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COMPARATIVE STUDY ON DIFFERENT VEGETABLE OILS AS ALTERNATIVE TO TRANSFORMER OIL CONSIDERING ACIDIC PROPERTIES

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***Abstract*: To shift from the overdependence on petroleum/mineral oil for the insulation of transformer core, this work sought to suggest vegetable oil as an alternative. To validate the authenticity of the vegetable oil, tests were done to determine the Free Fatty Acid (FFA), acid value and the interfacial tension, which were used to compare the standard value and suggest the best performing vegetable oil suitable for transformer cores. The results obtained for Jatropha, coconut oil, Melon seed and Palm Kerner Oil (PKO) were 3.983 MgKOH, 0.2805 MgKOH, 1.5145 MgKOH and 9.8735MgKOH for FFA respectively, 7.966, 0.561, 3.029 and 19.747 for acid values respectively, and 40dynes/cm, 48dynes/cm, 43dynes/cm, and 45dynes/cm for an interfacial tension respectively. Though the values deviate slightly from the standard values (Nil for FFA, 0.597 for acid value and 48dynes/cm i.e. 2dynes/cm less than the standard value for Interfacial tension), it can be clearly seen that coconut oil possesses properties close to the accepted standard value, and can be recommended for transformer oil alternative.**

***Keywords:* Acid value, Coconut Oil, Free Fatty Acid, Interfacial Tension, Jatropha Oil, Melon Oil, Palm kernel Oil, Vegetable Oil, Transformer Oil.**

I. INTRODUCTION

Conventionally, mineral oil has been the most commonly used transformer coolant because of its excellent properties [1]. These qualities have made petroleum-based oils to be nearly unrivaled and unmatched. On the contrary, mineral oil has a very low safety index. Also, this over dependence on petroleum oil may lead to shortages in the near future [2]. In addition, because of its effect on the environment coupled with its poor biodegradability due to its low fire resistance, poor partial discharge and high gassing tendency, it has made mineral oil vulnerable to locations where high fire security standards are required [3]. The excellent performance of mineral oil has ensured their use as electrical insulants over the last century and will ensure their continued use for decades to come [4]. However, there are three principal reasons why we should be seeking for alterative natural insulating liquids [5]. These are the poor biodegradability of mineral oil, its non-renewability and the heavy demand for petroleum products, which could lead to serious shortages as soon as the mid-21st century [6]. This is why vegetable oil has been suggested in this work as substitute considering its close behavior with mineral oil [7].

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In the work of [8], they addressed the transformer's hot-spot temperature (HST) and overload capacity, and suggests an online parameter monitoring system based on modeling. They evaluated the convection and heat dissipation process by developing a temperature-fluid coupling field of the 315 kVA vegetable oil distribution transformer in both two- and three-dimensional geometries. Description of the creation of an effective distribution transformer using vegetable insulating oil and an amorphous core was carried out by [9]. Along with the fluid's non-toxicity and quick biodegradation, a significant reduction in load losses and guaranteed functioning at higher temperatures were also achieved. The production, processing, and characterization of vegetable oils used as transformer oil were reviewed by [10]. The most popular vegetable oils for use as transformer oils are listed along with their key benefits over mineral oils. An overview of the present research on vegetable oils is provided by the descriptions of the various experimental projects conducted in various nations.

Several factors contribute to the selection of insulating fluids, but for the purpose of this work, FFA, Acid value and interfacial tension have been considered, which contribute to the insulation properties, acidity and corrosion of the transformer core. These values will be compared with the standard value and will recommend which vegetable oil is best for transformer core coolant.

II. METHODOLOGY

2.1 Acid value

This is the number of NaOH required to neutralize the oil. The test method by the American society for testing of materials (ASTM) provides that the acidity of oil in a transformer should not be allowed to exceed 0.2 mg KOH/g oil. This is the critical acid number and degradation increases rapidly once this level is exceeded. The acidity of used oil is due to the formation of acidic oxidation products.

Determination of acid value

25 ml of diethyl ether and 25 ml of ethanol were mixed in a 250 ml beaker. The resulting mixture was added to 20g of oil in a 25 ml conical flask and a few drops of phenolphthalein were added to the mixture. The mixture was titrated with 0.1m KOH to the end point with consistent shaking for which a dark pink color was observed and the volume of 0.1m KOH (Vo) was noted.

The calculations were carried out in accordance with the equation shown in Eq. (1) as stated in [11].

$$\text{Acid value} = \frac{\text{mL KOH}^{*}\text{N}^{*}56.1}{\text{wt of SAmple in gms}} \quad (1)$$

Where mL KOH is the standardization of 0.1mKOH against 0.1mHCl = 0.1064KOH

Average Volume of acid obtained during titration = N

The weight of the sample = 0.2 kg

2.2 Free fatty acid (FFA)

Almost all vegetable oils contain fatty acid. This is because of the long continuous glycerol chain they possess. A weighted mass of 0.67g of raw vegetable sample was transferred into a beaker and 50ml of ethanol was added to it. The mixture was placed on a hot plate. As the temperature was raised, the mixture started boiling and the ethanol absorbed the free fatty acid on the vegetable sample oil. The estimation of FFA [12] is shown in Eq. (2)

$$\text{FFA} = \frac{\text{Acid valve}}{2} \quad (2)$$

2.3 Interfacial tension

This is the dynes per centimeter (dyne/cm) required to rupture a small wire ring upward a distance of one centimeter through the oil sample interface. When contaminants are present in the oil, the film strength of the oil is weakened. This requires less force to rupture.

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III. RESULT

After the experimental procedure, the results were gotten as shown on Table 1, and Fig. 1 to Fig. 3.

Table 1: Comparative properties of mineral oil and vegetable oils without nano-particle

Property	Standard transformer oil	Jatropha	Coconut oil	Melon seed	Palm kernel oil (PKO)	International standard value
Acid value	0.597	7.966	0.561	3.029	19.747	
FFA (MgKOH)	Nil	3.983	0.2805	1.5145	9.8735	
Interfacial tension (dynes/cm)	50	40	48	43	45	

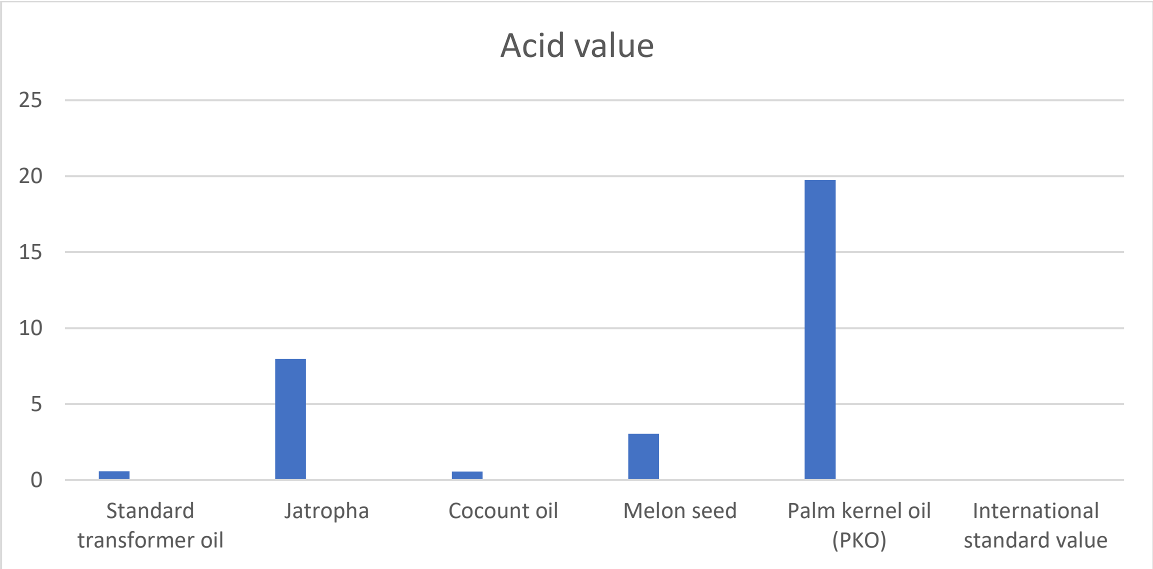

Fig. 1: Comparison between standard transformer oil and vegetable oil acid value

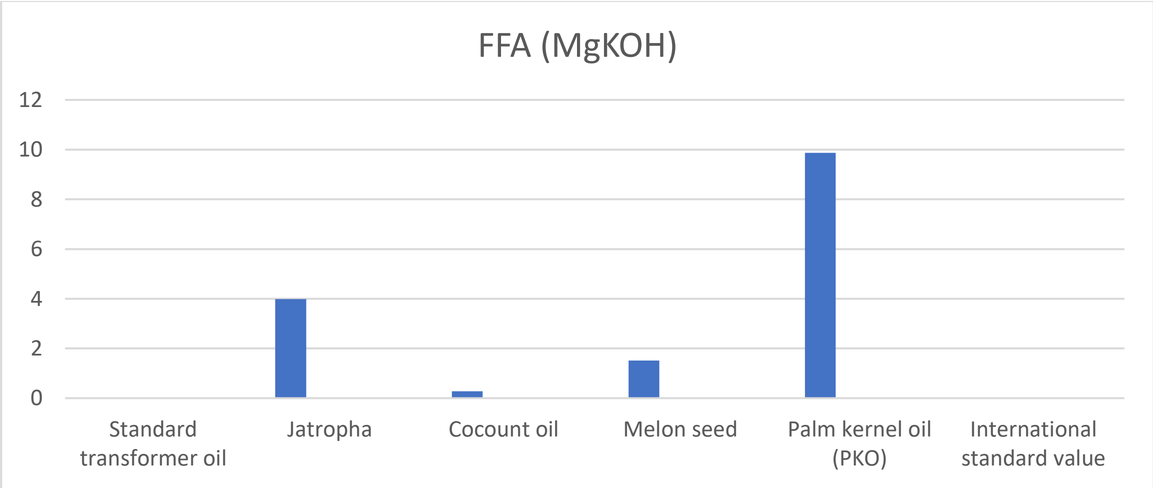

Fig. 2: Comparison between standard transformer oil and vegetable oil FFA

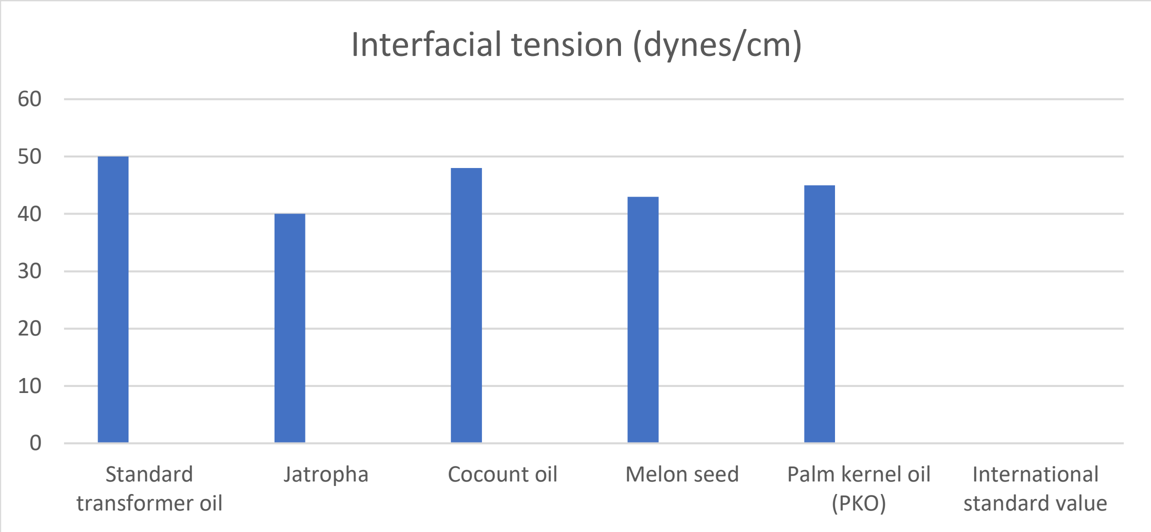

Fig. 3: Comparison between standard transformer oil and vegetable oil interfacial tension

IV. DISCUSSION

The acid value of standard transformer oil is 0.597 while the acid values of Jatropha, coconut, melon and palm kernel oil are7.966, 0.561, 3.029 and 19.747 respectively as seen in Fig. 1. Here, the disparity between the acid value of standard transformer oil and the sample oils is too much, except for coconut oil which is close to the standard value. From Fig. 2, the free fatty acid of standard transformer oil is nil while the free fatty acid of Jatropha, coconut, melon and palm kernel oil are 3.983, 0.2805, 1.5145 and 9.8735. The free fatty acid of palm kernel oil is much higher than the other three samples. For coconut oil, the free fatty acid is close to nil, which is the standard value and can be seen as the best value as compared to other vegetable oils. From Fig. 3, the interfacial tension of standard transformer oil is 50 dynes/cm while the interfacial tension of Jatropha, coconut, melon and PKO are 40 dynes/cm, 48 dynes/cm, 43 dynes/cm and 45 dynes/cm respectively. From the results, the difference between the standard transformer oil and the sample oils is not much. Coconut oil has a value of 48 dynes/cm which is closest to standard transformer oil with a difference of 2.

V. CONCLUSION

The work suggested an alternative of vegetable oil to conventional mineral oil used in transformer core insulation which may have deficiency and under supply in the future considering its high demand. To ascertain the authenticity of the vegetable oil, four vegetable oils were compared using their acid values, free fatty acid and their interfacial tension as it can aid to reduce and monitor corrosion acidity. The result gotten shows a deviation from the standard value, except for coconut oil which shows close similarity using the FFA, acid value and interfacial tension. This shows that coconut oil will be preferred compared to other vegetable oils to substitute mineral oil for transformer coolant.

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