Physiochemical Properties of Fuel Oil from Pyrolysis of Palm Kernel Shell

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Abstract:- **Physiochemical Properties of Fuel Oil from Pyrolysis of Palm Kernel Shell was carried out The PKS was collected from different geographical locations, identified and authenticated before it was washed, sun dried and crushed to a standard grade of 425 µm. The PKS was later pyrolysed in the reactor from 400 to 450ºC. The fuel oil product was passed through a condenser submerged in ice bath for cooling to 10ºC.Fuel oil of 36.65% was recovered from Dura specie of PKS obtained from Ubima (Rivers State) after pyrolysis, with a higher heating value of 42.2 MJ/Kg, and a flash point of 37.9ºC, API gravity at 15ºC was found to be 37.29 with density of 828kg/m^3. (The physical and chemical properties of the biofuel, produced from different PKS species was evaluated in this study). The heat required for pyrolysis of 1000kg/day of palm kernel shell was obtained from scale up of heat requirement as revealed from laboratory results. The structural elucidation of oil produced from pyrolysis of PKS using Gas Chromatography-Mass Spectrometer in this technique, the measurement of the molecular weight of the compounds were determined from which the molecular ions were identified and measured to ascertain the exact number of hydrogen, carbons, oxygen and other atoms that were present in the molecule in order to give the molecular formula. The energy required to pyrolyse the PKS was 841500KJ while the product temperature and the atmospheric temperature were 723K and 378K respectively. It was concluded that the fuel oil produced from the designed PKS pyrolyser met the specifications of fuel oil JET A2 kerosene.**

Key words: Physiochemical, properties, fuel oil, pyrolysis, palm kernel shell.

INTRODUCTION

The solar energy stored in chemical form in plants is among the most precious and versatile resources on earth. Biomass is defined as any organic matter; particularly cellulosic or ligno-cellulosic matter which is available on a renewable or recurring basis both small and large scale levels (Najmi *et al.,* 2007). It already supplies 14% of the world's primary energy consumption. On average, biomass produces 38% of the primary energy in developing countries. In many industries, where agricultural products were being processed; it is being common practice to use organic waste or biomass residues as fuel for production of the energy needed for the processing. Physically, PKS is chosen as a source of bio-energy because it is relatively dense when compared to other biomass varieties, which has positive implications for transporting it for processing (Okoroigwe *et al.,* 2014). Zhenglong *et al.,* (2012) also concluded that physicochemical properties of the feedstock make it easy to convert palm kernel shells to bioenergy.

The GC/MS analysis reveals the presence of useful chemicals such as phenols and ketones in the bio-oil. Thus, conversion yields additional energy sources that can be harnessed to increase energy output of the feedstock. Zhenlong *et al.*,(2012). Its conversion to bioenergy via fast pyrolysis is a promising technique for achieving maximum energy output of oil palm plantations There are number of benefits when using biomass residues as fuel instead of using fossil fuels; Biomass fuels do not create any rise in the amount of greenhouse gas in the atmosphere, biomass contains almost no sulphur thus, the combustion of the biomass creates hardly any sulfur acid. The ash is normally alkaline. If biomass ash is spread to the environment it will counteract acidification.

Using biomass residues as fuel often solve as waste disposal problem and create instead an income for the waste producer or user. FAO, (2012).There is problem of insufficient energy source and the need for an alternative, less expensive and renewable energy source. Also, there is need to convert the land pollution caused by palm kernel shells to energy source by using the shells which is a waste after the removal of palm kernel nut.

The scope of the research is to produce bio-fuel from palm kernel shells in laboratory scale, evaluate physical and chemical properties of the bio-fuel. Okoroigwe *et al.,* (2014).

MATERIALS AND METHODS

Materials: Palm Kernel Shells (Dura & Tenera specie PKS Mass Spectrophotometer Separating funnel, water for cooling,-A Batch pyrolyser unit made of mild steel which was constructed with an hopper and connected (air tight) to a glass condenser for proper condensation of gaseous product, Density g/m^3, Mass of PKS Initial concentration C_{A0}, Conversion X_{AO}, N_{AO} at 1000kg, Heat capacity C_P, Input quantity of heat Q. Ademiluyi, F. T. (2016).

Palm Kernel Shells (PKS) used in this investigation was obtained from Umuagwo in Imo State, Obaagun in Osun and Ubima in Rivers States. The specimen used was a mixture of palm kernel shells since the varieties are not usually sorted during palm oil processing. Other materials and equipment used include; Bomb calorimeter, thermometer, two Condensers and Butane Gas.

EXPERIMENTAL PROCEDURE The samples collected were washed, sun dried in open air at ambient temperature of 31˚C. It was transferred to cellophane bags and sealed. The samples were crushed using Grinding machine to a

particle size of 425µm. The parent feedstock was characterized to determine the heating values, moisture and ash content.

The ultimate analysis for the determination of Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur was carried out.

PYROLYSIS OF PALM KERNEL SHELLS

Fuel oil was produced in laboratory scale using Palm Kernel Shells of different species in order to identify Palm Kernel Shells with the highest fuel oil yield. Five hundred grams 500g, 1000g and 1500g of fresh samples of Tenera and Dura species of Palm Kernel Shells obtained from Osun, Imo and Rivers States, were washed and dried. It was transferred to cellophane bags and sealed. The samples were crushed using crusher to a particle size of 425µm dried and later poured serially and separately into the reactor through the hopper. The hopper was properly sealed to avoid leakages before switching on the heater. The shells were pyrolysed until the product temperature rise   to 400ºC, the reaction time and temperature were taken as the reaction progresses further

to 450^{0}C. The fuel oil produced was cooled using condensers Ajayi *et al.,* (2020)

a. Total Ash Value

These measures the amount of the residual substance not volatilized when the sample was ignited at 450ºC. Ash may be physiological when it is derived from the plant tissue or non-physiological when derived from extraneous matter which are determined together and are therefore called total ash (AP, 1986).

Each porcelain crucible was thoroughly washed and rinsed with water before drying at 80 ^{0}C for 2 hours in an electric hot air oven. On drying, each crucible was allowed to cool in a desiccator before weighing. Into each crucible, 4 g of the sample was weighed, covered and transferred into an electric furnace for incineration at 450 ^{0}C until free from carbon indicated by the whiteness of the ash (AP, 1986). After ashing, each crucible was transferred with the aid of metal tong onto an asbestos tile and then put in a desiccator for cooling. On cooling, each crucible was reweighed and the percentage total ash value calculated as follows;

$$\text{Percentage total ash} = \frac{Wt. of\ ash}{Wt\ of\ sample} \times 100 \qquad (1)$$

a.   b. Determination of Water Content in Fuel Oil by Distillation

This method was used for the determination of water in fuel oil obtained from palm kernel shells. The fuel oil sample was heated under reflux conditions with water - immiscible solvent which was co-distils with the water in the sample. Condensed solvent and water are continuously separated in a trap as the water settles in the graduated section of the trap, the solvent returns to the distillation flask. Five (5) ml sample was measured and carefully poured into distillation flask while heat was subsequently applied slowly to the flask for 30-60mins. After initial

heating, the boiling rate was adjusted so that the condensate proceeds no more than 3 quarters of the distance up the condenser inner tube. The distillate was allowed to discharge into the trap at the rate approximately 2 to 5 drops per second. Distillation was made to continue until no water was visible in any part of the apparatus except in the trap and the volume of water in the trap remained constant for 5mins. This procedure was repeated until no water was visible in the condenser. When the carryover of water was completed, content and trap were cooled to 20^{0}C.

The % volume was calculated as:

Volume % =
$$\frac{Volume\ of\ water\ in\ trap\ ml - Solvent\ blank\ ml}{Volume\ ml\ of\ test\ sample}\ x\ 100 \qquad (2)$$

c. Determine the Specific Gravity of Fuel Oil at 15/15^{0}C:

One hundred (100) ml of the fuel oil PKS was poured in the weighed distillation flask at 15^{0}C to within 0.1g. Precaution was taken not to allow any of the oil to flow into the vapour tube during this operation. The thermometer was fitted tightly into the flask by means of a cork and adjusted in such a way that it would be in the middle of the neck and the lower end of the capillary was leveled with the bottom of the inside of the vapour tube at the junction with the neck of the flask.

Condenser tube was swabbed out to remove any material remaining from a previous test. Flask and its contents were placed in position on the flask guard with the vapour tube inserted into the condenser tube. The connection was made tight by means of a cork through which the vapour tube passes and the position of the flask was adjusted so that the vapour tube extends into the condenser tube. A clean dry receiver was 7placed at the outlet of the condenser so that the condenser tube or the adaptor extends into it at 25mm but not below 100-ml mark. Receiver was immersed up to 100-ml mark in a transparent bath of water maintained at 15±3^{0}C. Top of the receiver was covered closely during distillation with a piece of paper cut to fit the condenser tube tightly against the top of the receiver and also to provide the additional weight for overcoming the buoyant effect of the liquid in the cooling bath. The ice-cold water through the condenser jacket was circulated. Heat was applied to the flask and distilled the oil at a rate not more than 2.5ml/min until it ceases to foam, after which keep the rate of distillation constant at 2 to 2.5ml/min (approximately one drop per sec). Volume of distillate collected in the cylinder was recorded at each multiple of 25^{0}Cand the process continued without interruption to 300^{0}C. The heating of the flak was stopped and allowed the condenser to drain into the receiver. The total volume of distillate collected in the receiver was recorded as the distillate. The relative density at 15/15^{0}C was determined and recorded.

d. Sulphur Determination Through Combustion of Sample:

The fuel oil sample measured was burnt using combustion apparatus. Combustion atmosphere was drawn through one absorber of a set to serve as a blank on the purity. Glassware was reserved for this procedure to avoid any possible contamination from other sources. The absorber solution and chimney was transferred to a 250ml beaker, the absorber was rinsed two to three times with 10ml portions of water. Thereafter, the rinsed absorber was added to the solution in the beaker. The volume of the absorbed solution was reduced to 20ml by evaporation on a hot plate. The resulting solution was transferred quantitatively to a 50ml volumetric flask and the beaker was rinsed with several small portions of H_2O. Three milliliter of HCI was added (1:12) to the flask, make up to volume with water, and mixed thoroughly. Having known the sulphur content of the absorber solution, the entire contents of the volumetric flask was used for the analysis and 10ml of the aliquot was transferred to a second 50ml volumetric flask and the solution was diluted in both flasks to volume with HCI (1:12). More diluted solution was first used then followed by more concentrated solution. The entire contents of the 50ml volumetric flask containing the solution to be analysed was poured into a 100ml beaker. Then the combustion atmosphere was treated blank in the same way to obtain a combustion atmosphere reagent blank reading by subtracting its initial absorbance from that obtained after addition of $BaCI_2.2H_2O$. The net absorbance of the solution analysed was obtained (sulphur) by subtracting the initial absorbance and the combustion atmosphere reagent blank reading from that obtained after addition of $BaCI_2.2H_2O$.

Amount of sulphur in the sample is calculated as:

Sulphur content, ppm

$$=\frac{A}{WF} \; x \; 1000 \qquad (3)$$

Where:

A = milligrams of sulphur read from the calibration curve,

W = grams of sample burned,

F = aliquot fraction of the sample solution used for the analysis.

e. API Gravity at 15^0C:

API gravity is an old fashioned measure of the American Petroleum Institute comparing the oil with a very light and a very heavy American crude oil and is given as degrees API:

API gravity deg. =

$$\frac{141.5}{SP.Gravity \; at \; 60°F/60°F} - 131.5 \qquad (4)$$

The fuel oil sample from PKS was transferred to a clean hydrometer cylinder without splashing. Air bubbles in the liquid were removed by use of a clean filter paper. The sample was then stirred with the thermometer. As a constant reading was obtained, the temperature to the nearest 0.2^0C was recorded. Then the hydrometer was depressed about two divisions into the liquid. The hydrometer was allowed to come to rest without touching the walls of the cylinder. The hydrometer was read to the nearest scale division and recorded. After this, the sample was stirred again and the temperature was recorded which does not vary from the first temperature by more than 0.5^0C.

f. Determination of Flash Point by Tag Closed Tester

Flash Point was carried out **t**o determine the lowest temperature of the sample at which application of an ignition source causes the vapour of the sample to ignite. The sample was charged into the test cup and placed in position, covered with the lid before the cold water tap was turned on to maintain a steady state flow of the process. This flow of cold water maintained steady rise in temperature. After this, the test flame was put on and the electric heater (inbuilt in the apparatus) was switched on and the increase in temperature at regular intervals was observed. At every $1°C$ rise in temperature, the test flame introduced into the test cup concurrently brings it up again. When the test flame application causes a distinct flash in the interior of the cup, this temperature would be observed and recorded as the flash point of the sample.

g. Pour Point of Fuel Oil from PKS:

Pour Point of Fuel Oil was done to determine the temperature of fuel oil at which a cloud haze of wax crystals appears at the bottom of a container. When the oil is cooled during storage and also to determine the lowest temperature at which movement of the oil is observed.

The fuel oil sample was maintained at room temperature, then moisture present was removed by titration through dry lint-less filter paper until the oil was perfectly clean. The sample (test oil) was poured into the jar to the lower reference or level mark. The jar was then closed tightly with the cork carrying the thermometer.

The high pour point thermometer has to be used if the expected pour point is above 0^0C and the low pour point thermometer if the expected pour point is within the range of -15^0C to -35^0C. Then the position of the cork and the thermometer are adjusted to fit the cork tightly with the thermometer bulb resting on the bottom of the jar. After which, the disk was placed in the bottom of the jacket and the ring gasket was placed around the test jar 25mm from the bottom. Then, the test jar was inserted in the jacket.

At each test thermometer reading at $1°C$, the test jar was removed from the jacket without disturbing the oil for inspection of cloud point, and then replaced in the jacket again.

h. Determination of Saybolt Viscosity at 15°C:

The bath was maintained at the test temperature within the limits (0.01°C). A calibrated viscometer (a wide capillary for a very viscous liquid and a narrower capillary for a less viscous liquid) was inverted to charge the sample by applying suction to the tube and immersing the other end of the tube in the sample. After this, the fuel sample was drawn through the tube, filling the bulb of the viscometer to the reference mark on it. Excess sample was wiped off the tube and later the viscometer was inverted to its normal position. Then, the viscometer was mounted in the constant temperature bath, keeping the tube vertical. The viscometer was allowed to remain in this position for a sufficient time to ensure that the sample reaches temperature equilibrium (about 20mins at 37.8°C, 25mins at 99°C, and 30mins at 135°C).

The time required for the leading edge of the meniscus to pass from timing mark E to timing mark F measured to the nearest 0.1 second. The reading was obtained and recorded in mm^2/s at 15°C.

i. Heat of Combustion

The heat of combustion (standard enthalpy change of combustion) is the enthalpy change when one mole of the compound undergoes complete combustion in excess oxygen under standard conditions. It is given the symbol ΔH°_{comb} and standard conditions simply refer to room conditions with a temperature of 298K and pressure of 1 atm.

Aluminum can was weighed and its mass was recorded, 300mL of water was also measured and poured carefully into the can. A thermometer was inserted into the can and its initial temperature in the water was recorded before the can was clamped on the retort stand. The capped ethanol spirit burner was weighed and its mass was recorded before the burner was lighted and the water heated until the temperature rises by 20°C. The flame was later extinguished the burner was capped. Water was stirred gently and the maximum temperature reached was recorded. The spirit burner was reweighed and mass difference was determined. The process was repeated using fuel oil.

j. Distillation Range

This test covers the determination of the distillation range of liquids boiling between 30 and 350°Cthat are chemically stable during the distillation process, by manual or automatic distillation procedures. The method is applicable to organic liquids such as hydrocarbons, oxygenated compounds, chemical intermediates and blends thereof (ASTM, 1999).

One hundred (100) ml of the sample was measured by using a graduated receiver and the fresh specimen was transferred directly to the flask after allowing the graduate to drain for 5 min. the flask was connected to the condenser by inserting the vapour tube of the flask into the condenser, making a tight connection with a well-rolled cork. The position of the heat shield was adjusted so that the neck of the flask was vertical and the vapor tube extended into the condenser tube in a distance of 50 mm while the bottom of the flask rested firmly in the hole of the heat shield. The thermometer was inserted into the neck of the flask through a tight-fitted cork stopper so that the upper end of the contraction chamber was leveled with the lower side of the vapor tube at its junction. The receiver was placed without drying at the outlet of the condenser tube in such a position that the condenser tube extended into the graduate at least 25 mm but did not extend below the 100ml mark. The cylinder in a transparent bath temperature was maintained at 10 to 20°C throughout the distillation. A flat cover was placed on the top of the graduate to prevent condensed moisture from entering the graduate. The heat input was adjusted so that the distillation proceeded at a rate of 4 to 5ml/min (approximately 2 drops per second) and collection of the first drop of distillate was started within 15 min of the start of heating. The receiving cylinder was moved in a way that the tip of the condenser tube touches one side of the cylinder after the first drop falls (initial boiling point). The readings of the distillation was recorded using thermometer after collecting 5, 10, 20, 30, 40, 50, 60, 70, 80,90 and 95 mL of distillate. The distillation was continued without changing the heater setting beyond the 95 % point until the dry point was observed. The temperature was recorded at this point as the dry point. The barometric pressure was read and recorded. After the condenser tube has been drained, the total volume of distillate was read and recorded as recovery (ASTM, 1999).

k. Total Carbon
There are two batches of TOC analyzers with auto-samplers: the Shimadzu TOC-5000A and the Shimadzu TOC-V. Both use high-temperature combustion with the same proprietary catalyst and NDIR detection while TOC-5000A was used in this experiment.

Gas Chromatography/Mass Spectrophotometer (GC/MS) Analysis of Fuel Oil

Initial temperature of GC/MS of 80°C was maintained for 2 minutes which started at 10°C and allowed to rise to 280°C which was held for 6mins. The volume of the sample injected was 1µL while the column used was HP5MS with the length of 30m high, internal diameter was 0.32mm and the thickness was 0.25µmm. The mobile phase used was Helium gas (He) and the flow rate was 2mil/min, the instrument used for the analysis was Agilent Technology. The mobile phase was 7890GC System. The model of the MS detector was 5975 Agilent Technology and the injector temperature used was 250°C.
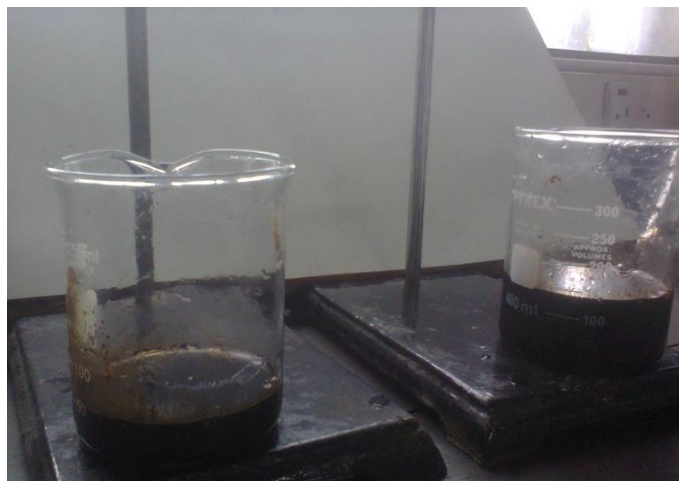
Fig. 1 Fuel Oil Obtained from Kernel Shells

RESULTS AND DICUSSION

Fig. 2 shows the chart of fuel oil produced in laboratory scale using palm kernel shells of different species (Dura from Ubima, Tenera from Osun state and Tenera from Omagwa Rivers State) in order to identify palm kernel shells with highest fuel oil.

The fuel oil yield from Dura specie collected from Ubima in Rivers State has the highest oil yield of maximum peak with the value of 535ml compared to fuel oil produced from Tenera specie collected from Omagwa in Imo State and Tenera from Osogbo in Osun state with the peak of 518 and 500ml respectively.

Final product temperature of Dura and tenera osun was 350ºC while that of tenera omagwa was 330ºC. The pyrolysis time of Dura (100mins) was also longer than that of two tenera species (80mins).
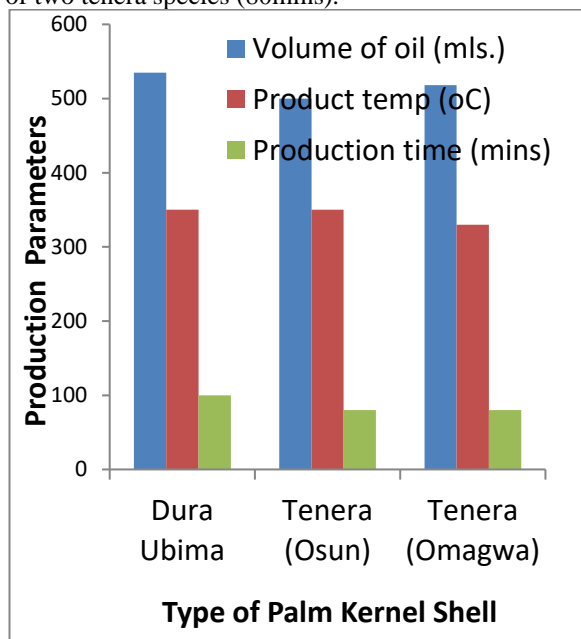
Fig. 2 Production Parameters With Different Palm

PHYSICAL PROPERTIES OF FUEL OIL PRODUCED FROM PALM KERNEL SHELLS

Table 1 shows the physical properties of fuel oil produced from palm shell from Dura through pyrolysis. These were carried out through physical and experimental analysis. The specific gravity or relative density of the fuel oil produced was found experimentally to be 0.8285. This shows that the fuel oil produced is lighter than water. This was compared with other fuel oil and it was discovered that specific gravity of Aviation JETA2 kerosene has the close range of 0.8308 while the oil produced by Ashok (2008) was 0.879 at 15ºC.and ASTM D-1298.with a negligible difference of 0.0023. The American Petroleum institute gravity is a measured of how heavy or light a petroleum is to water. If the API gravity is greater than 10, it's lighter and floats on water. If less than 10, it's heavier and shrinks. Therefore, in this work the API gravity at 15^0C of the fuel oil produced from palm kernel shells is 39.29 this has an equivalent value of 37.9 API.gravity at 15ºC of fuel oil JET A2 and ASTM D-287.

Density at 15ºC is the mass per unit volume of fuel oil produced from palm kernel shells was found to be 828kg/m^3.This was compared with other fuel oil and discovered to be equivalent to fuel oil produced by Leon *et al* .,(1996) that is 839kg/m^3,ASTM D-1298.The viscosity obtained from this fuel oil was found to be 6.42mm^2/s this was critically examined with other less viscous high viscous fuel oil and later discovered that viscosity of 8mm^2/s for fuel jet A2 oil is closer to this value.

The sulphur content of the fuel oil from PKS produced through pyrolysis was found to be 0.66% this was compared to the properties of fossil fuel from palm kernel shells as obtained by moisture free basis 0.51% and also with standard test method ASTMD 482 of 0.1% for Biodiesel/low sulfur diesel fuel blends.

Flash point of a fuel oil is the lowest temperature at which there will be enough flammable vapour to ignite when an ignition source is applied. In this work, the flash point was 37.9^0C this was compared to the standard test method for the Biodiesel/low sulfur Diesel STMD 93 to be 37.9^0C.

Distillation is an excellent method for purifying a liquid and a liquid contains closely packed but mobile atoms or molecules of varying energy. , in this work, distillation range was 28-250ºC which correlated with that of Leon's *et al*., (1996) report under ASTM D86 standard curve.

Water content of fuel oil determines the storage period at which the oil can stand on bench before deteriorating. Very low water content of 2.4 Wt% showed that it can stand for a long period on bench and this water can easily dry-up without affecting the quality of fuel oil and this result also correlated with that of Jean *et al*., (2014) on *J. curcas* seed oil which gave 2.4 Wt% water

The total ash value gives the amount of residual substances not volatilized when the drug sample is ignited and it is useful as a diagnostic tool and a good pointer to detecting the adulteration. In this work, the recommended percentage total ash value limit for the fuel oil should not exceed 0.136 % and correlated with *Jatropha curcas* seed oil with 0.168% (Jean *et al*., 2014).

. The heat of combustion is the total energy released as heat when a substance undergoes complete combustion with oxygen under standard condition. The chemical reaction is typically a hydrocarbon or other organic molecule reacting with oxygen to form carbon dioxide and water and release heat. 422MJ/Kg heat of combustion was produced by fuel oil in this work.

Thermal conductivity is the intrinsic property of a material which relates its ability to conduct heat. Heat transfer by conduction involves transfer of energy within a material without any motion of the material as a whole and conduction takes place when a temperature gradient exists in a solid medium or stationary fluid. Conductive heat flow occurs in the direction of decreasing temperature because higher temperature equates to higher molecular energy or more molecular movement. The fuel oil produced $0.29 Wm^{-1}K^{-1}$ conductivity at 15°C in this work.

Carbon content has been known to be directly proportional to the concentration of the fuel oil (Leon *et al*., 1996). 64.2 % carbon was reported in the fuel oil of PKS and correlated with the standard curve of ASTM D5291 (Leon *et al*., 1996).

a. Structural Elucidation from Pyrolysis of Palm Kernel Shells Using Gas Chromatography/Mass Spectrophotometer

The impure spectrums containing different compounds present in the fuel oil as shown (Fig.3) which was further segmented by GC/MC. The structural elucidation of oil produced from pyrolysis of PKS using Gas Chromatography-Mass Spectrometer in this technique, the measurement of the molecular weight of the compounds were determined from which the molecular ions were identified and measured to ascertain the exact number of hydrogen, carbons, oxygen and other atoms that were present in the molecule in order to give the molecular formula. For example, creosol (4-methyl-2-methoxyphenol (Fig.4) a phenolic compound showed a molecular ion (M$^+$) at m/z 138 with some useful fragments in particular at m/z 123 which is 15 mass units less than the molecular ion and certainly corresponded to {M – Me}$^+$, indicating the molecule contained a methyl group (15 mass units) that is readily lost in the mass spectrometer. Also, 2,6-dimethoxyphenol (Fig.5) showed molecular ion (M$^+$) at m/z 154 with fragment at m/z 139 which is 15 mass units less than

Table 1 Physical Properties of Fuel Oil Produced From Palm Kernel Shells
from the oil as shown in Fig.1

Physical Properties	ASTM	Present Work	unit	Aviation A2
Specific gravity at 15ºC	D1298	0.8285	-	0.8308
API at 15ºC	D287	39.29		37.9
Density at 15ºC	D1298	828	g/m^3	-
Saybolt viscosity at 15ºC	D445	6.42	mm^2/s	8
Sulfur content	D4294	0.66	%	0.33
Flash point	D56	38	ºC	37.9ºC
Pour point	D97	-11	ºC	0 – 40
Distillation range	D86	28-250	0ºC	204
Water content	-	2.4	Wt%	-
Ash Value	D482	0.132±0.04	%	<0.01%
Heat of combustion	D3338	42.2	MJ/Kg	42.8
Specific heat capacity at 15ºC	-	1.89	KJ/Kg.K	-
Thermal conductivity at 15ºC	-	0.29	Wm^{-1}K^{-1}	-
Total carbon	D189	64.2	%	-

the molecular ion and corresponded to {M – Me}$^+$, indicating the molecule contained a methyl group (15 mass units). Other phenolic compounds found are 4-ethyl-2-methoxyphenol (Fig.6), 2-methoxy-4-propylphenol (Fig.7), 5-tert-Butylpyrogallol (Fig.8) and esters such as hexadecanoic acid methyl ester (Fig.9),9-octadecenoic acid (Z)-methyl ester (Fig.10) and nonadecane (Fig.11) and hexadecane (Fig.12) in the oil. Furthermore, (Fig.13) revealed the presence of fourteen hydrocarbon compounds signals, seen under different peak per minute which can improve its rating as fuel oil.
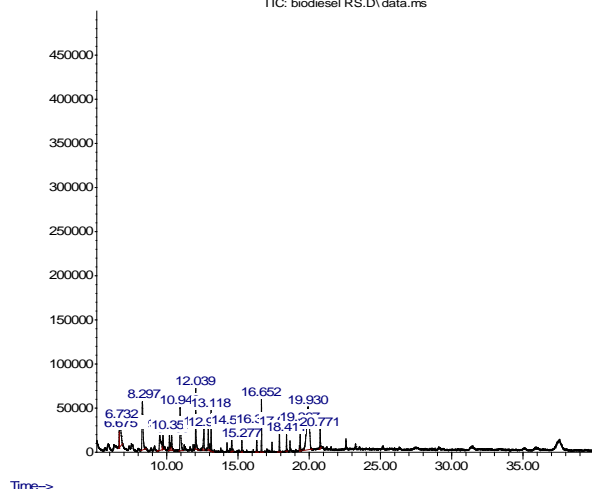

Fig .3 :Chromatography/Mass Spectroscopy of Fuel Oil Produced from Pyrolysis of Palm Kernel Shells
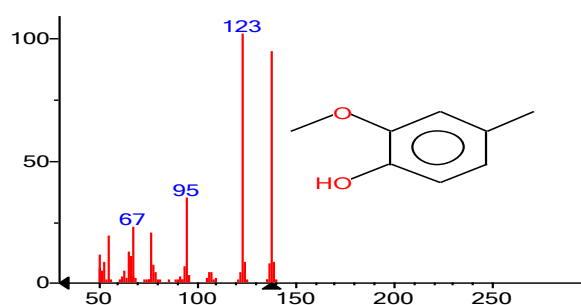

Fig. 4: Mass Spectrum of Creosol

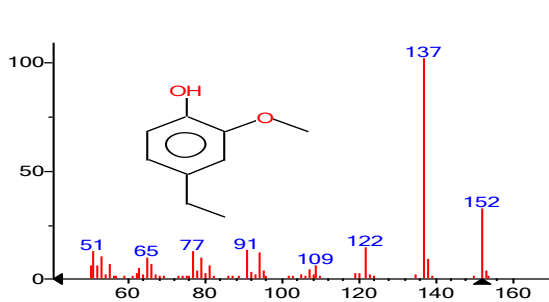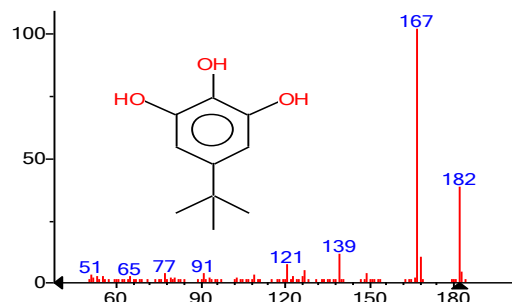**Fig.5: Mass Spectrum of Phenol, 2, 6-Dimethoxy**

Fig.8: Mass Spectrum of 5-Tert, Butylpyrogallol
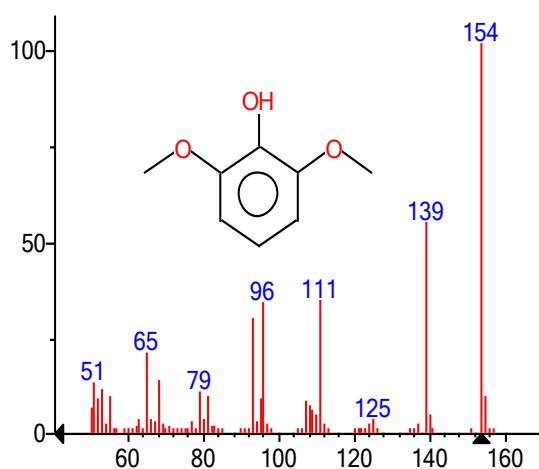

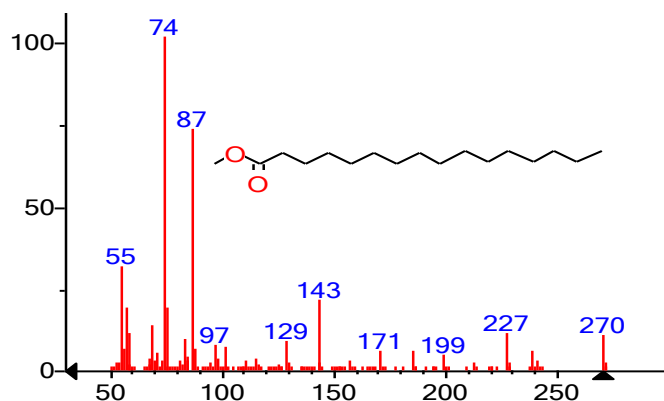**Fig.6**; **Spectrum of Phenol, 4,- Ethyl-2-Methoxy**

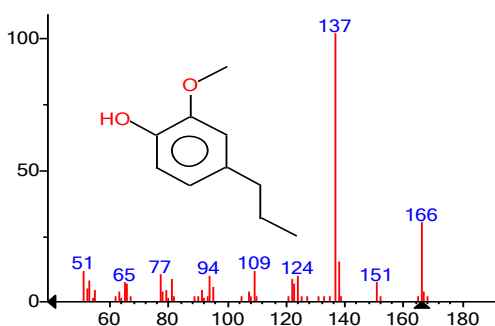**Fig 9: Mass Spectrum of Hexadecanoic Acid, Methyl, Ester**

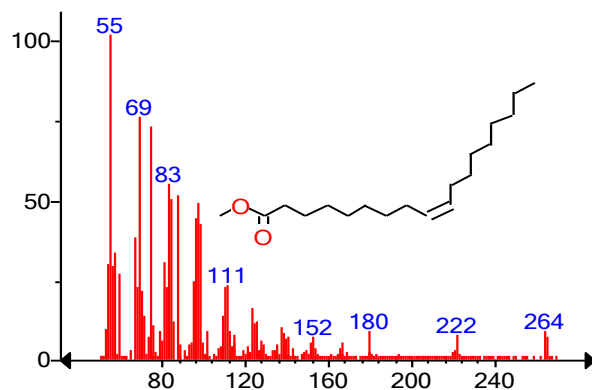**Fig.7: Mass Spectrum of Phenol2- Methoxy-4-Propyl**

Fig.10: Mass Spectrum of 9- Octadecenoic Acid (2) Methylester
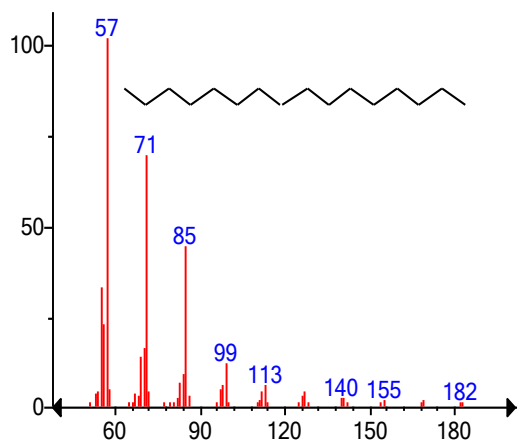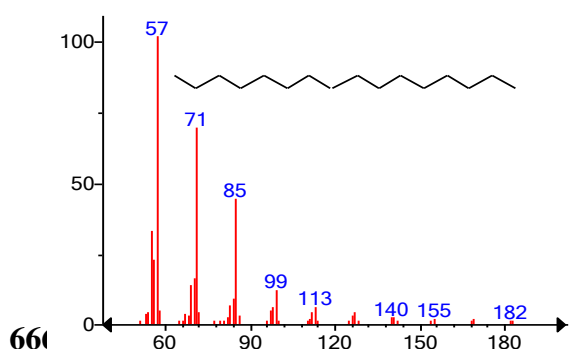
Fig. 11: Mass Spectrum of Nonadecane

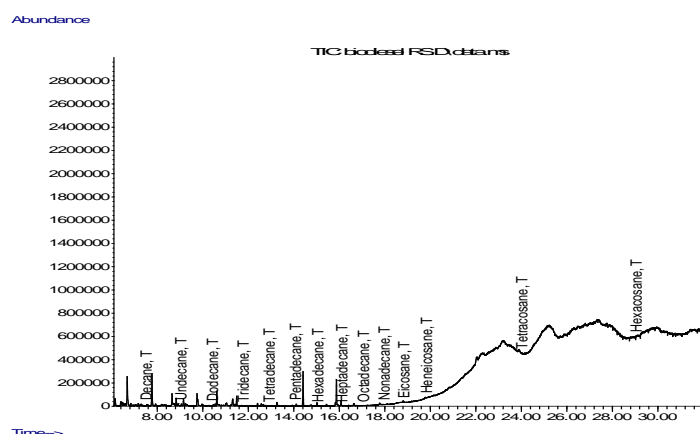**Fig 12: Mass of Spectrum of Hexadecane**

Fig 13: Gas Chromatography/Mass Spectroscopy for the Hydrocarbon Content and the Fuel Oil From Palm Kernel Shells

CONCLUSION

The following conclusions were drawn from the research work as shown below:

(i) The research demonstrates the significance of physiochemical properties of the palm kernel shell on the quality of fuel oil obtained using pyrolysis process.

(ii) The operating condition is one of the functional factors that control effectiveness of the process as well as products identified to be present in the end product (fuel oil).

(iii) The fuel oil obtained is of high quality when compared with the once obtained from fossil fuels as well as the product is more environmentally friendly.

(iv) The following products were identified to be present in the fuel oil, such as spectrum of phenol, 4-ethyl-2-methoxy, mass sprectrum of creasol, 5-Tert Butylprogallol, Hexadecanoic Acid, Methyl, Ester, 9-octadecenoic Acid (2) Methlester, Nonadecane and Hexadecane.

In conclusion, it is revealed that palm kernel shell as a raw material could be found useful in the production of fuel oil of high quality and less environment impact generated when used. The research demonstrated that the palm kernel shell which in most community is regarded as waste is now converted to a useful product that can generate wealth for nations.

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