# PALM OIL- GOOD AS TRANSFORMER OIL

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## ABSTRACT

The exorbitant cost of petroleum based transformer oil has been a disturbing issue in power sector. Now substitutes that cost less have been discovered. Palm fruits (elaeis guineensis) obtained from market were processed. The products, palm and palm kernel oils, were demoisturized to a good extent and subjected to series of tests. The results obtained were very competitive with that of the petroleum based transformer oil. It was, therefore, deduced that these oils (palm oil and palm kernel oil) can be very good in high voltage insulation and cooling. So they can serve as alternatives or replacements to the petroleum based transformer oil presently in use.

**Key words: Insulation, peroxide value, dielectric strength, flash point, pour point, biodegradable.**

## 1.0 INTRDUCTION

There is hope that palm oil and palm kernel oil will efficiently serve as transformer oil. A research conducted recently at Nnamdi Azikiwe University showed that the duo have very good dielectric properties required for high voltage insulation. Therefore they can compete favourably with the mineral oil, presently, being used for transformer cooling and insulation. The transformer oil obtained from petroleum can pose some health hazards. It is not bio-degradable and can be dangerous to crops and aquatic lives. On their own parts, palm and palm kernel oils are biodegradable and are not harmful to crops and aquatic lives. They are stable to heat because of their high bond energy. Again, they can resist corrosion and friction. Unfortunately, palm and palm kernel oils have high pour points but they can flow at temperature above 30°C.

The average room temperature in tropical Africa is 30°C. The expected operating temperature in this zone is 30+Tf. Where Tf is the temperature of the transformer's winding, which is always above 40°C. So palm and palm kernel oils can be comfortably used without further treatment in this zone.

The structures of some vegetable oils are shown in fig.1.

$$
\begin{array}{lclcl}
RCOOH & & HO-CH_2 & & RCOOCH_2 & & \\
R^{1}COOH & + & HO-CH & \longrightarrow & R^{1}COOCH & + & 3H_2O \\
R''COOH & & HO-CH_2 & & R''COOCH_2 & & \\
\text{Fatty acid} & & \text{alkanol} & & \text{ester} & & \text{water}
\end{array}
$$

Fig 1: structures of some vegetable oils

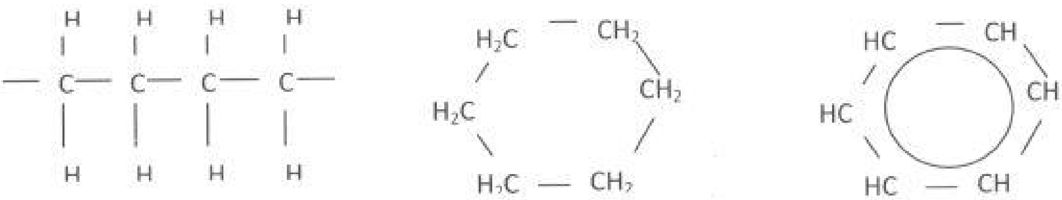
Where R.R$^1$ and R" can be the same or different. The fatty acids commonly found in lipids are long chain alkanoic acids of the general formula, RCOOH where R usually contain about 10 to 18 carbon atoms.

The terminal – COOH group is polar, hence the acid is able to dissolve in water. The carboxylic acid group ionizes in water to a certain degree to form hydrogen ion and carboxylate ion. Fatty acids are thus weak acids.

$RCOOH(aq) \quad RCO(aq) + H^{+}(aq)$

The long alkyl group is not soluble in water because it is non-polar. Fatty acids are of two groups: unsaturated fatty acids and saturated fatty acids

The unsaturated fatty acids have some double bonds in their hydrocarbon chain while saturated fatty acids have no double bonds in their hydrocarbon chain the nature of vegetable oils is that they consists of complex mixture of propane -1, 2, 3 – triol esters. The proportion of each constituent is a product of their properties. in comparison with fats, vegetable oils have lower melting points because they are composed of higher proportion of esters of unsaturated fatty acids.



(a)Paraffin (b) Naphtene (c) Aromatic

Fig 2: Structures of some mineral oils

## 1.1 COST ANALYSIS

From market survey, the prices of these oils are shown in Table 1.

Tabel: comparative prices of oils in Nigeria

| OIL | QUANTITY | COST(₦) | % OF TRANSFORMER OIL |
|---|---|---|---|
| Palm oil | 200L | 25,000 | 17 |
| Palm kernel | 200L | 60,000 | 40 |
| Transformer (mineral) oil | 200L | 150,000 - 200,000 | 100 |

Table 2: Comparison between Transformer oil and Palm/Palm kernel oils

| Criteria | Mineral oil | Palm/palm kernel oils |
|---|---|---|
| Source | Seismic Product from petroleum (mineral) oils | Produced from economic trees /farms |
| Flammability | Highly flammable. | Less flammable . |
| Effects on the environment | Causes environmental and health hazard: dangerous to crops and aquatic lives. Accelerates corrosion | Environmental friendly. Slows down corrosion. Biodegradable and nontoxic. |
| Cost | More expensive in Nigeria | Cheaper than mineral oil |
| Effect to other insulating materials | Accelerates aging of rubber, PVC and most insulating materials | More tolerable by other insulating materials |
| Pour point | Lower pour point. | Higher pour points. |
| Flash point | Lower flash point | Higher flash point |

## 2.0 TESTS

### (i) POUR AND FLASH POINTS

The pour and flash points of the oil samples are shown in Table 3.

Table3: Pour and Flash points of oil samples

| | Sample type | Parameter | |
|---|---|---|---|
| | | Pour point (°C) | Flash point (°C) |
| 1 | Transformer oil | Below 0° | 270 |
| 2 | Palm kernel oil | 30 | 340 |
| 3 | Palm oil | 30 | 304 |

It should be noted that pour point of any oil is the temperature below which the oil starts to freeze while the flash point is the temperature where the oil catches fire (point of ignition).

### (ii) AGING TEST OR PEROXIDE VALUE

In order to obtain peroxide values of oil samples, accelerated stress were applied to the samples up to the point of wear. Values were recorded and shown in Table4.

Table4: Peroxide values (Aging test) of oil samples

| S/N | SAMPLE TYPE | PEROXIDE VALUE mgE/Kg | | | |
|---|---|---|---|---|---|
| | | 4 days | 14 days | 20 days | 30 days |
| 1 | Transformer oil | 1.0 | 3.0 | 6.0 | 8.0 |
| 2 | Palm kernel oil | 6.0 | 9.0 | 12.0 | 15.0 |
| 3 | Palm oil | 10.0 | 16.0 | 28.0 | 30.0 |
| 4 | Groundnut oil | 4.0 | 8.0 | 14.0 | 16.0 |
| 5 | Coconut oil | 12.0 | 16.0 | 26.0 | 28.0 |

### (iii) MOISTURE CONTENT

Tests were carried out to determine the moisture content at certain temperatures

1g of the specimen was used as sample for the test

Let weight of petridish and oil sample before drying $=W_1$

Weight of petridish & sample after drying $=W_2$

Weight of moisture $=$ W1-W2

% moisture content$=\frac{Wt\ of\ moisture}{Wt\ of\ specimen}\times 100$

i.e % moisture content$=\frac{W1-W2}{W1-Wp}\times 100$

Where Wp=weight of petridish

Table5 Released moisture (%) at different temperatures

| | SAMPLE TYPE | TEMPERATURE ($^{O}C$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 30 | 50 | 100 | 150 | 200 |
| 1 | Transformer oil | NIL | NIL | NIL | 32.3 | 29.11 | 10.3 |
| 2 | Palm kernel oil | NIL | NIL | NIL | 12.65 | 11.83 | 2.0 |
| 3 | Palm oil | NIL | NIL | NIL | 27.88 | 21.84 | 18.2 |

(iv) DIELECTRIC STRENGTH (VOLTAGE BREAK-DOWN) TEST

Equipment used:

MAKE-Megger oil tester

Model- (OTS 60PB) oil tester set

Spherical electrode gap = 2.5mm

Ambient temperature: $30^{O}C$

(aa) Method of testing [BS 148 (1984)]

Samples were demoisturized through heating. Electric heating was employed to avoid contamination by carbon dioxide. Six tests were done on each sample and the average was recorded as shown below.

(a) **Sample1-Palm oil.**

Temperature=30°C
Average break-down voltage=51Kv
Standard deviation ($\sigma$) =9.6
Dielectric loss factor (tan $\sigma$) =0.17

(b) **Sample2-Palm kernel oil.**

Temperature=30°C
Average break-down voltage=51Kv
Standard deviation ($\sigma$) =10.19
Dielectric loss factor (tan $\sigma$) =0.18

(c) **Sample 3- Transformer (mineral) oil**

Temperature =30°C

Average break-down voltage=50Kv

Standard deviation ($\sigma$) =5.1
Dielectric loss factor (tan $\sigma$) =0.09

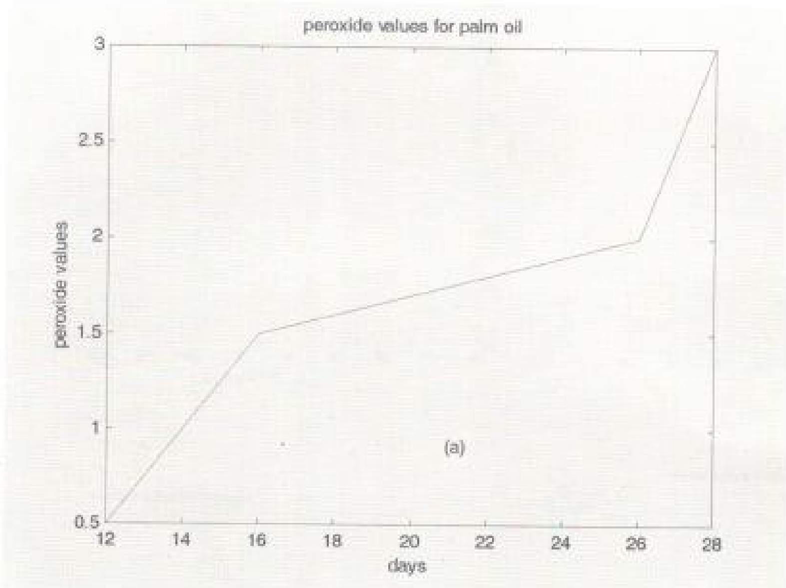
Table6: Summary of all results

| | Sample type | Average breakdown voltage at 30°C | % Moisture expelled at 150°C | Pour point (°C) | Flash point (°C) | Peroxide value (30 days) |
|---|---|---|---|---|---|---|
| 1 | Transformer oil | 50kv | 20.11 | Lower than 0°C | 270 | 8.0 |
| 2 | Palm kernel oil | 51kv | 11.83 | 30 | 346 | 15.0 |
| 3 | Palm oil | 51Kv | 21.84 | 30 | 304 | 30.0 |

## 3.0 ANALYSIS OF RESULTS

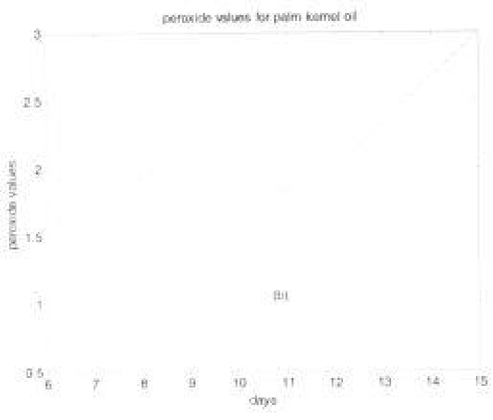
From Table 3, it is seen that the pour points for palm and palm kernel oils are 30°C, while that of the transformer (mineral ) oil is below 0°C. That means that palm and palm kernel oils cannot flow at 30°C and below. They can be used in the zones where the ambient temperature is above 30°C. For them to be used in the zones with temperature below 30°C, some form of treatment is required.

The table also shows that palm and palm kernel oils are safer in areas with high temperature since their flash points are higher than their transformer (mineral) oil counterpart. The dielectric strengths of all of them (palm oil, palm kernel oil and transformer [mineral] oil) are almost the same. Fig 3 shows the plots of all the results (graphically).

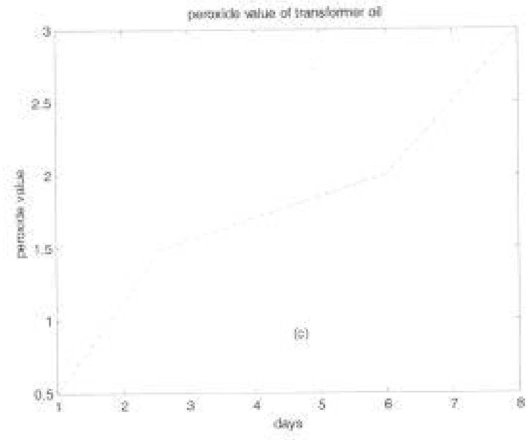



(a)

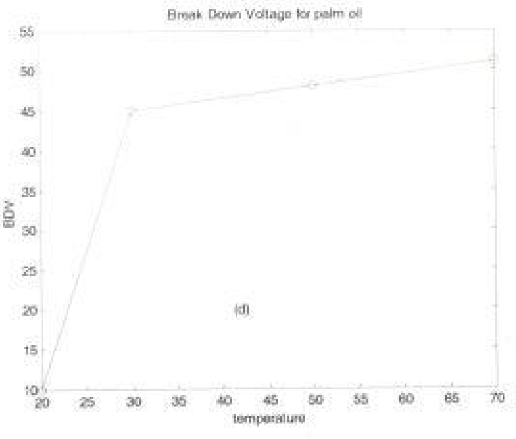
(a) Peroxide value for palm oil
(b) Peroxide value for palm kernel oil
( c) Peroxide value for transformer [mineral] oil
(d) Break- down voltage [dielectric strength] for palm oil
(e) Break- down voltage [dielectric strength] for palm kernel oil
(F) Break- down voltage [dielectric strength] for transformer oil
(g) Expelled moisture for palm oil
(h) Expelled moisture for palm kernel oil
(j) Expelled moisture for transformer oil


peroxide values for palm kernel oil
peroxide values
days

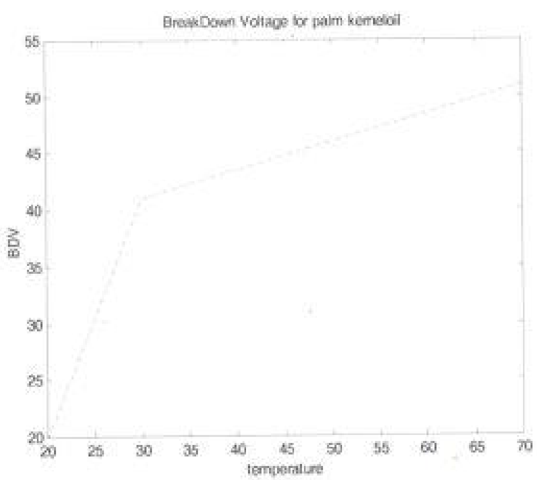
(b)


peroxide value of transformer oil
peroxide value
days
(c)

(c)

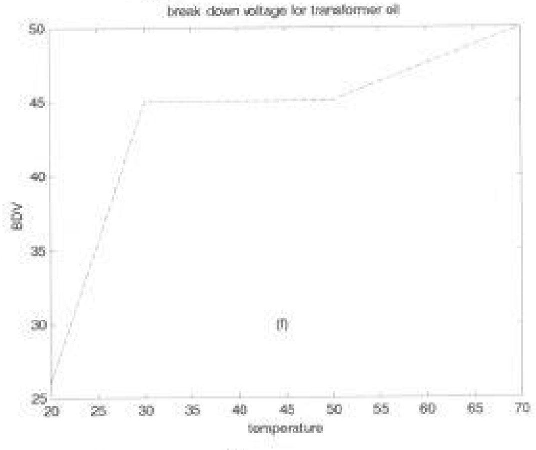

Break Down Voltage for palm oil
BDV
temperature
(d)

(d)

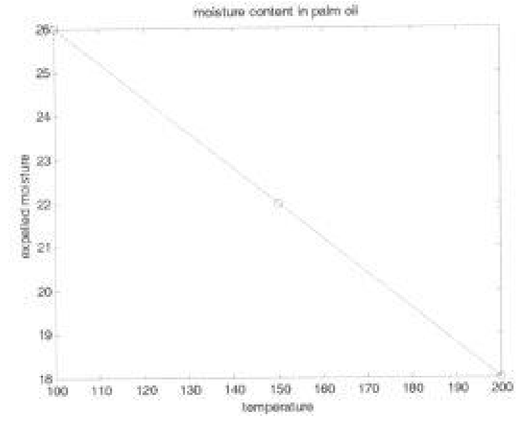

BreakDown Voltage for palm kerneloil
BDV
temperature

(e)

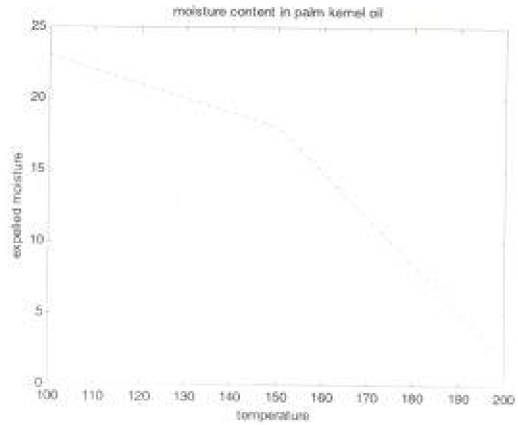
(d)


break down voltage for transformer oil
BDV
temperature
(f)

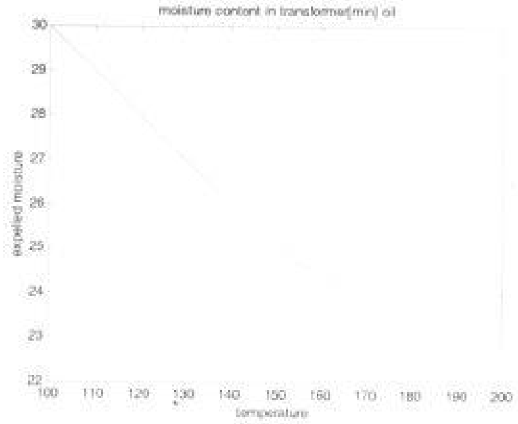
(f)


moisture content in palm oil
expelled moisture
temperature

(g)




(h)




(j)

Fig.3: Plots of test results: (a) to (j) as indicated above

## 4.0 CONCLUSION

Palm and palm kernel oils can be used for high voltage insulation and cooling in transformers. They are biodegradable and are not dangerous to aquatic lives and crops. They do not pose health hazards and are cheaper than the petroleum based transformer oil. They can be used without further treatment in the zones where the average ambient temperature is 30°C and above. More research work is needed to make them flow at lower temperatures.

## REFERENCES

1. Alt Energy Mag. Com, "What the Hack is a Smart Erid," 2001 htt//www.altenergymag.com/articles/09.04.01/smartgrid/grid.ipg.

2. J.P. Crime", Newly Developed Analytical Techniques for charctaerization of Insulating Oils", in Electrical Insulating Oils, H.G. Erdman, Ed: ASTM, 1988.

3. T.V. Oommen, "Vegetable Oil for Liquid – Filled Transformers, IEEE – Electrical Insulation Magazine, 2002.

4. R. Eberhardt[1], H.M. Muhr[1], W. Lick[1], F. Baumann[2], "Campariso" of Alternative Insulating Fluids", IEEE – Annual report conference on Electrical Insulation Dielectric Phenomena. Pp.591-593 October 26 – 29, 2008.

5. P. McShane, "Relative properties of the New Combustion – Resistant Vegetable – Oil Based Dielectric Coolants for Distribution and Power Transformers" IEEE Transaction on Industry Applications, Vol.37, No. 4, pp 1132 – 1139, July/August 2001.

6. B.Bhushan, Introduction to Tribology Wiley, 2002.

7. S.J. Randles, "Esters", in synthetics, Mineral Oils, and Bio-Based Lubricants: Chemistry and Technology, I.R. Rudnict, Ed. Florida: CRC Press, Taylor & Francis Group, 2006.

8. B. Lloyd, "The End of Oil", University of Otago July 2005.

9 D.P. Stockton, J.R. Bland, T.M. McClanahan, J. Wilson, D.L. Harris, and P. McShane, "Natural Ester Transformer Fluids: Safety, Reliability and Environment

10 performance". IEEE – Petroleum and Chemical Industry Technical Conference, September 17 – 19, 2007.
11 R. Bartnikas, "Dielectrics and Insulation" in the Electrical Engineering Handbook Second Edition, R.C. Dorf, Ed: CC Press, 1997.

12 M. Mirzai, A. Gholami, and F. Aminitar, "Failures Analysis and reliability calculation for power transformers", Journal of Electrical System, 2006.

13 "IEEE Guide for loading Mineral – Oil – Immersed Transformers", IEEE Std C57.91, 1995.

14 T.W. Dakin, "Electrical Insulation Deteriation Treated as a Chemical Reaction Rate Phenomenon", AIEE Transactions, Vol.66, pp.113 – 122, 1947.
15 "IEEE standard test procedure for thermal evaluation of oil – immersed distribution transformers", in IEEE std C57.100, 1986.

16 IEC, "IEC 61125 – Unused Hydrocarbon – based Insulating Liquids Test Methods for Evaluating the Oxidation Stability", 1992.
17 A. Bradwell, Electrical Insulation, London: Peter Peregrinus Ltd, 1983.

18 M. Koch, M. Fischer and S. Tenbohlen, "The breakdown Voltage of Insulation Oil under the Influence of Humidity, Acidity, Particles, and Pressure, International Conference APTADM, Poland, 2007.