0.01e	1.80±0.01c	2.40±0.10b	2.80±0.10a	2.50±0.01b	0.8 max
2	Free fatty acid (%)	0.50±0.01d	1.50±0.01a	0.80±0.02c	0.20±0.02e	0.45±0.01d	0.50±0.01d	0.90±0.03c	1.20±0.13b	1.30±0.13ba	1.20±0.01b	-
3	Saponification value (mgKOH/g)	245.30±0.12d	255.30±0.10c	223.53±0.08j	234.60±0.01f	257.40±0.25b	238.10±0.17e	227.30±0.08i	232.50±0.11g	228.10±0.23h	259.10±0.24a	-
4	Peroxide value (mEq/kg)	2.60±0.029i	14.0±0.06b	4.0±0.06h	4.9±0.19g	8.0±0.06e	14.0±0.17b	5.5±0.12f	9.0±0.17d	11.0±0.15c	18.0±0.35a	-
5	Iodine value (gI2/100g)	41.2±0.01a	39.8±0.010bc	41.2±0.01a	40.3±0.01b	40.4±0.23b	38.6±0.17d	40.4±0.25b	39.5±0.45c	40.4±0.10b	33.3±0.20e	-
6	Relative density	0.85±0.00b	-	0.87±0.01a	-	-	-	0.89±0.00a	0.89±0.00a	0.86±0.01ab	-	0.86-0.90
7	Flash point (^{o}C)	127.00±0.12d	-	116.80±0.35e	-	-	-	154.60±0.12b	158.80±0.31a	149.20±0.06c	-	130
8	Pour point (^{o}C)	3.50±0.15c	-	4.40±0.20a	-	-	-	3.90±0.12abc	4.10±0.17ab	3.70±0.12bc	-	-
9	kinematic viscosity (mm2/sec)	3.40±0.21d	-	3.90±0.12bc	-	-	-	4.40±0.15a	3.60±0.15cd	4.10±0.06ab	-	1.9-6.0
10	Cloud point (^{o}C)	Cloud point	8.70±0.21a	-	7.30±0.12c	-	-	-	8.30±0.15ab	7.80±0.15bc	7.40±0.15c	

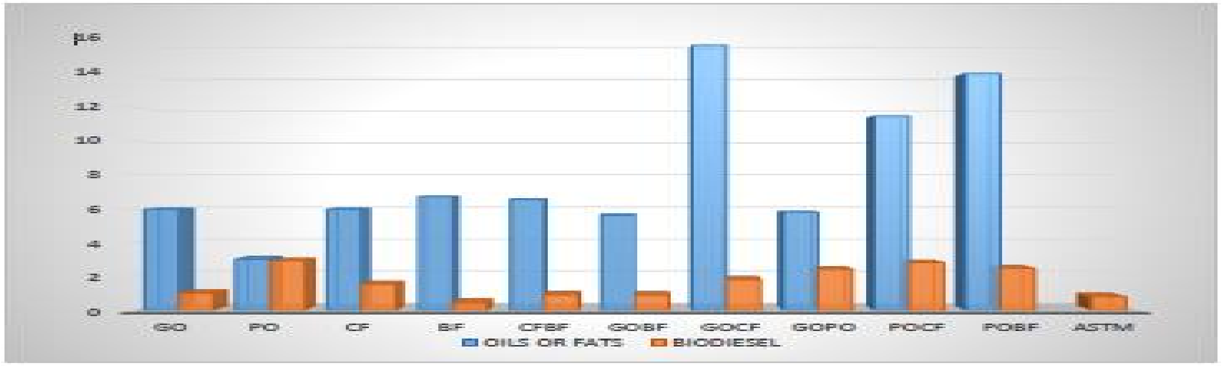

Figure 1.1. Acid value of the fats or oils and the biodiesels

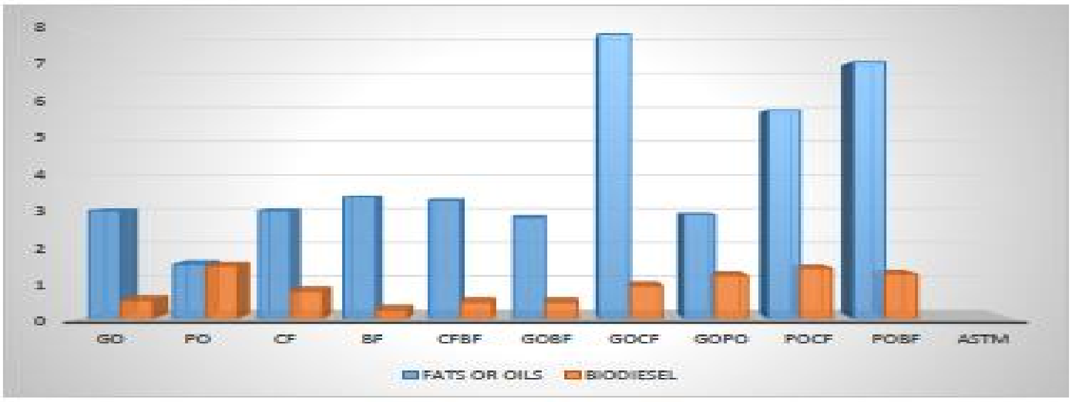

Figure 1.2. Free fatty acid of the fats or oils and the biodiesel

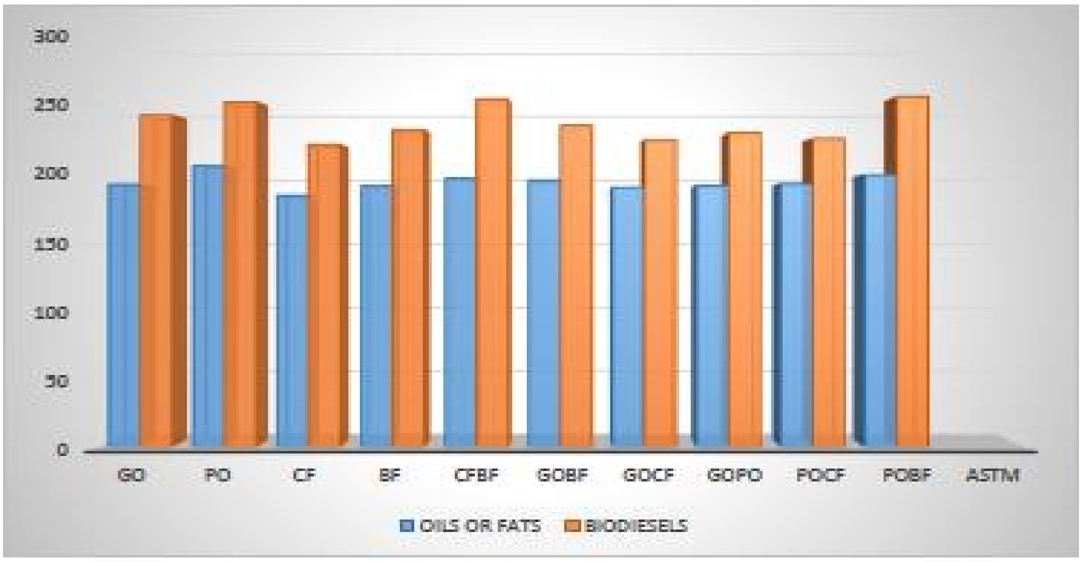

Figure 1.3. Saponification value of the fats or oils and the biodiesels

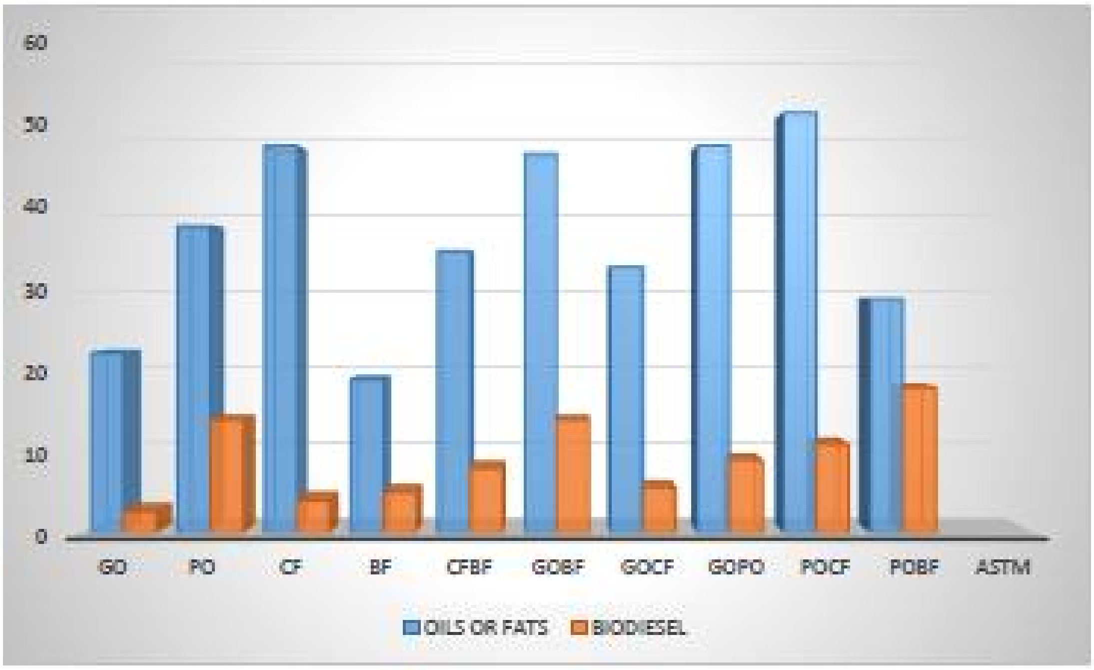

Figure 1.4. Peroxide value of the fats and oils and the biodiesel

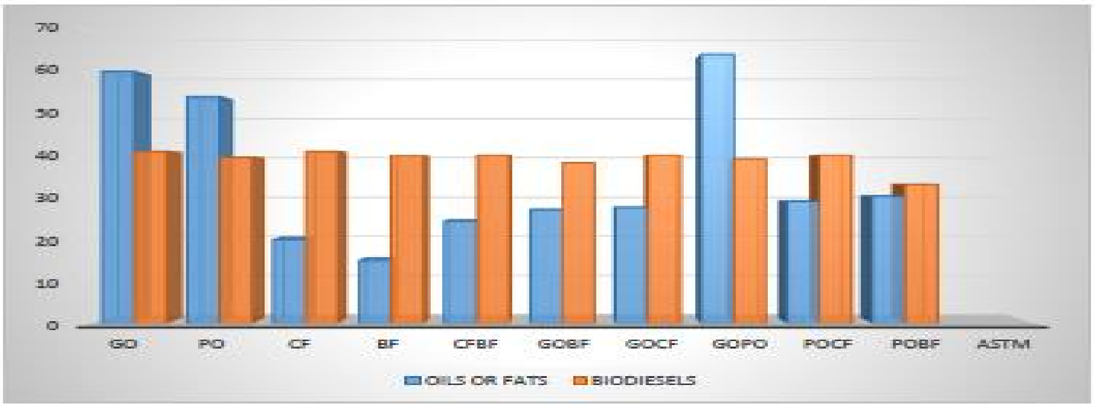

Figure 1.5. Iodine value of the fats and oils and the biodiesels

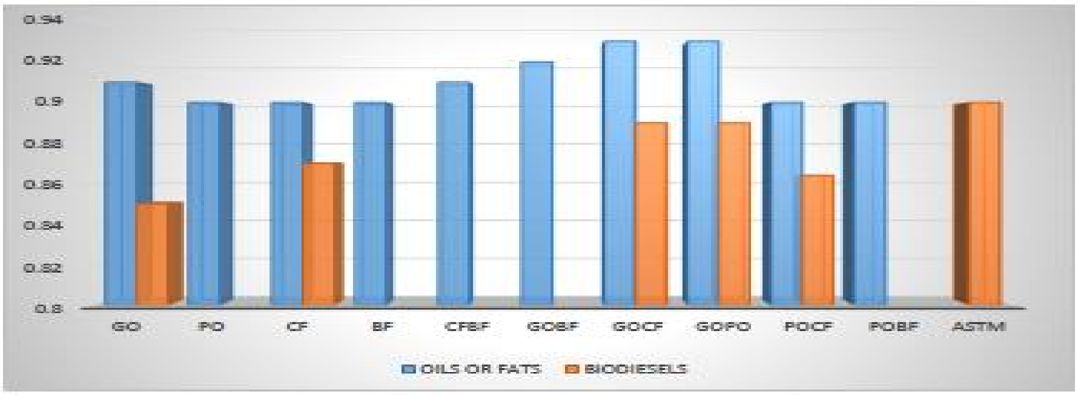

Figure 1.6. Relative density of the oils or fats and the biodiesels

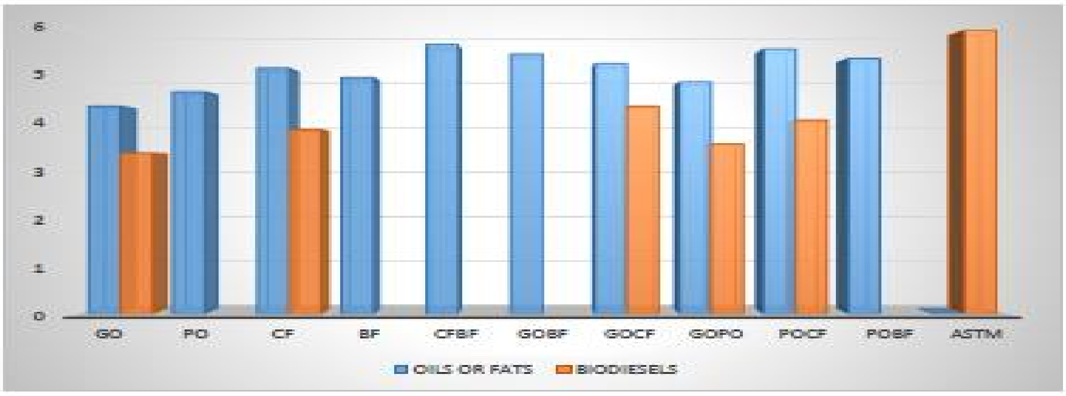

Figure 1.7. Kinematic viscosity of the oils or fats and the biodiesels

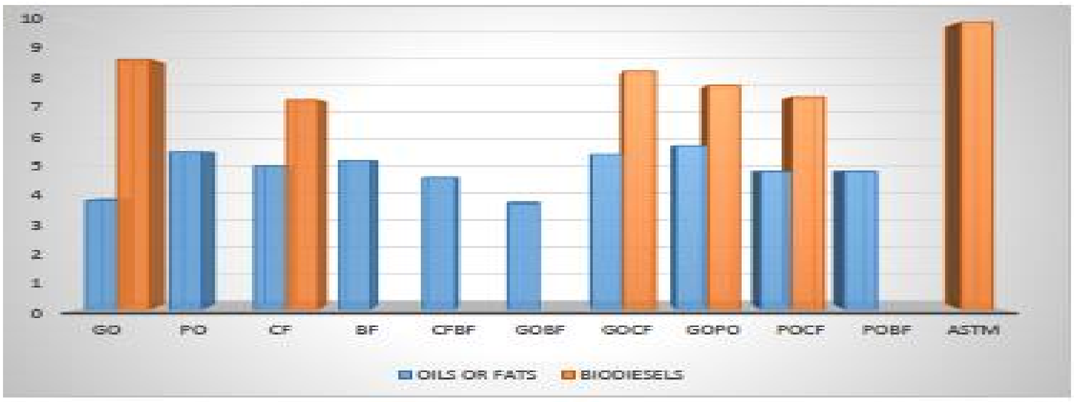

Figure 1.8. Pour point of the oils or fats and the biodiesels

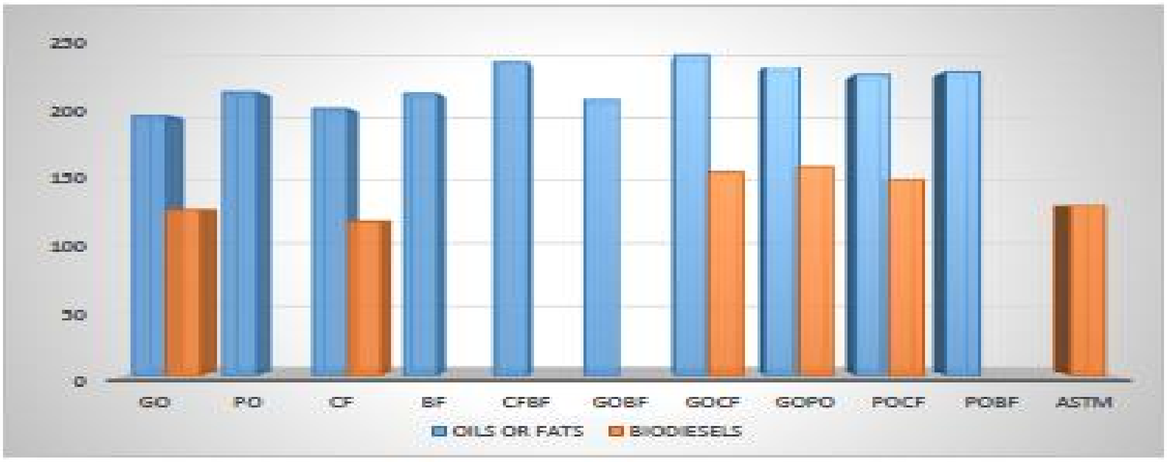

Figure 1.9. Flash point of the fats or oils and the biodiesels

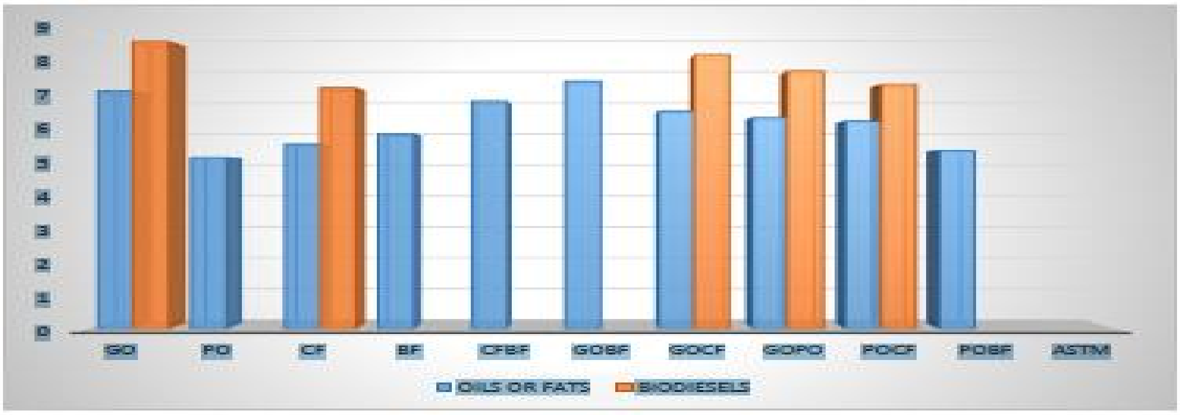

Figure 1.10. Cloud point of the oils or fats and the biodiesels

GOCF (6.60±0.12^{o}C) had significantly higher cloud point value than the other oil types but there was no significant difference in the cloud point value of PO (5.20±0.12^{o}C) and POBF (5.40±0.15^{o}C). Biodiesel from CF and POCF both had the least cloud point and significantly different from the other oil types, biodiesel from GO (8.70±0.21^{o}C) tends to have a higher cloud point compare to others, followed by biodiesel from GOCF (8.30±0.15^{o}C) this could be as a result of high and low saturations of the oils and fats. Cloud point is a great property of fuel necessary to be considered at low temperature regions because at low temperature the fuels start to solidify and form waxy materials, makes it a bad fuel in regions with temperature below 7^{o}C, so therefore all biodiesel produced can be used in tropical rain forests where temperatures do not go as low as 7^{o}C.

4.4 Statistical analysis of the oils, fats and biodiesels

Analysis of the oil type by PCA using the 10 physiochemical parameters reduced all the oil type in fat and oil into 4 principal components and 5 components in biodiesel. Fig 2.1 and 2.2 illustrate the physiochemical relationship between the oil types in fat and oil and biodiesel with respect to two major components. The ordination in Fig. 2.1 revealed a distinct and distance physiochemical relationship among the oil types. Fig. 2.1 consist of five major distinct association. The first and the second groups consist of 1, 6 (GO and GOBF) and 2, 8 (PO and GOPO) clusters, which distantly related and occupy upper part and lower part of the component 2 respectively. The third and four group consist of 7, 9 (GOCF and POCF) and 5, 4, 10 (CFBF, BF and POBF) clusters which were also distantly related and occupy the middle and upper part of component 1. CFBF form a loading around the origin on the right end of component 1 while fifth group (CF) form around the middle part of component 1.

The oil characterization of fat and oil could therefore be said to depict the one that is related (distantly) to each other.

Figure 2.2 which represents the oil type in biodiesel showed six groups. The first and second groups consist of 10, 2 (POBF and PO) and 5, 6 (CFBF and GOBF) formed loading at the upper and middle part of component 2 respectively. This showed a kind of similarity in the transesterified products found in these components. The third consist of 7, 8, 9 (GOCF, GOPO and POCF) which were closely related while the remaining groups, four, five and six, 3, 1, 4 (CF, GO and BF) respectively were not related. The 3 and 1 loading on component 1 and 4 loading towards the end of component 2 were all distantly related which indicates that these transesterified products are not related in anyway.

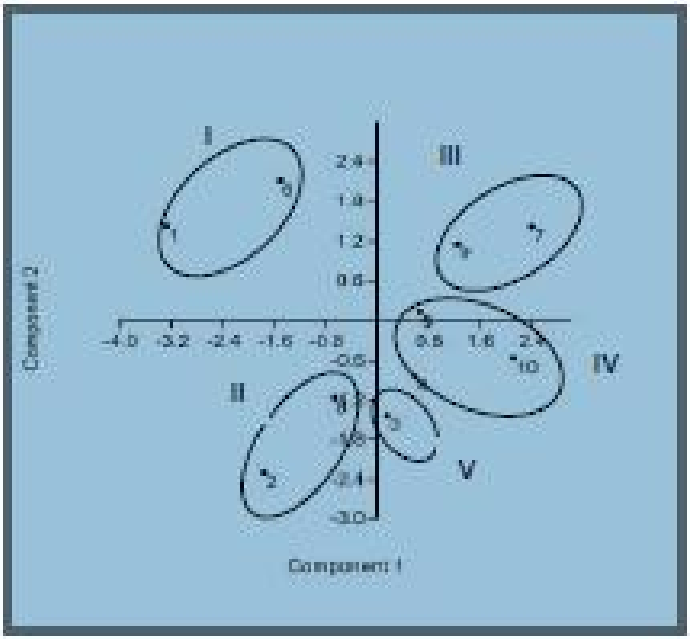

Fig 2.1. Oil type ordination of Fat and oil by PCA

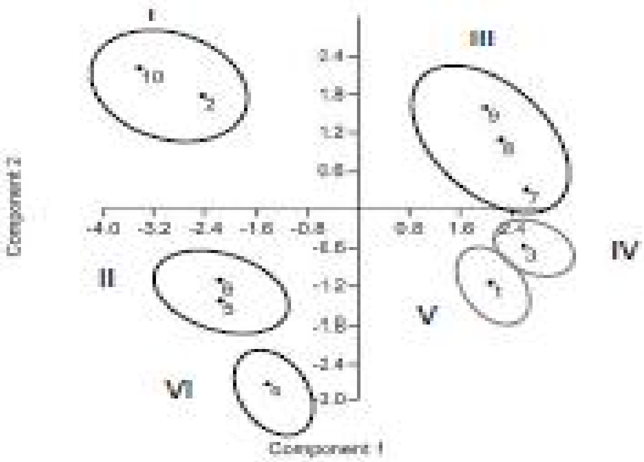

Fig 2.2. oil type ordination of biodiesel by PCA

Conclusion

Biodiesels were produced from CF, GO, GOCF,GOPO and POCF, the experimental result gave 87.5%, 86%, 82.4%, 76.35% and 73.5% yield respectively. Most of the physico-chemical properties (including acid value, free fatty acid, peroxide value, iodine value, saponification value, pour point, flash point, cloud point, relative density and kinematic viscosity) of the biodiesels conformed to the ASTM standards except for the acid values and flash points. The composite biodiesels GOCF, POCF and GOPO all conformed to the flash point. Among all composites, GOCF combination tends to give satisfactory fuel properties which conforms to almost all ASTM biodiesel standards and can also be blended with normal petro-diesel to give good quality diesel for engines. This is of high benefit to commercial biodiesel producers who are looking for quality oils that are cheap and readily available.

Health wise, chicken fat, CF and beef fat, BF are not good for consumption because of their high saturation which can lead to cardiovascular diseases such as atherosclerosis, coronary heart disease (CHD), cerebrovascular disease (stroke), hypertension, peripheral artery disease, rheumatic heart disease, congenital heart disease and heart failure, instead of discarding them because of their health implications, they could turn into an economically viable product such as biodiesels.

Recommendation

Government should look into the production of biodiesels to help improve humanity and national development in rural areas, since the raw materials are produced locally and to help reduce the issue of environmental degradation resulting from the normal diesel. Producers should pay more attention to the combination of oils and fats to help eradicate the issue of edible oils used in biodiesel causing food shortage and use more of animal fats and inedible oils because they seem not to be useful health wise compared to edible oils which could be diverted to the food industries.

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