GLOBAL JOURNAL OF ENGINEERING RESEARCH, VOL. 1, NO. 1, 2002: 23 - 30

EFFECTS OF THE FREE FATTY ACID CONTENT ON THE ELECTRICAL PROPERTIES OF PALM OLEIN

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(Received 5 September 2001; Revision accepted 18 October 2001)

ABSTACT

Repeated alkali refining of a palm olein sample produced oils of varying acid values. The physico-chemical as well as some electrical properties were compared with those of a standard transformer oil. The smoke point, flash point fire point and viscosity decreased linearly with the acid values of the oil samples.

The break down voltage increased linearly with decreasing acid value. Palm olein samples with lower acid values had higher break down voltage than the transformer oil. The highest break down voltage of 54.2 kV was for a refined palm olein with an acid value of 0.0299-mg KOH/g-oil. Moisture affected the break down voltage of the transformer oil more adversely than the acid value. The dielectric constant, dielectric conductivity and dissipation factor of the palm olein samples had a similar variation with frequency as the transformer oil, the magnitude however depended on the acid value of the samples. For a given frequency these properties were, in general, highest for samples of the lowest acid value

Keywords: palm olein, free fatty acid, moisture, electrical properties, frequency

INTRODUCTION

Transformer oils are typically, finely refined fractions of crude oil. They consist of mixtures of aromatics, naphthenes and aliphatics (Endico et al 1983, Dakin 1976). Transformer oils provide the insulation and cooling required in transformers. Preliminary, studies (Owuanumba1997, Odigie1998) have shown that the vegetable oil had similar electrical properties, and can perform the same functions as the traditional Transformer oils.

In service transformer oils may be exposed to varying conditions of temperature, moisture and air. This leads to oxidative degradation, which is characteristic of the transformer oil and its additive content. These degradations will have deleterious effect on the performance of the transformer oil (Beaty 1978). Vegetable oils, being triglycerides, are relatively less inert than the transformer oils of mineral origin and are expected to undergo similar degradations as the transformer oils when exposed to air and moisture. This degradation in the properties of the transformer oils is reflected in the formation of sludge and increase in the neutralization number or the free fatty acid content of the oil.

If the promise shown by the vegetable oil and transformer oils is to be realized, it is important to be able to quantify this change in properties on the electrical properties. This will determine the extent of reliability in the use of vegetable oil as transformer oil. Indeed the usual Transformer oils in service are routinely checked for their neutralization number. Besides, vegetable oils come in at different levels of acid value, depending on their storage conditions. It is important to ascertain the level of acid value,

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which is acceptable for vegetable oil to be used as transformer oils.

In this study, a vegetable oil palm *olein* is treated to obtain oils of varying acid values. The electrical properties of these samples are measured and compared with those of the conventional transformer oil. The effect of moisture on the performance of the vegetable oil and the conventional transformer oils were also compared.

EXPERIMENTAL PROCEDURE

Materials: The palm olein sample was obtained from PRESCO Industries, Benin City. The palm olein was obtained from the fractionation and bleaching of palm oil. The fresh transformer oils used for comparison were obtained from the Electrical Engineering Department of University of Benin.

Reagents used: NaOH, KOH, ethanol and benzene are of the analar grade

EXPERIMENTS

Chemical refining of the palm olein: Each oil sample used had to undergo the following refining steps:-alkali neutralization and drying.

Alkali neutralization was effected by adding a 5% NaOH solution to a weighed quantity of the oil maintained at 75°C. The quantity of alkali depended on the measured acid value of the untreated palm olein. After stirring, and allowing to settle, the soap formed was separated.

To obtain oil of lower acid value this procedure was repeated for a given oil sample

The remaining oil was washed twice with 10% hot water (95°C) to remove any soap particles. The oil was then dried.

DRYING OF OIL SAMPLES

Any oil sample had to be dried before its electrical properties were measured. The oil sample was placed in a flask that was connected to a vacuum pump. With the vacuum pump switched on the oil was warmed to and maintained at 60°C. At the low pressure inside the flask, water molecules boiled out of the flask. The drying process was affected for five hours in order to ensure effective drying of the oil samples. The same drying process was used for the transformer oils.

PHYSICO- CHEMICAL PROPERTIES OF THE OIL

The properties measured were the smoke point, flash point fire point, density and viscosity

The physico-chemical properties of the oil samples were all carried out according to the official methods of the American Oil Chemist Society (AOCS).

ELECTRICAL PROPERTIES

These were the - breakdown voltage Capacitance and dissipation factors (Dielectric properties).

1. Break down voltage:

A high voltage tester was used. Two electrodes, 2.5mm apart constituted the test cell of the equipment. An electrical field is established between the two electrodes when a voltage is applied. The electrical field grows as the voltage is raised gradually until there is flash. This is the maximum voltage beyond which a breakdown occurs. This was repeated 5 times for each sample after allowing for the escape of air between measurements.

2. Dielectric properties

The Universal Impedance Bridge was used for the measurement of the capacitance of the oil sample. The test cell used comprised concentric cylinders. This was attached to the unknown arm terminals of the bridge. The capacitance of the unit was measured by the null balance method using the bridge and an earphone. This was done by using a vessel with air as the dielectric and with the annular space filled with an oil sample. The changes in capacitance resulting from these measurements were used the appropriate formulae to determine the various dielectric properties. Also the dissipation factor was directly measured using the bridge. However these values were modified with the appropriate formulae

RESULTS AND DISCUSSION

The effect of repeated alkali refining on the acid value of the treated palm olein samples has been illustrated in Fig 1. There was a progressive decrease in the acid value with number of treatments. This is to be expected since some free fatty acid is removed in each treatment. It is pertinent to point out that the acid value of the untreated oil is about 10 times that of the transformer oil. This emphasizes the need for the treatment to lower the acid value if any meaningful comparison of the performance of palm olein samples with that of the transformer oils is to be made. The acid value of only two palm olein samples (out of the five used) became lower than that of the transformer oil. These were obtained after the 3rd and 4th treatments. One should also point out that with more efficient equipment -low pressure and high temperature steam deodorization - the lower acid value of the palm olein samples could have been obtained in one step.

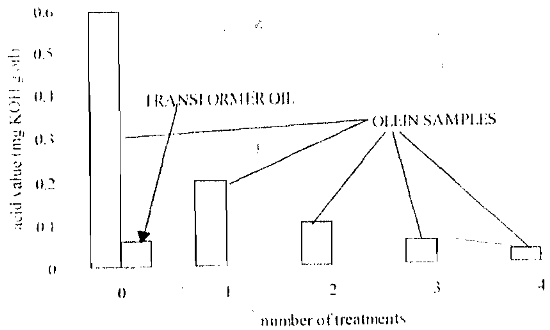

Fig. 1 variation of Acid value with number of treatments

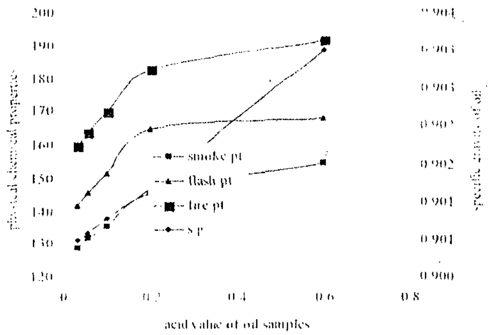

Fig 2 Effect of alkali treatment on physical and chemical properties of oils

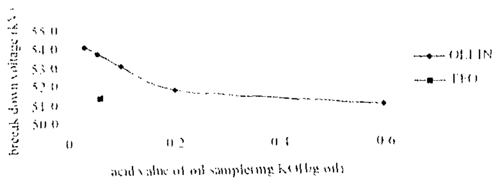

Fig 3a Variation of Breakdown voltage with acid value of all olein oil samples(treated and untreated)

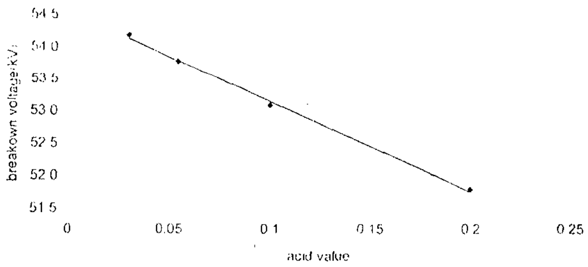

Fig.3b Variation of Breakdown voltage with acid value of treated oil samples

VARIATION OF THE PROPERTIES WITH ACID VALUE OF THE PALM OLEIN SAMPLES

The single most important effect of the treatment on the property of the palm olein samples is the acid value .The acid value not only affects the keeping properties of the oil but also correlates well with other physico-chemical and electrical-properties of the oil.

The treatment process is a reactive- extractive process in which the free fatty acids reacted with the alkali while other substances such as the color bodies are extracted into the aqueous phase. Fig 2 shows how the acid value of the palm olein varies with other physical-chemical properties. This strong correlation emphasizes the appropriateness of the acid value as the single most important criterion for assessing the treated oil. Fig 2 also shows a steady decrease in the smoke point, flash point and fire point of the palm olein with decreasing acid value. The specific gravity and the viscosities also showed similar trends. Even at the lowest acid value, the smoke point, flash point and fire point still had higher values than that of the transformer oil. The treatment of the oil does not therefore pose any danger to the fire stability of the palm olein vis-à-vis the transformer oil. Equation 1 is of the form given below and describes this variation (correlation coefficient > 0.98.)

$$y = a + b \times AV \qquad ---1$$

where

y = a property such as smoke point ,flash point and fire point

AV = acid value

a and b are constants

VARIATION OF BREAKDOWN VOLTAGE WITH THE ACID VALUE OF THE OIL SAMPLES

The variation of the breakdown voltage with the acid value is shown in Fig 3. There is a steady decrease in the breakdown voltage as the acid value of the palm olein sample increased. A straight-line relationship is obtained (correlation coefficient > 0.98).

By this equation and the acid value of the transformer oil, the breakdown voltage of the transformer oil is much lower than expected. This could be attributed to the presence of other impurities in the transformer oils. The results of the palm olein samples are consistent with those obtained from earlier studies on the electrical properties of vegetable oils (Owuanumba, 1997, Odigie1998). The free fatty acid present ionizes to produce other components, which render the oil more conductive, hence the lowering of the breakdown voltage.The variation of the dielectric strength with the acid value of the palm olein samples is illustrated in Fig.4. The trend is similar to the variation of the breakdown voltage with acid value - decreasing the dielectric strength with increasing acid value. This is to be expected since by definition is given by equation below:

Dielectric strength = breakdown voltage/ distance

Similar reasoning should account for this variation. The control of the acid value of the palm olein should be next focus. Additives are routinely added to improve the oxidative stability of transformer oil while in service. The studies of the oxidative stability of vegetable oil need to be undertaken. This should bring out the real potential of vegetable oil as possible transformer oil.

EFFECT OF MOISTURE LEVEL ON THE BREAKDOWN VOLTAGE OF OIL SAMPLES

The effect of moisture level of the palm olein as well the transformer oil on the break down voltage is shown in Fig 5. Again the trend is expected. Water molecules are polar like the free fatty acid. Such molecules are easily

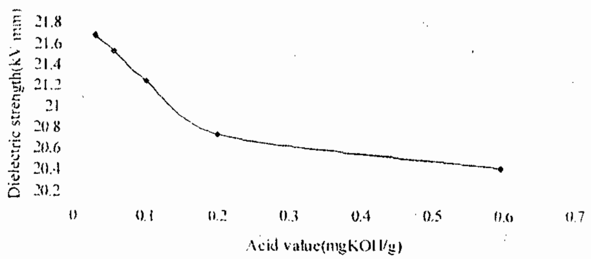

Fig.4 : Dielectric strength versus acid value

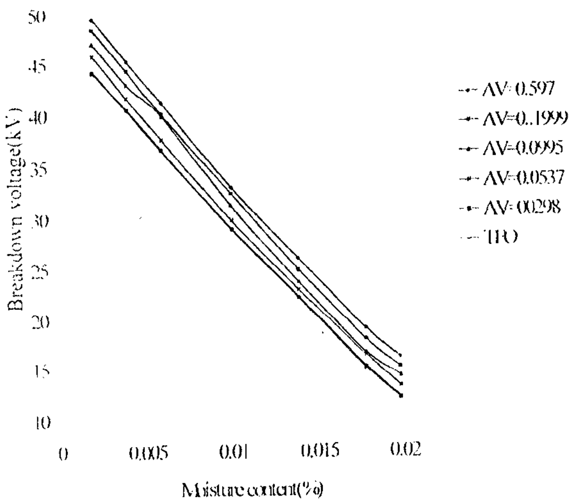

Fig.5:Effect of moisture level and acid value on breakdown voltage

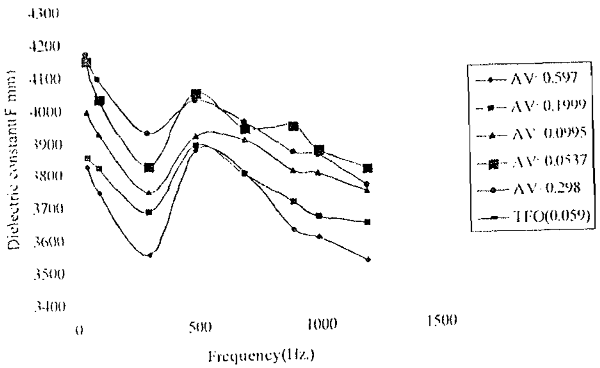

Fig.6 :Variation of Dielectric constant with frequency and acid value

ionized thereby increasing the ionic concentration and mobility. Also water associates very easily with ionizable constituents such as the free fatty acid. It helps to dissociate the ions by virtue of the high dielectric constant and provides a local environment of greater mobility (Endico et al 1974). An examination of the data reveals that fall in breakdown voltage for the transformer oil is much more considering its acid value. It has the third lowest acid value .Yet it has the worst fall in breakdown voltage when water is added, it's acid value is only a tenth of the raw palm olein yet its performance is closer only to that of the raw palm olein. There must be some synergistic effect between the free fatty acid, the water molecules and other substance, which contributes to the sharper drop. Perhaps the difference in the nature of the acidic substances produced in the two oils could explain the trend.

VARIATION OF DIELECTRIC CONSTANT OF OIL SAMPLES WITH THE FREQUENCY

The dielectric constant is calculated from equation (2)

$$Er' = 0.9060\ (C_{pm} - C_{po}) \qquad \text{------------ (2)}$$

where

C_{pm} = mean parallel capacitance

C_{po} = parallel capacitance for empty holder

This was repeated for the palm olein samples of difference acid value

The variation of the dielectric constant with the acid value of oil sample and frequency is shown in Fig 6. This gives a typical behavior of dielectric at different frequencies. As the frequency of measurement is increased the dielectric constant decreases because of the inability of the polarizing charges to move with the increasing frequency. At higher frequencies the charges cannot move with sufficient speed to follow the increasing rate of alternations. At the lower frequency the ionic interface polarization decreased first. This was followed by molecular dipolar polarization decline.

At lower acid values there are fewer polar molecules (free fatty acid) that are as a result more spaced. They are thus able to move higher speed to follow the alternation of the electrical field. The dielectric constant depends on the rates of polarization and the speed of the charges.

EFFECT OF ACID VALUE OF OIL SAMPLES AND FREQUENCY ON THE DISSIPATION FACTOR

The dissipation factor is calculated from

Table 1: Variation Of Acid Value(AV) With Number Of Treatments

Number Of Treatment	1	2	3	4	5	TFO
Acid Value(AV)	0.5970	0.1990	0.0995	0.05373	0.0297	0.0597

Table 2: Effect Of Akali Treatment On Physical And Chemical Properties Of Oil Samples

Acid Value(AV0 of olein samples	Smoke point(°C)	Flash point(°C)	Fire point(°C)	Specific gravity(s.g)
0.5970	155	168	192	0.9030
0.1990	146	165	183	0.9012
0.0995	136	152	170	0.9008
0.05373	132	146	164	0.9006
0.0298	129	142	160	0.9005
TFO	121	140	158	0.9082

Table 3a: Variation of Breakdown Voltage(BDV) With Acid Value(AV) Of All Olein Samples (Treated & Untreated)

Acid Value(AV) Of Olein Samples	0.5970	0.1999	0.0995	0.0537	0.0298	TFO
Average Breakdown Voltage(BDV)	51.0	51.8	53.10	53.8	54.20	51.40

Table 3b: Variation of Breakdown Voltage (BDV) With Acid Value (AV) Of Treated Olein Samples

Acid Value(AV) Of Olein Samples	0.1999	0.0995	0.0537	0.0298	TFO
Average Breakdown Voltage(BDV)	51.8	53.10	53.8	54.20	51.40

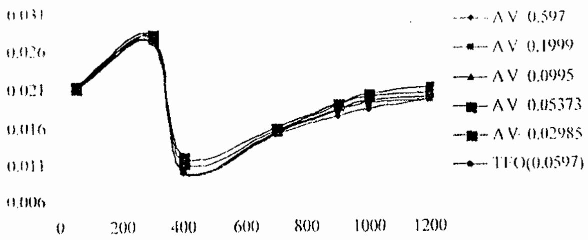

Fig.7:Effect of frequency and acid value on dissipation factor

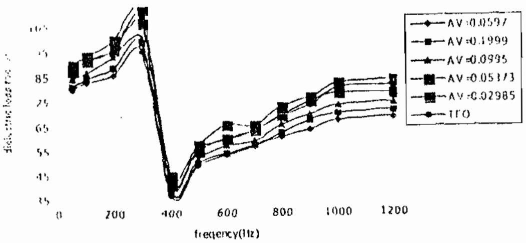

Fig 8 variation of dielectric loss factor with acid value of oil and frequency

equation 3

$$D = (C_{pm} D_m - C_{po})/(C_{pm} - C_{po}) \quad \text{------------} (3)$$

D_m = mean of dissipation factor for parallel and series capacitances.

The variation is illustrated in Fig 7. Again all the samples showed a similar variation with that of the transformer oil. The variation is typical for dissipation factors vs. frequency measurements for dielectrics. In Fig 7, there are maximum and

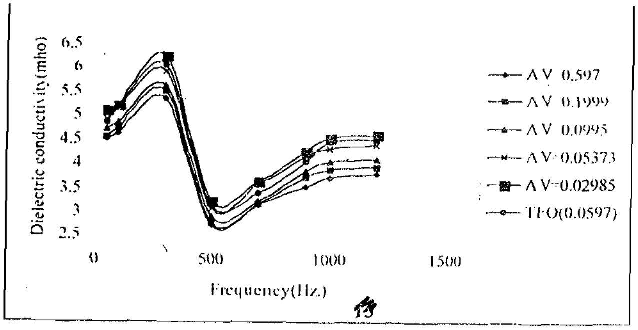

Fig.9:Variation of dielectric conductivity with acid value and frequency

minimum dissipation factors at frequencies of 300 and 400 Hz respectively. This maximum corresponds to the relative dielectric constant dispersion region. The maximum is associated with the molecular dipolar rotation, which occurs when the mobility is such that the molecular rotation can just keep up with the frequency of the applied field.

At frequency higher that 600 Hz there is a linear relationship between the dissipation factor and the frequency. There was some deviation for the transformer oil in the 1000 to 1200 Hz ranges.

VARIATION OF DIELECTRIC LOSS FACTOR WITH FREQUENCY AND ACID VALUE OF OIL SAMPLES

The variation is illustrated in Fig 8.The strong similarity with Fig 7 stems from the calculation of the dielectric loss factor using equation (4)

$$E_R^{//} = E_r^{/} \times D \qquad \text{---(4)}$$

It follows that when both the dielectric constant and dissipation factor are high the dielectric loss factor will also be high. There is a maximum at 300 Hz and a minimum at 400 Hz for all the oil samples. In the 600 to 1200Hz range however, the relationship between the dielectric loss factor and frequency is linear (correlation coefficient of 0.86.)

VARIATION OF THE DIELECTRIC CONDUCTIVITY WITH FREQUENCY AND ACID VALUE OF OIL SAMPLES.

The dielectric conductivity is calculated from equation 5

$$\sigma = = 0.0556\ Er^{//} \qquad \text{---5}$$

The variation is shown in Fig 9. The similarity between Figs.8 and 9 stems from equation 5. The dielectric conductivity follows the same trend with frequency as the dielectric loss factor. All the oil samples, transformer oil inclusive, follow the same variation. For a given frequency, the dielectric conductivity is higher for oils of the lowest acid value.

CONCLUSION

The repeated alkali refining produced palm olein samples of widely differing acid values. This

Table 4: Variation Of Dielectric Strength With Acid Value (AV)

Acid Value(AV)	0.5970	0.1999	0.0995	0.0537	0.0298	TFO
Dielectric Strength	20.40	20.72	21.24	21.52	21.68	20.36

Table 5: Variation of Breakdown Voltage(BDV) With Moisture Level And Acid Value(AV)

Moisture Level(ML)	AV= 0.5970	AV= 0.1999	AV= 0.0995	AV= 0.0537	AV= 0.0298	TFO
1	44.20	45.80	47.00	48.40	49.50	46.00
2	40.60	41.70	43.00	44.30	45.30	42.50
3	36.60	37.60	38.90	40.10	41.20	37.00
5	28.90	29.80	31.20	32.40	33.00	30.00
7	[illegible]	22.90	23.70	24.90	26.00	23.50
9	[illegible]	16.30	16.60	17.90	19.01	16.50
10	12.00	13.20	14.20	15.05	16.10	13.00

affected not only their free fatty acid content but also other physico-chemical properties such as the smoke point, flash point, fire point and viscosity. There is a good linear correlation between these properties and the acid value of the oil.

Palm olein samples with lower acid value had higher breakdown voltages than the transformer oil. There is a good linear relationship between the breakdown voltage and the acid value of the oil samples. The effect of moisture on the break down voltage was more pronounced on the transformer oil than on the palm olein samples. The dielectric properties of the palm olein samples varied in the same manner as the standard transformer oil used for comparison purposes. Given the importance of the acid value on performance, interest should now be focused on the control of the acid value of vegetable oil samples when being used as transformer oils.

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