

## THE EFFECT OF AN ANTI-OXIDANT ON THE BREAKDOWN VOLTAGE OF PALM OLEIN SAMPLES

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### ABSTRACT

The effect of the anti-oxidant (hydroquinone) on the breakdown voltage of palm olein samples was studied. The oil samples had different acid values resulting from the different degrees of neutralization treatments given. The hydroquinone addition ranged from 0.23 to 1.13 weight percent of the oil.

The hydroquinone had a positive effect on the breakdown voltage of the oil samples. The increase in the breakdown voltage was rapid at low concentrations of the hydroquinone with the increase tending towards an asymptotic value at higher concentrations. The effect of the hydroquinone on the breakdown voltage was also dependent on the acid value of the oil. Oil samples with lower acid values had sharper increases in their breakdown voltages. Percentage increase in the breakdown voltage of 66.67 (vis-à-vis the additive-less samples) was recorded for oil sample of acid value of 1.515 mg KOH/g oil and containing 0.45% by weight hydroquinone. These results show that the one major problem (oxidative stability) in the use of vegetable oil as transformer oil can be overcome without an adverse effect on their electrical properties.

**Key words:** Breakdown voltage, Anti-oxidant, Palm olein, Neutralization, Acid value.

### INTRODUCTION

Any oil whether of synthetic, vegetable, mineral or animal origin, if free from water, acid, alcohol, amines and similar conducting liquids, will withstand the minimum electric strength test prescribed for insulating oils (Sillars, 1973). Vegetable oils -Soybean oil, cotton seed oil etc -consist principally of glyceride esters of fatty acids and are characteristically soluble in organic solvents (Kirk-Othmer, 1978).

Transformer oils are used in power transformers for the purpose of insulation and cooling. The production of satisfactory insulating oils is partly dependent on choosing suitable crude stocks and partly on refining techniques in relation to the stocks being used (Sillars, 1973).

One of the most interesting recent developments is a growing realization that vegetable oils present a practical alternative to fuels, lubricants derived from fossil fuels (Weiss, 1983). In the formulation of transformer oils from base stocks, the use of additives is necessary since no oil -vegetable or mineral possesses all the properties required by modern technology. Such additives are often specific in function and are used in concentrations varying from parts per million up to about 20 percent (Halton, 1962). Types of additives include; viscosity index improvers, pour point depressants, oxidation inhibitors (anti-oxidants) anti-corrosion agents etc.

The aromatic content of oil increases its tendency to absorb oxygen when subjected to discharge,

and was widely, believed to increase its tendency to oxidation (Sillars, 1973). The use of oxidation inhibitors in transformer oils has been fairly common practice in the U.S.A for some years (Sillars, 1973). The best known are 2,6-ditertiary butyl -p-cresol (DBPC), hydroquinone, butylated hydroxy toluene (BHT), etc.

One major problem in the use of vegetable oil as transformer oil is their expected lower resistance to oxidation than the mineral oils. In this study, the effect of an anti-oxidant on the breakdown voltage of palm olein was examined. Their positive effects (increase in oxidation stability) without a decrease in their electrical properties will enhance the potential use of such oils in transformers.

## EXPERIMENTAL PROCEDURE

### Materials

The major test material is the palm olein oil. This was obtained from PRESCO, a palm oil processing mill in Benin City. Other reagents used are KOH, toluene, neutralized alcohol and hydroquinone.

### Experiments

#### Determination of acid value of oil

The acid values of the oil samples were measured after and before each KOH neutralization step. The acid value of oil is expressed in terms of milligrams of KOH required to neutralize the free fatty acids in one gram of oil. The acid value determination was made by weighing accurately about 10g. of the oil in a flask and adding 100 ml of a mixture of 60ml of toluene and 40ml. Of alcohol which has been neutralized. This was titrated with 0.1M potassium hydroxide solution using phenolphthalein as indicator. The acid values of the samples were calculated from the formula:

$$AV = 56MV(W)$$

where AV is the acid value in mg KOH/g of oil.

V is the volume of KOH solution at end point.

W is the weight of oil sample

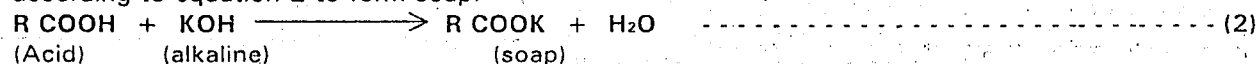
M is the molarity of potassium hydroxide solution

#### Degumming of oil:

The essence of degumming is to remove the phosphatides present in the oil. The oil was weighed into a beaker in a water bath maintained at 70°C. While the oil was being stirred, water (about 5% by weight of the oil) was added. The mixture was stirred continuously for 30 minute after which it was allowed to cool. The "gums" separated out from the oil and settled at the bottom of the beaker. The oil was finally separated from the gums in a separating funnel.

#### Neutralization

In the neutralization process, the free fatty acids reacted with the potassium hydroxide according to equation 2 to form soap.



The oil was warmed to 40°C. While stirring, the potassium hydroxide was added drop wise to the oil to neutralize the free fatty acid. Different degrees of neutralization were achieved by adding different amounts of potassium hydroxide solution. The mixture was then warmed to 60°C and the stirring stopped only when the soap stock showed signs of separating. The soap stock was separated from the oil in a separating funnel. The neutralized oil samples were washed with warm water to remove any remaining soap particles.

The oil samples were then dried to remove all traces of moisture that must have been introduced during the degumming, neutralization and washing steps. The oil was heated in a flask indirectly through a water bath to a temperature of about 60°C. The flask was connected by means of a rubber tubing to a vacuum pump to suck the water vapour above the oil.

#### Measurement of the breakdown voltage of oil

Five different measurements were made on each of the oil samples each measurement with a different concentration of anti-oxidant ranging from 0.23 to 1.13 weight percent of oil. The breakdown voltage is the maximum voltage the oil can withstand while remaining as an insulator. The method consists of immersing two electrodes from a voltage source in the oil and continually increasing the voltage until the oil starts conducting. The test cell consists of a glass vessel 55mm by 90mm and 100mm high with two spherical electrodes 13mm in diameter made of brass with a gap of exactly 4mm. The alternating current was supplied through a transformer so that it shall be approximately of sine wave form and having a frequency of between 25 and 100 Hz., and capable of being raised uniformly from zero. The oil was placed to a depth of 40mm above the electrodes and left undisturbed for 10 minutes for air bubbles to escape. The power was switched on and the voltage across the electrodes was steadily increased to a specified value in 10 seconds. The voltage at which the breakdown of the insulation occurs between the electrodes is the breakdown voltage. Five different readings were taken for each sample after a time interval of 10 minutes. The average of the readings is taken as the Breakdown voltage of each sample of oil

### RESULTS AND DISCUSSION

The results obtained from the various experiments conducted are as presented in Tables i - v and Figures 1 - 3.

#### Acid value of sample s of oil

The acid values of the oil samples due to different degrees of potassium hydroxide neutralizations are shown Table 1. Sample A is the crude olein oil. B, C, D, and E represent oil samples after different degrees of neutralization.

#### Breakdown voltage of olein oil samples:

The breakdown voltages of the olein oil samples at different anti-oxidant concentrations are shown in the tables 2,3,4 and 5.

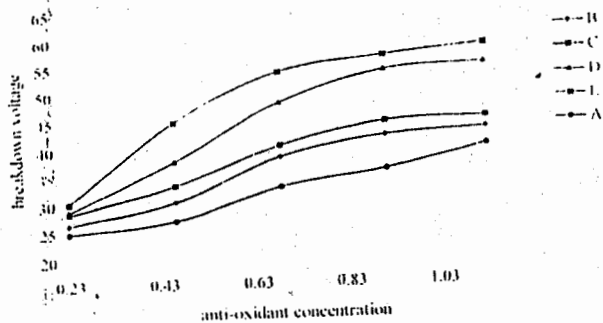


Fig. 1: Effect of anti-oxidant concentration on breakdown voltage

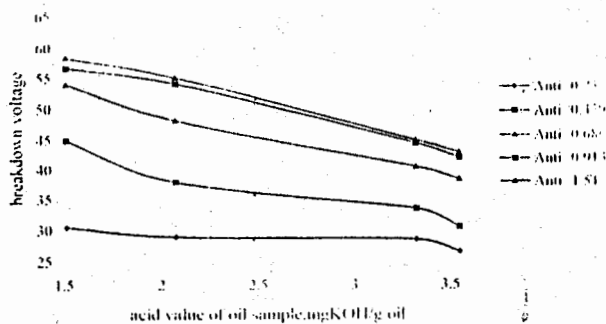


Fig. 2: Breakdown voltage as a function of acid value of oil

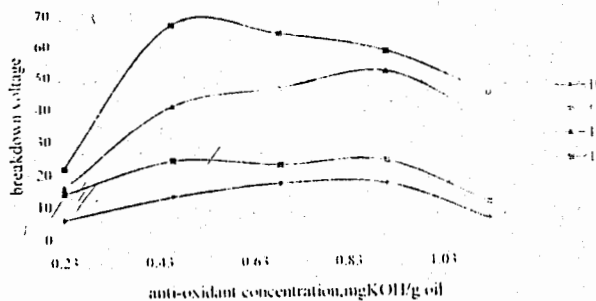


Fig. 3: Increase in breakdown voltage vs. anti-oxidant concentration

### Effect of anti-oxidant (hydroquinone) concentration on breakdown voltage.

In figure 1, the breakdown voltage of the samples at room temperature is presented as a function of anti-oxidant concentration. The trend is the same for all the oil samples. The addition of anti-oxidant increased the breakdown voltage and the stability of the oil samples. This observation is in line with some findings (Sillars, 1973). The time taken under standard conditions for inhibited oil to absorb the equivalent of 300 ml of oxygen per 100g of oil, which broadly corresponds to the production of an acid value of 1 mg of KOH per gram of oil was measured. This was called the useful life period. They found that the useful life period is approximately proportional to the quantity of inhibitor used. The rate of increase in breakdown voltage was higher at low concentrations of anti-oxidant. At high concentrations of anti-oxidant, the rate of increase in breakdown voltage with concentration decreased. This is evident in figure 2. The reasons for the increase in the breakdown voltage with anti-oxidant concentration include the following:

a) Anti-oxidant is not ionic and therefore will not increase the conductivity of the oil.

Table 1: Acid values of oil samples.

Sample of Oil	A	B	C	D	E
Acid value (mg KOH/g oil)	3.927	3.55	3.324	2.076	1.515

Table 2: Breakdown voltage of Crude Olein Oil (Sample A)

Anti-oxidant concentration (wt %)	0.23	0.459	0.686	0.913	1.13
Average Breakdown voltage (kV)	25	27	33	38	40

Table 3: Breakdown Voltage of Neutralized Samples

Anti-oxidant concentration (wt %)	Sample B AV=3.550	Sample C AV=3.324	Sample D AV=2.076	Sample E AV=1.515
0.230	26.5	28.5	29.0	30.5
0.459	30.5	33.5	38.0	45.0
0.686	38.5	40.5	48.2	54.0
0.913	42.0	44.5	54.1	56.8
1.130	43.0	46.0	55.1	58.5

Table 4: Increase in breakdown voltage due to different degrees of neutralization

Anti-oxidant concentration (wt %)	Increased breakdown voltage (kV)			
	Sample B	Sample C	Sample D	Sample E
0.230	1.5	3.5	4.0	5.5
0.459	3.5	6.5	11.0	18.0
0.686	5.5	7.5	15.2	21.0
0.913	6.0	8.5	18.5	20.8
1.130	2.2	4.2	1.3	17.7

Table 5: % increase in breakdown voltage with anti-oxidant concentration

Anti-oxidant concentration (wt %)	Percentage increase in breakdown voltage (%kV)			
	Sample B	Sample C	Sample D	Sample E
0.230	6.00	14.00	16.00	22.00
0.459	12.96	24.07	40.70	66.67
0.686	16.96	22.73	46.06	63.64
0.913	16.66	23.61	51.38	57.78
1.130	5.50	10.50	35.75	44.25

- b) The anti-oxidant interrupts the free radical mechanism of glyceride auto oxidation and hence stop the production of ions such as free fatty acids from the natural degradation of the oil (Sherwin, 1976, Thompson, 1966)
- c) It is also possible for the anti-oxidant to combine with some of the free fatty acid present in the oil.

This reduction in the free fatty acid content reduces the conductivity of the oil and hence improves the breakdown voltage of the oil. The higher the amount of anti-oxidant, the greater the quantity of free fatty acid or other ions that will be eliminated. It is obviously difficult to remove the last traces of the acid present in the oil.

Effect of acid value on breakdown voltage

In figure 3 the breakdown voltage of the samples at room temperature is presented as a function of acid value for a given anti-oxidant concentration. The extent of increase in the breakdown voltage also depends on the properties of the oil. By reducing the acid value through repeated potassium hydroxide neutralization, the extent of increase in breakdown voltage was observed to increase - see figure 4.

The oxidation of free fatty acids produces moisture containing compounds such as ketones,

alcohols, and carboxylic acids that may condense to polymers such as lacquers, gums, sludges, etc (Halton, 1962). The higher the extent of oxidation the greater the effect on the breakdown voltage since the amount of moisture - containing compounds will increase. The moisture content of oil has been shown by (Weiss, 1983) to be inversely proportional to the breakdown voltage. The function of the anti-oxidant is to extend the induction time thereby delaying oxidation.

The results show that the use of chemicals opens the potential use of vegetable oil as transformer oil. Although oxidation stability problems exist when mineral oils are used as transformer oil these problems are expected to be higher when vegetable oils are used. This is due to the difference in the chemical composition of the two oils. There is the possibility that an oxidation stability agent could adversely affect the desirable electrical properties of the oil. This could negate the use of such an additive. What is required now is a more serious quantitative study of both the oxidation stability and electrical properties of both oils (mineral and vegetable oils) in the presence and absence of anti-oxidants. This should point out the true potential of vegetable oil as transformer oil.

## CONCLUSION

From the experimental results and their analysis, the following conclusions are here by made:

- a. Increasing the concentration of anti-oxidant in an oil sample increased the breakdown voltage.
- b. Reducing the acid value of an oil sample increased the breakdown voltage for a given anti-oxidant concentration.
- c. The rate of increase in breakdown voltage of an oil sample decreased with increasing concentration of anti-oxidant.

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