Novelty Journals

ISSN 2394-7349

International Journal of Novel Research in Engineering and Science
Vol. 11, Issue 1, pp: (33-37), Month: March 2024 - August 2024, Available at: www.noveltyjournals.com

ANALYSIS OF STANDARD TRANSFORMER OIL AND VARIANT VEGETABLE OIL FOR OPTIMUM OPERATION OF TRANSFORMER

Uzoma Osuji[1], Chinonso S. Ezeonye[1], Fabian I. Izuegbunam[2], Nnamdi Iheaturu[3]

[1]Department of Electrical & Electronic Engineering, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria

[2]Department of Electrical/Electronic Engineering, Federal University of Technology, Owerri, Imo State, Nigeria

[3]Department of Polymer & Textile Engineering, Federal University of Technology, Owerri, Imo State, Nigeria

DOI: https://doi.org/10.5281/zenodo.11112349

Published Date: 04-May-2024

***Abstract*: The requirement to create a safer, non-flammable, and ecologically friendly transformer coolant to replace the petroleum-based oil currently used as transformer oil is the aim of this study. To identify a viable and sustainable vegetable oil substitute for transformer oil, electrical and chemical experiments were conducted on samples of melon, jatropha, coconut, and palm kernel oil (PKO) with the aid of mechanical and solvent method. The insulation breakdown voltage test results of the vegetable oil samples without nanoparticle addition were Jatropha oil 21 kV, Coconut oil 18 kV, Melon seed oil 15 kV and PKO 25 kV, while with the introduction of nanoparticles, the results became 25 kV, 19 kV, 15 kV and 35 kV respectively. Results obtained from the research show that PKO can suitably serve as coolant in a distribution transformer rated 11 kV/415 V which can serve as a good substitute for mineral oil. The following technical data from the research will help transformer designers make important decisions about the use of biodegradable transformer coolant.**

***Keywords:* Breakdown Voltage, Coconut Oil, Density, Flashpoint, Jatropha Oil, Melon Oil, Nano-Particle, Palm kernel Oil, Petroleum Oil, Transformer.**

I. INTRODUCTION

Transformer oil is a liquid mineral used for electrical insulation of high voltage equipment, including switches, tap changers, circuit breakers, transformers, capacitors, cables, bushings, and insulation against corona discharges and heat dissipation [1]. Due to its superior qualities, mineral oil has been the most widely utilized transformer coolant. Because of these characteristics, there is little or no competition for oils derived from petroleum. Conversely, the safety index for mineral oil is extremely low. Also, this over dependence on petroleum oil may lead to shortages in the near future. 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. Furthermore, an excessive reliance on petroleum oil could soon result in shortages. Mineral oil has rendered areas where strict fire safety regulations are mandated susceptible due to its negative impact on the environment, poor biodegradability resulting from its low fire resistance, poor partial discharge, and high gassing propensity [2]. Because of its excellent aging behavior, low viscosity, and strong resistance to oxidation, mineral oil has been the primary insulating liquid in industrial

International Journal of Novel Research in Engineering and Science
Vol. 11, Issue 1, pp: (33-37), Month: March 2024 - August 2024, Available at: www.noveltyjournals.com

power systems for many decades ago. Mineral oils are no longer the only option because distribution transformers must be used in areas with strict fire safety regulations. Researchers and engineers have looked into a plethora of alternatives to mineral oil because they want a safer, non-flammable, and environmentally acceptable insulating liquid for use in power equipment. Over the last 40 years, considerable advancements have been made in this area [3].

In the study of [4], they evaluated the thermal behavior of two distribution transformers operating at various powers submerged in dielectric vegetable oil and contrasted their results with those of two constructively equal transformers submerged in mineral oil. The transformers meet the criteria of current standards, according to the results. In their work, [5] investigated the effects of furans in natural ester oils utilizing transformer insulation nanocarriers. The results of their study show that natural esters have a high inverse association with antioxidants, making them a biodegradable option for transformer insulation.

Mineral oil's superior performance has guaranteed its usage as an electrical insulator for the past 100 years and will guarantee it for many more. Nonetheless, there are three main reasons we ought to look for alternative natural insulating liquids: mineral oil's low biodegradability, its non-renewability, and the high demand for petroleum products, which can cause severe shortages as early as the middle of the twenty-first century. Furthermore, transformer coolant of local quality must be supplied in order to serve as a backup in the event of an emergency. This would dissipate the losses as heat, so acting as thermal energy management. Therefore, this research will provide an alternative transformer coolant that is safer and non-flammable.

II. METHODOLOGY

The four samples of vegetable oil used in this work are:

Jatropha Oil: Since jatropha is a non-food seed, it doesn't affect food in any way. It is common throughout the world's tropical, semi-tropical, and desert climates [6]. After the peeled seeds were mechanically extracted, the press cakes that were left behind were chemically extracted either directly with hexane or with a soxhlet.

Melon Seed Oil: Melon is a member of the cucurbitaceous family. They grow well in deserts, subtropical areas, tropical areas, and temperate areas [7]. After being room temperature dried, the seeds were blended using an electric blender. Using a soxhlet device, 100g of seed samples were extracted for six hours at 40–60°C using petroleum ether. Lipid samples were obtained as the residue after the extract was deseloventized in a vacuum on a rotary evaporator at 35°C.

Palm Kernel Oil (PKO): The primary oil crop grown in tropical and subtropical regions is oil palm. Screw presses are the main method used to extract PKO from vegetable oil.

Coconut Oil: The edible oil known as coconut oil, sometimes called copra oil, is obtained from the meat or kernel of a fully grown coconut that is harvested from the coconut palm (Cocos nucifera) [8]. To make copra, coconut oil can be taken from the shell either wet or dry, then dried with fire or sunshine. Coconut oil is obtained by pressing or dissolving copra in solvents.

The method of estimations for oil density, viscosity, and moisture content as stated in [9, 10] are stated in Equations (1) to (3).

The oil density is measured using Equation 1:

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad (1)$$

Where mass = W_3 - W_1, W_3 is the mass of oil and pyconometer, W_1 is the mass of empty pyconometer, V is the volume of oil in pyconometer (50ml).

The viscosity is measured using Equation 2:

$$V = 0.24t - \frac{50}{t} \qquad (2)$$

International Journal of Novel Research in Engineering and Science
Vol. 11, Issue 1, pp: (33-37), Month: March 2024 - August 2024, Available at: www.noveltyjournals.com

Where t is the time of flow, and V is viscosity.

The moisture content is measured with aid of Equation 3:

$$\text{Moisture content} = \frac{M_i - M_f}{M_f} \times \frac{100}{1} \qquad (3)$$

Where M_i is the initial weight of the oil, and M_f is the final weight of the oil.

III. RESULT

The results comparative properties of mineral oil and the four sample vegetable oils are shown in Table 1 while Table 2 shows the breakdown voltage ranges when nano-particle was introduced.

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

Property	Standard transformer oil	Jatropha oil	Coconut oil	Melon seed oil	Palm kernel oil (PKO)	International standard value
Breakdown voltage (kV)	56.8	21	18	15	25	≥ 30
Flash point (ºC)	146	263	368	244	282	≥ 145
Density (g/cm^3)	0.81	0.8804	0.8872	0.8867	0.8843	≤ 0.91

Table 2: Comparative breakdown voltage (BDV) range result between conventional transformer oil, vegetable oil & international standard value with nano-particle

Electrical property	Conventional transformer oil	Coconut oil	Melon oil	Jatropha oil	PKO oil	International Standard Value (AST)
Breakdown Voltage (kV)	56 – 60	17 – 19	14 – 15	20 – 25	25 – 35	≥ 30

The breakdown voltage results of the sample vegetable oil (without nano-particle and with nano-particle) and the international standard value are shown in Fig. 1 and Fig. 2, while Fig. 3 and Fig. 4 show the comparison between the four-sample oil and transformer oil in terms of flash point and density.

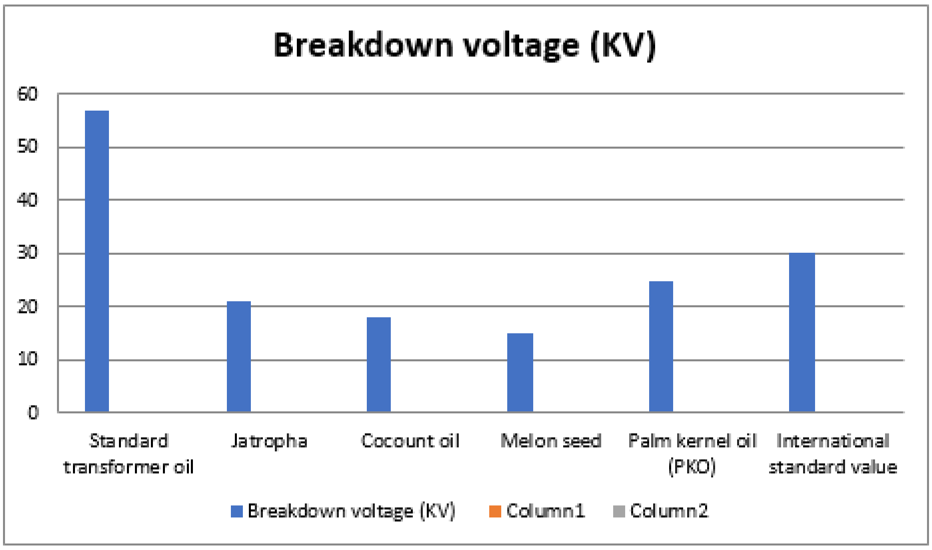

Fig. 1: Comparison of breakdown voltage (BDV) of standard oil and vegetable oils without nano-particle

Novelty Journals

ISSN 2394-7349

International Journal of Novel Research in Engineering and Science
Vol. 11, Issue 1, pp: (33-37), Month: March 2024 - August 2024, Available at: www.noveltyjournals.com

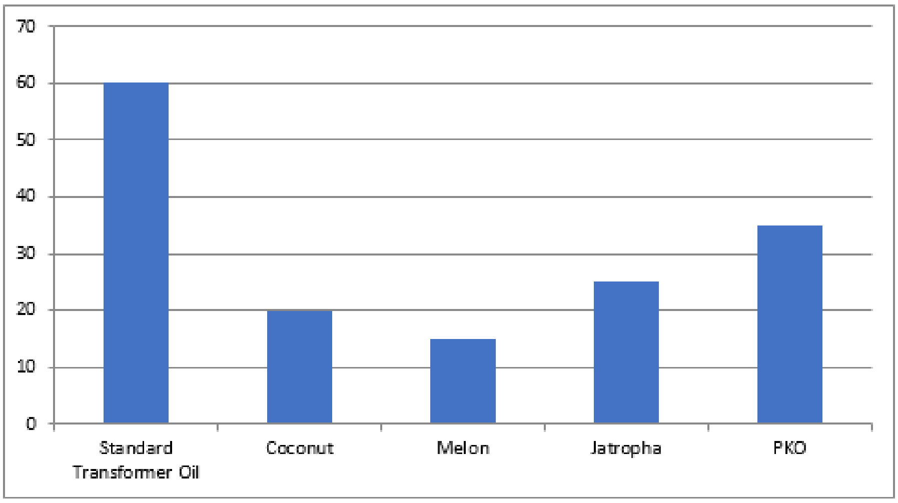

Fig. 2: Comparison between breakdown voltage (BDV) of Standard Oil and Vegetable Oils with nano-particles

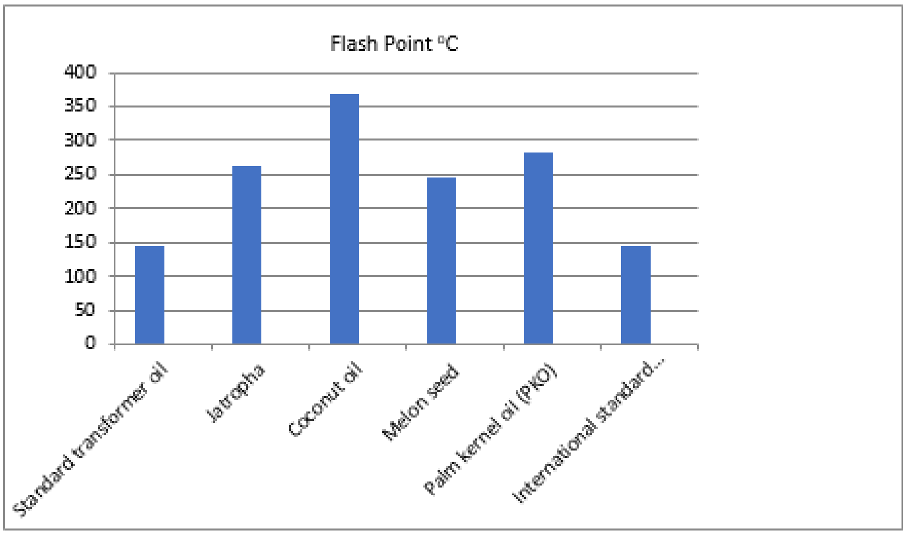

Fig. 3: Comparison between standard transformer oil and vegetable oil flash point

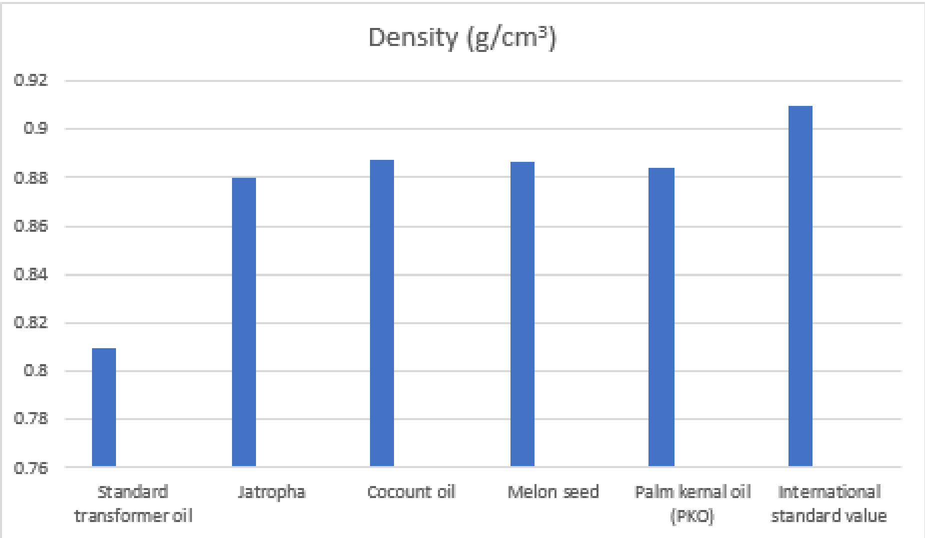

Fig. 4: Comparison between standard transformer oil and vegetable oil density

IV. DISCUSSION

From the results at Table 1 and Fig. 1, the breakdown voltage (BDV) of Jatropha, coconut, melon and PKO without nano-particle are 21 kV, 18 kV, 15 kV and 25 kV respectively. It is seen that none of them reached the range of the international standard value of ≥ 30 kV. PKO which has the highest BDV is 5 kV less than the international standard value. From Table 2 and Fig. 2, at the introduction of little grams of nano-particle (TiO_2), a considerable rise in the breakdown voltage was seen in the sample oils. PKO without nano-particle had 25 kV which is 5 kV less than the international standard (AST) of ≥ 30 kV, rose to 35 kV, thereby surpassing the limit of the international standard value. The flash point of standard transformer oil is 146°C while the flash points of Jatropha, coconut, melon and PKO are 263°C, 368°C, 244°C and 282°C respectively as can be seen from Fig. 3. From the results, it is clearly seen that conventional transformer oil has a low flash point of 146°C thereby making it susceptible to volatile regions while the flash points of samples are almost double of the of conventional transformer oil with coconut oil having the highest flash point of 368°C. This is also another indication that vegetable oil is an ideal alternative for distribution transformers. The density of standard transformer oil is 0.81 g/cm^3 while the densities of Jatropha, coconut, melon and palm kernel oil with no particle are 0.8804 g/cm^3, 0.8872 g/cm^3, 0.8867 g/cm^3 and 0.8843 g/cm^3 respectively. This comparison as depicted in Fig. 4 shows that there is a slight difference between the density of standard transformer oil and the sample oils which still falls within the international standard limit of ≤ 0.91g/cm^3.

V. CONCLUSION

From the results shown, the breakdown voltage of PKO without nano-particles stood at 25 kV which is 5 kV less than the international standard value of ≥ 30 kV but at the introduction of little grams of nano-particles, titanium dioxide (TiO_2), the breakdown voltage reached 35 kV which surpassed the limit of the international standard. This means that PKO sample can serve as transformer insulating oil for an 11 kV/415 V distribution system. However, the major limitations of PKO are poor oxidation stability and high viscosity index. Based on the analysis of the sample oils, there may be need to develop the vegetable oils more. The moisture content, acid value, free fatty acid (FFA), and iodine value of the vegetable oil may pose fresh research work which requires future work.

REFERENCES

[1] M. J. Heathcote, The J & P Transformer Book, 13 ed. Elsevier 2007.

[2] I. Fofana and J. Sabau, "Application of Petroleum-Based oil in Power Transformer, in National Gas Research progress, Nova science publishers' inc., 2008.

[3] I. Fofana, "50 Years in the Development of Insulating Liquids", IEEE Electrical Insulation Magazine, Vol. 29, No. 5, pp. 13-25, 2013.

[4] F. N. Diego, F. E. I. Diego, C. R. Hector, "Evaluation of the use of Vegetable Oil in Distribution Transformers", Ingeniare Revista Chilena de ingenieria, Vol. 20, No. 2, pp. 185-190, 2012.

[5] R. Samikannu, R. A. Raj, D. Karuppiah, N. R. Dasari, S. K. Subburaj, S. Murugesan, and S. S. Akbar, "Reclamation of Natural Esters using Nanocarriers as the Biodegradable Choice for the Transformer Insulation", Environmental Technology & Innovation, Vol. 23, pp. 1-19, 2021.

[6] H. B. H. Sitorus, R. Setiabuby, S. Bismo, and A. Berousal, "Jatropha Curcas Methyl Ester Oil Obtaining as Vegetable Insulating Oil", IEEE Transactions on Dielectric and Electrical Insulation, Vol. 23. No. 4, pp. 2021-2028, 2016.

[7] M. Milovanovic, and K. Picuric-Jovanovic, "Characteristics and Composition of Melon Seed Oil", Journal of Agricultural Sciences, Vol. 50, No. 1, pp 41-47, 2015.

[8] TIS: Transport Information Service, "Coconut Oil", German Insurance Association, Berlin, 2015.

[9] A. Beheshti, M. Shandebi, and S. Z. Heris, "Heat Transfer and Rheological Properties of Transformer Oil-Oxidized MWCNT Nanofluids" Journal of Thermal Analysis and Calorimetry, Vol. 118, No. 3, pp. 1451-1460., 2014.

[10] A. R. Hussein, M. M. Yaacob, and M. A. Alsaedi, "Faults Diagnosis and Assessment of Transformer Insulation Oil Quality: Intelligent Methods Based on Dissolved Gas Analysis a – Review", International Journal of Engineering & Technology, Vol. 4, No. 1, pp. 53-60, 2015.