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Investigation of the Suitability of Groundnut and Coconut Oils for High Voltage Insulation

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Abstract: *Insulating fluids play different roles in high voltage Engineering. They can be used as transformer oil and also for impregnated tapes. Groundnut (Arachishypogaea) and coconut (cocos nucifera) oils were tested under controlled temperature for their suitability in high voltage insulation. While groundnut oil showed better promise for use even as transformer oil, coconut oil result showed that the oil cannot withstand extra high voltage. However, it can be used very comfortably for low voltage insulation.*
Keywords*: High voltage insulation, groundnut oil, dielectric strength, biodegradable, pour point, flash point.*

I. Introduction

While the search for alternatives for mineral oils used for extra high voltage insulation continues, samples of groundnut (Arachis hypogaea) and coconut (cocos nucifera) oils were subjected to tests under controlled temperature for their suitability as insulation oil.With the worldwide growing demand for electrical energy, environmental and safety issues cannot be neglected. Power transformers being crucial elements in electric power transmission network also have to follow this trend. For more than one century, power transformers are filled with mineral oil serving as a heat transfer and insulating medium [1]. Nowadays significant efforts are aimed in quest for a more environmentally friendly replacement of this petroleum-based product. Natural esters or vegetable oils, refined from plant materials are gaining attention in recent times as alternatives. They are nontoxic, more biodegradable and less flammable than mineral oils [2].

Ester oils are advantageous compared to traditional mineral oil as these oils are less flammable, non-toxic and more biodegradable. A number of vegetable oils such as sunflower, palm oil, palm kernel oil and rapeseed have been tested and found suitable [3]. However, not much has been found in the literatures on suitability of groundnut oil (Arachishypogaea) and coconut (cocosnucifera) oil as suitable high voltage insulation oils. A typical vegetable oils for consideration as alternative ester-based high voltage insulation oilsare groundnut and coconut oils. The insulation fluid developed from these oils has showed high biodegradability[4-6]. The major drawback of groundnut oil and coconut oil is their high pour points, but they can flow at temperature above $28^{\cdot C}$ and $30^{\cdot C}$ respectively. However, the average room temperature in tropical Africa is $30^{\cdot C}$ and the expected operating temperature in this zone is 30^{o}C. Coconut oil displayed a very low breakdown voltage of 4KV, which makes it unsuitable for use as transformer oil.

The structures of some vegetable oils are shown in figs.1 and2

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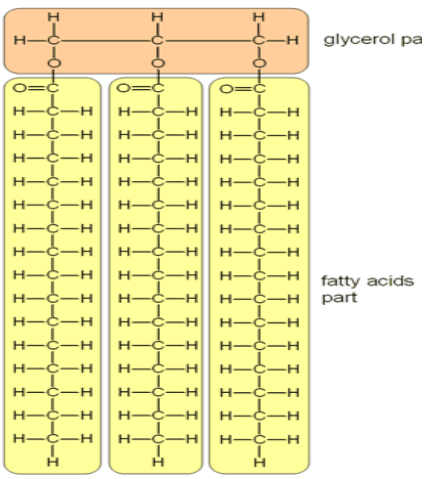

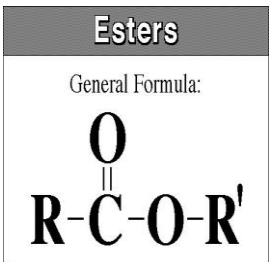

Fig 1: General Structure of an ester molecule. Fig 2: The structure of a vegetable oil molecule

R and R1 represent alkyl groups. The two oxygen atoms bonded to the carbon atom constitute the functional group. The remaining carbon atoms could be long chains of carbon molecules (complex) or as simple as these in the Fig 1. The general formula and the esterification process (Production of Esters, RCOOH) is the equilibrium reaction between a carboxylic acid and alcohol (R1OH). Water (H2O) is the by - product.

$RCOOH + R^1OH \quad RCOOR^1 + H_2O.$

Esters can be extracted from palm nuts, soybeans, groundnuts, coconut oil etc.

1.1 Cost Analysis

From market survey, the prices of these oils are shown in table 1 below:

Oil	Quantity	Cost (N)	% of transformer oil
Groundnut oil	200L	40,000	17
Coconut oil	200L	55,000	30
Transformer (Mineral Oil)	200L	150,000-200,000	100

Table 2: Comparison between mineral oil, groundnut oiland coconut oil

Criteria	**Mineral Oil**	**Groundnut Oil & coconut Oil**
Source	Produced from petroleum crude.	Produced from plants
Environmental Properties	Contains compounds that do not readily biodegrade. It may also contain traces of carcinogen.	Highly biodegradable, non-toxic, does not contain petroleum, silicone or halogens
Leaks and Spills	Some bacteria have the ability to absorb these toxic oils and synthetically convert it into a food items. It could be formed by hybridization for more than one type of bacteria found in nature. This could possibly cause a large number of exchanges between different genes to reach the desired qualities to produce a new type of bacteria that do not exist in nature. Harmful to crops and aquatic lives.	(i)Relatively rapid biodegradation may eliminate the need for environmental awareness related to find new complicated dynamic processes to curb eco-concerns during spills. (ii) are not harmful to crops and aquatic lives
Fire-risk	Catches fire more easily leading to higher probability of transformer fires	Reduces the frequency and impact of transformer fires, virtually eliminates sustained fires

II. TESTS

I. Pour and Flash Points

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

Table 3: Pour and Flash Points of oil Samples

S/N	Sample type	Parameter	
		Pour point (°C)	Flash Point (°C)
1	Transformer oil	Below 0°	270.
2	Groundnut oil	28	340
3	Coconut oil	30	340

It should be noted that pour point of any oil is the temperature at which the oil begins to freeze. It is desired that pour point of transformer oil need to be low [7]. Also, flash point is the lowest temperature at which oil can evaporate to form an ignitable mixture in air or combustible concentration of gas. Flash point is very vital for it signifies the chances of fire hazard.

III. 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 table 4:

Table 4: Peroxide values (Aging test) of oil sample

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	Groundnut oil	4.0	8.0	14.0	16.0
3	Coconut oil	12.0	16.0	26.0	28.0

Peroxide value is a measure of extent of glycerides constituent decomposition by lipase action, which is added by light, air and moisture. It is also an indication of the level of rancidity of the oil. A low peroxide value increases the suitability of the oil for a long-time storage due to a low level of oxidative and lipolytic activities. Refining of oils can result in considerable decrease of peroxide value of various oils.

IV. Moisture Content

Moisture content is the amount of moisture or water contained in the insulating oil. This can vary with the method of processing. The presence of moisture in any insulating oil reduces its dielectric strength. Moisture in transformer oil makes it less thick with a lower boiling point. Moisture content is a direct proportionality to transformer oil aging [8]. Also the paper insulation is adversely affected by moisture in transformer oil. 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 = W_1-W_2

% Moisture Content = $\frac{Weight\ of\ moisture}{weight\ of\ Specimen}$ x 100

i.e % Moisture Content = $\frac{W_1 - W_2}{W_1 - W_p}$ x 100

Where W_p = weight of petridish

Table 5: Released Moisture (%) at different temperature.

S/N	Sample Type	Temperature (°C)					
		10	30	50	100	150	200
1	Transformer oil	Nil	Nil	Nil	32.3	29.11	25.30
2	Groundnut oil	Nil	Nil	Nil	8.90	5.80	4.60
3	Coconut oil	Nil	Nil	Nil	19.10	14.30	12.50

V. Dielectric Strength (Voltage Breakdown) Test.

The dielectric strength is determined by taking note of the voltage at which sparks occur between two electrodes immersed in oil and a specific gap between them. Low level of dielectric strength shows presence of moisture and may be other conducting substances in the oil [9].

Equipment Used:

oil tester

Model-(OTS60PB) oil tester set.

Spherical electrode gap = 2.5mm

Ambient Temperature: 30°C

Method of Testing [BS 148 (1984)]

Samples were de-moisturized through heating. Electric heating was employed to avoid contamination by carbon(iv)oxide. Six tests were done on each sample and the average was recorded as shown below.

a) Sample 1- Groundnut oil
   Temperature = 70°C
   Average breakdown voltage = 30kv
   Standard deviation(σ) =2.79
   Dielectric loss factor (tanσ) =0.05
b) Sample 2- Coconut oil
   Temperature = 70°C
   Average breakdown voltage = 4kv
   Standard deviation (σ) =2.60

Dielectric loss factor (tanσ) =0.05

c) Sample 3- Transformer (Mineral)oil
Temperature = 70°C
Average breakdown voltage = 55kv
Standard deviation (σ) =
Dielectric loss factor (tanσ) =0.02

Table 6: Summary of all results

S/N	Sample type	Average breakdown voltage at 70°C (kv)	% moisture expelled at 150.C	Pour point (.C)	Flash Point (.C)	Peroxide value (30 days)
1	Transformer oil	55	29.11	Lower than 0°C	270	8.0
2	Groundnut oil	30	5.80	28	340	16.0
3	Coconut oil	4	14.30	30	340	28.80

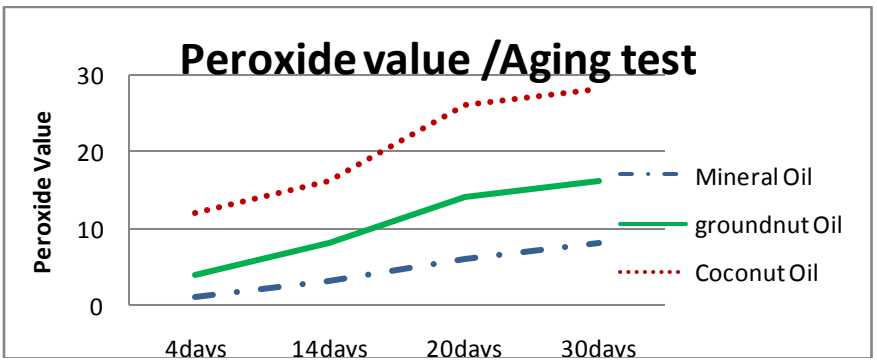

Fig. 3A. Peroxide value.

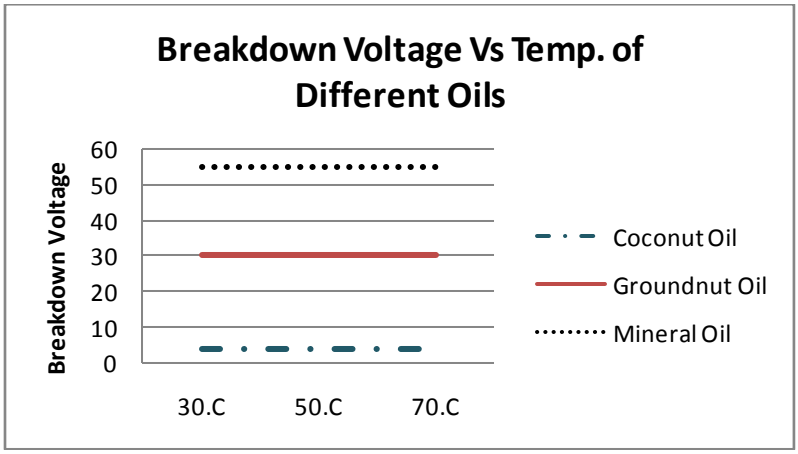

Fig 3b: Dielectric strength test

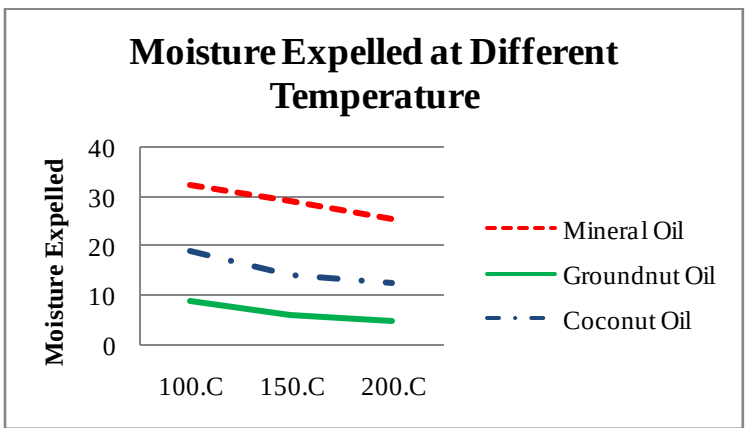

Fig. 3c: Expelled moisture at different temperatures

VI. Analysis Of Results

From table 6, it is seen that the pour point for groundnut oil and coconut oil are 28°C and 30°C respectively, while that of transformer (mineral) oil is below 0°C. That means that groundnut oil and coconut oils cannot flow below 28°C and 30°C respectively. They can be used in the zones where the ambient temperature is above 28°C.

The results show that groundnut oil and coconut oil are safer in areas with high temperature since their flash points are higher than transformer (mineral) oil. The dielectric strength of groundnut oil and transformer (mineral) oil are 30kv and 55kv respectively which is a good property of transformer oil. The major setback for coconut oil is its low dielectric strength which is 4kv. This single deficiency makes it unsuitable to be used for high voltage insulation

VII. Conclusion

The dielectric strength and other properties of groundnut and coconut oils were investigated..Both oils can be used for impregnated tapes for cables and others.While groundnut oil can be used on extra high voltage systems, coconut oil can be restricted to low voltage systems. Groundnut oil can even be used as transformer oil for 66 Kv systems and below. Both oils are biodegradable and can be easily obtained in Nigeria at affordable cost. They cannot pose any danger to crops and aquatic lives at spillage. Groundnut and coconut oils can be refined further to improve on their qualities.

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