



Research Paper / Makale

Physiochemical and Electrical Properties of Refined Luffa (*Luffa Cylindrica*) Seed Oil as Bio-Transformer Oil

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Received/Geliş: 10.06.2021

Accepted/Kabul: 29.11.2021

Abstract: Researchers have attested that oils of ester are biodegradable and environmentally friendly when compared to petroleum transformer lubrication and insulation oils. These benefits inspired us to explore the possibility of using refined luffa cylindrica seed oil (RLSO) as substitute source for transformer oil. To authenticate its suitability, it is imperative to make a comparison of electrical and physicochemical properties with transformer mineral oil (TMO) and ASTM standard specification. In this work the oil of Luffa cylindrica was extracted giving a yield of 31.13% and the extracted oil undergone having undergone a two-step acid-based transesterification process using first acid pretreatment and Alkaline Transesterification. The produced RLSO and TMO were analyzed for electrical and physicochemical properties utilizing standard procedures. The properties measured are pH, boiling point, density at 29.5°C, specific gravity at 25°C, viscosity at 27°C, free fatty acid, acid value, iodine value, peroxide value, saponification value, others are flash point, cloud point, pour point, breakdown voltage and relative permittivity dielectric constant at 25°C. Most of the results obtained shows that RLSO compares relatively well with TMO and the values also meeting the ASTM standard specification for bio-transformer oils. Hence refined Luffa cylindrica oil can be used substitute to conventional transformer oil since it met most of the ASTM standard specifications.

Keywords: breakdown voltage, transformer oil, DFT, luffa cylindrical, transesterification

Biyo-Transformatör Yağı Olarak Rafine Luffa (*Luffa Cylindrica*) Tohum Yağının Fizyokimyasal ve Elektriksel Özellikleri

Öz: Araştırmacılar, petrol trafo yağlama ve izolasyon yağlarına kıyasla ester yağlarının biyolojik olarak parçalanabilir ve çevre dostu olduğunu onaylamışlardır. Bu faydalar, transformatör yağı için yedek kaynak olarak rafine luffa cylindrica tohumu yağı (RLSO) kullanma olasılığını keşfetmemiz için bize ilham verdi. Uygunluğunu doğrulamak için, transformatör mineral yağı (TMO) ve ASTM standart spesifikasyonu ile elektriksel ve fizyokimyasal özelliklerin bir karşılaştırmasını yapmak zorunludur. Bu çalışmada, Luffa cylindrica'nın yağı, %31.13'lük bir verim vererek özütlendi ve özütlenen yağ, birinci asit ön işlemi ve Alkali Transesterifikasyon kullanılarak iki aşamalı asit bazlı bir transesterifikasyon işleminden geçirildi. Üretilen RLSO ve TMO, standart prosedürler kullanılarak elektriksel ve fizyokimyasal özellikler açısından analiz edildi. Ölçülen özellikler pH, kaynama noktası, 29.5°C'de yoğunluk, 25°C'de özgül ağırlık, 27°C'de viskozite, serbest yağ asidi, asit değeri, iyot değeri, peroksit değeri, sabunlaşma değeri, diğerleri parlama noktası, bulut noktası, akma noktası, kırılma gerilimi ve 25°C'de bağıl geçirgenlik dielektrik sabitidir. Elde edilen sonuçların çoğu, RLSO'nun TMO ile nispeten iyi karşılaştırdığını ve değerlerin ayrıca biyo-trafo yağları için ASTM standart spesifikasyonunu da karşıladığını göstermektedir. Bu nedenle rafine Luffa cylindrica yağı, ASTM standart özelliklerinin çoğunu karşıladığı için geleneksel transformatör yağının yerine kullanılabilir.

Anahtar Kelimeler: Arıza gerilimi, trafo yağı, DFT, luffa silindirik, transesterifikasyon

How to cite this article

Oyelaran, O.A., Sanusi, O.M., Borisade, S.G., Abioye, J.O., Olumroti, I.A., "Physiochemical and Electrical Properties of Refined Luffa (*Luffa Cylindrica*) Seed Oil as Bio-Transformer Oil" El-Cezeri Journal of Science and Engineering, 2021, 8(2); 133-143.

Bu makaleye atıf yapmak için

Oyelaran, O.A., Sanusi, O.M., Borisade, S.G., Abioye, J.O., Olumroti, I.A., "Biyo-Transformatör Yağı Olarak Rafine Luffa (*Luffa Cylindrica*) Tohum Yağının Fizyokimyasal ve Elektriksel Özellikleri" El-Cezeri Fen ve Mühendislik Dergisi 2021, 8(2); 133-143.

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1. Introduction

Economic and industrial progression in modern era has hastened the necessity for persistent energy requisite across the nations of the world. The exhaustion of fossil resources such as oil, gas, and coal that raises as a result their persistent usage, price unpredictability, energy insecurity, apprehension over degraded environment and non-renewability inspired global search for a substitute energy sources [1]. The persistent search these days for economic and sustainable growth requires the coherent use of resources, which includes investing in renewable and greener processes [2]. Transformers used in power sector are using insulating oil commonly referred to as transformer oil serving as coolant and electrical insulator [3]. Martin and Wang, [4] wrote that Cooling is achieved as soon as heat is absorbed by the oil winding coil transmitting it to the surroundings flowing through the ducts. In the power sector, this veracity entails improving the safety and efficiency in both its generation and distribution. Hence the anxiety about reliability, safety and performance has grown substantially on fluid applied in power transformers [5]. To safeguard cooling and electrical insulation for over a century mineral oils have been in utilized in power transformers [6].

In the last three decades Natural esters have attracted much attention as substitute transformer oil [7]. Vegetable oils are fully biodegradable, relatively higher fire and flash point and fairly good insulating properties. Bio-transformer is an alternative oil produced from biological renewable sources such as animal fats and vegetable oil. The rising prices of petroleum products couple with the fears in supply and rubble of world climatic condition triggered by its continual usage have reawakened researchers to look for an alternative to mineral transformer oil. Conversely, those commonly used vegetable oils are rival to its usage as food, hence, the need to search and recognize oils that are non-edible in place of edible oils. Nonedible oils for instance castor and olive seed oils [8], jatropha (*Jatropha curcas*) seed oil [9], calabash seed oil [10], neem (*Azadirachta indica*) seed oil [11] and others have been studied for use as transformer oil. Even so ease of access of these feedstock are at variance, therefore necessitates searches for new innovative oils sources.

Luffa cylindrica is a cucumber family plant. It is climbing annual species of herbaceous that can grow upto 15 metres [12]. It is mostly grown in the tropics and the oil content in the seed is about 31.6%, and which is higher than that of cotton (18.28%) and (11 - 25%) for soya bean. It is an eco-friendly resources non-toxic, of low-density, biodegradable with physical and chemical stable properties [13]. *Luffa* oil has been found to be a potential oil for biodiesel production [14]. Nonetheless, no work has been reported in writings on the use of *luffa* seed oil as bio-transformer oil. Therefore, this work examined the possibility of using refined *luffa* oil as a bio-transformer oil for use in power transformer. The result obtained in this research will make available information on the use of *luffa* oil as feed stocks for producing bio-transformer oil and will assist in determining the oil properties and its comparism with standard mineral transformer oil and the ASTM standard.

2. Experimental Methods

2.1. Materials Collections

Fresh seed of *Luffa cylindrica* were obtained from Ogbomoso, Nigeria and Transformer mineral SinapacTrans001 purchased from Lagos Nigeria. The reagents and other materials were procured from Honor Laboratories and Chemicals, Abuja and are of standard grade.

2.2. Preparation of Seeds and Oil Extraction

Fresh seeds of *Luffa cylindrica* were obtained from a farm. The seeds removed from the dry spongy mesophyll fruit. The shell of seeds were removed and the seeds dried pending the splitting of the seed coat and shredding of cotyledon. To separate seed coat and cotyledon air blowing was used.

The method used by Rashid and Anwar, [15] was adopted where seeds were grinded using a grinder and 100g placed into a Soxhlet and a 2 litres round bottomed flask fitted. Extraction was effected using n-hexane on a water bath for 6 hours. A rotary evaporator was utilized in removing the solvent under vacuum. The amount extracted oil was determined using Equation 1:

$$\% \text{ Oil Content} = \frac{\text{Weight of oil extracted}}{\text{Weight of the seed}} \times \frac{100}{1} \quad (1)$$

2.3. Production of Refined Luffa Cylindrica Seed Oil (RLSO)

A Two Stage Acid-Base Transesterification procedure was used first acid pretreatment and Alkaline Transesterification.

2.3.1. Acid Pretreatment

The produced luffa seed oil (LSO) temperature was raised to 50°C to ensure homogeneity of the oil it was mixed constantly with the aid of magnetic stirrer. The experiment was carried out with a three 500 ml necked flask with rounded bottomed with thermometer and a reflux condenser attached and placed in a water bath and a temperature controller. To 0.60 w/w methanol was poured concentrated sulfuric acid and heated to 50 °C (2% based on oil weight) was poured on pre-heated oil in the reaction flask and stirred for 2 hours [16]. The product was decanted to a separating funnel and left for 2 hours so as to settle. The unreacted methanol is at the top layer, oil and fatty acid methyl ester (FAME) in the middle layer and at the bottom layer is water.

2.3.2. Alkaline Transesterification.

The low percentage free fatty acid oil produced from the pretreated LSO was heated to 60°C as suggested by Alamu *et al.*, [17] using a four necked flask stirring at 1000 rpm as used by Dorado *et al.*, [18] in a water bath with mechanical stirrer. Sodium hydroxide (NaOH) as catalyst of 1% based on oil weight was dissolved in mandatory quantity of methanol (of 6:1 methanol to oil ratio) as catalyst was added to the pretreated oil as used by Meher *et al.*, [19]. At the end of 2 hours of the reaction, into a separating funnel was poured the product and permitted to rest for 2 hours. There was dual divergent phases with glycerol at the bottom and RLSO on top. The RLSO and glycerol were then separated and using a rotary evaporator to recover the excess methanol in RLSO. To get rid of contaminations such as soap the RLSO was washed with hot de-ionized water and to eliminate the moisture its temperature was raised to 100°C, and left that temperature for an hour.

2.4. Physiochemical Properties Determinations

2.4.1. Physical State

The Colour, odour and other physical state of produced oils were assessed by sensual estimation.

2.4.2. Kinematic viscosity

ASTM D 445 recommended procedure was applied to determine viscosity of oils using suspended-level capillary viscometer. The U-shaped viscometer made of glassware was dipped into a hot water bath. It was then multiplied by a constant used for S3 viscometer, to obtain the viscosity at 27°C with 30°C set as initial temperature [20].

2.4.3. Free fatty acid (FFA) and Acid value

In determining the FFA of the oil, the method used by Sidohounde *et al.*, [21] and Fares *et al.*, [22] was adopted for this work where 25ml diethyl ether was mixed with 25ml ethanol. Indicator

solution of 1ml of 1% phenolphthalein was added to the mixture and was then neutralize with potassium hydroxide solution of 0.1M. 5g of the oil sample where then dissolved in the neutralized solvent mixture. Titration was the carried out with potassium hydroxide solution 0.1M with constant shaking until pink colour is obtained persisting 115 seconds. The acid value is calculated using Equation 2 and FFA using Equation 3:

$$\text{Acid Value} = \frac{\text{titration (ml)} \times 5.61}{\text{Weight of sample used}} \text{ (mgKOH/g)} \quad (2)$$

$$\text{And FFA\% is approximately } \frac{1}{2} \text{ acid value [23].} \quad (3)$$

2.4.4. Peroxide Value

The test was done in a reduce daylight. 1g of oil was poured into a boiling tube that is dry and clean. A gram of potassium iodide powder was added to 10ml of solvent mixture. To make the liquid to boil it was place on the boiling water bath to boils, it was then left to boil enthusiastically for above 30 seconds. It was then pour into titration flask with 20ml of 5% solution of potassium iodide solution freshly prepared. 25ml portions of water was used to wash the tube twice. Titration was then performed with starch as indicator using 0.002M sodium thiosulphate solution (aml). A blank determination was carried out. Blank titre (bml) [21]. Equation 4 was used to calculate the peroxide value.

$$\text{Peroxide Value} = \frac{2(a-b)}{\text{weight of oil}} \text{ (mEq/kg)} \quad (4)$$

where b = Blank titre value and a = Sample titre value

2.4.5. Saponification Value

Saponification value was obtained by weighing 2g of oil (by pipette dropping) to a flask, Alcoholic potassium hydroxide solution of 25ml was poured into the flask. The flask was then heated for 1 hour with reflux condenser attached on a water bath with intermittent shaking. On removing the flask from the water bath, 1ml of the 1% phenolphthalein indicator was added. Titration was then performed while still hot with 0.5M hydrochloric acid (aml). A blank determination omitting oil was then performed (bml) [24]. The saponification value was calculated using Equation 5:

$$\text{Saponification value} = \frac{(b-a) \times 28.05}{\text{weight of oil}} \text{ (mgKOH/g)} \quad (5)$$

where b is blank titre value and a is sample titre value

2.4.6. Iodine Value

In determining the iodine value of oil, 0.3g of samples oil (by means of acid of a dropping pipette) into a 25ml flat bottom flask glass stopper, carbon tetrachloride of was then dissolved in the sample. Wiji's solution of 20ml was added and a stopper moistened with potassium iodide solution was inserted. It was then mixed and allow to stand for 30 minutes in a dark cupboard. Freshly prepared 15ml of 10% potassium iodide solution with 100 ml water where added and mixed. It was then titrated with 0.1M sodium thiosulphate solution using starch as an indicator about the end point (aml). A blank determination omitting the oil was also carried out (bml) [24]. The iodine value was calculated using the Equation 6:

$$\text{Iodine value} = \frac{(b-a) \times 1.269}{\text{Weight of oil}} \text{ (g100/g)} \quad (6)$$

where b is blank titre value, a is sample titre value.

2.4.7. Density

The method used by Huseyin et al., [25] was used. An electronic weighing balance was used to weigh a small beaker. 2 ml of sample was poured into the beaker and the weight recorded. Density was determined using Equation 7.

$$\text{Density} = \frac{\text{Mass of oil}}{\text{Volume of oil weight}} \text{ (g/cm)} \quad (7)$$

2.4.9. Specific Gravity

To determine specific gravity of the oils an empty pycnometer bottle of 10 ml was weighted (W_1). The pycnometer bottle filled with water was then weighed (W_2). The pycnometer bottle filled with the same volume of oil as that of the water was also weighed (W_3) [21]. The specific gravity was then calculated using Equation 8.

$$\text{Specific gravity} = \frac{W_3 - W_1}{W_2 - W_1} \quad (8)$$

2.4.10. Determination of Flash Point of the Oils

The flash point was determined by pouring the sample oils (5ml) in a crucible and placed uncovered on a turned on hot-plate. A thermometer was then inserted into the sample oil and flame flashed on it intermittently using lighter. The temperature increase was carefully observed. The temperature when the fuel just starts to spark light was noted and recorded as the Flash Points. The observed flash points were recorded from the thermometer. Triplicate determinations were done and the mean value used as flash point of sample.

2.4.11. Determination of Cloud Point of Oils

Cloud point of the sample oils were determined using the method of ASTM (2013). The sample of oil was poured into a small beaker placed inside a big beaker and the sample was cooled at a 2°C rate with ice block. It was then monitored until a cloud was seen on the tip of inserted thermometer. The temperature at which cloud first appeared was recorded. Triplicate determinations were done and the mean value used as cloud point.

2.4.12. Determination of Pour Point of Oils

Pour point of sample oils was determined by the ASTM (2013) method. The sample of the oils were heated in a water bath kept between 48°C and 45°C and poured into the capillary tube tied-up with thermometer and place in the beaker containing water. It was then cooled at decrements of 2°C and to check for any movement the container was tilted. 2°C above temperature at which oil sample stops moving was noted as the pour point. Triplicate determinations were done and the mean value used as pour point.

2.5. Electrical Properties Determinations

The dielectric breakdown voltage (DBV) of fresh oil and after forty days, relative permittivity electrical constant at 25°C were determined following the American standard for testing and material (ASTM) methods.: Megger (OTS 60SX) was utilized to measure the dielectric strength of

RLSO and TMO samples. The process used for the experiment is simple with results displayed on LED screen. It is an automated device which assesses oil quality following ASTM standard. Sample of oil was placed between 2.5 mm gap two electrodes. An increasing constant voltage was applied until the discharges oil. The kV at which the discharge occurs is the breakdown voltage and it is noted [26]. Measurement of breakdown voltage were also performed at a number of temperatures level, starting from 25°C to 120°C. Six measurement were performed at each voltage level, and the average value recorded as the result. After pouring the samples into the test chamber, voltage application was started about 5 minutes in accordance to IEC -156, [27]. The delay time is require to warrant gas bubbles made during pouring process is been ejected prior to measurements using time delay between two successive measurements with not less than two minutes [27]. To allow for disperse and gas expelling, hence the need for the delay time after each measurement so as to avoid the result of the former influencing the later [28]. The temperature was kept comparatively constant at each temperature level using a special temperature control system.

3. Results and Discussion

3.1. Physicochemical Properties of Produced RLSO and TMO

The oil yielded of Luffa seed is of good quantity on extraction of 31.13% which is higher than that obtained by Ibeto et al., [29] whom wrote that *Brachystegia eurycoma* and *Luffa cylidrica* yielded 14.08 and 12.30% respectively but, lower than 44.85 for *Cucumis melo*. RLSO had an agreeably oily smell, tint yellow in colour and liquid at room temperature this attribute of RLSO confer it some benefits for it usage as bio-transformer feedstock. Density at 29.5°C of RLSO at 29.5°C was 0.85 g/cm³ which is within the acceptable limit of 55 – 89 g/cm³ [10] while that of TMO was 0.889 g/cm³. The results obtained for RLSO was higher than 0.52, 0.72 and 0.74 g/cm³ obtained for moringa, jatropha and castor and lower than 0.91 g/cm³ for Shea oil and similar to that of Cotton with 0.85 g/cm³ for bio-transformer oil [30]. Raja et al. [31] noted that higher energy for work output per unit volume will be available with higher mass of oil. The Specific gravity of RLSO is 0.8847 and is close to 0.89 – 0.91 the standard range for bio-transformer oil [10] while that of TMO is 0.8909. Viscosity is an important characteristic of transformer oil based on the fact that at lower temperature there is a raise in viscosity which upsets the fluidity of the oil [31]. This is an indication of inverse relationship between temperature and viscosity [10]. The produced RLSO has a viscosity of 8.81 cst as displaced on Table 1 which is relatively similar to that obtained for TMO of 9.03 cSt and the ASTM specification of 9.3–27 cSt [10]. The result is higher when compared to that of *Jatropha curcas* seed oil of 8.2 and 8.27cSt as reported by Garba et al., [23] and Evangelista et al., [6] respectively. Bashi et al., [32] emphases that for smooth operation electrical equipment, the oil temperature needs to be within the mild array. Hence 8.81 cSt for RLSO is good with respect to viscosity. Rafiq et al. [33] also wrote that insulating oil in power transformer also stimulates heat dissipation, ordinarily by natural convection. Consequently, the noted that lower viscosity oils can improve heat dissipation efficiency. The pH of 5.27 for RLSO is relatively closer to ASTM Specification of 5.5–8.2. It is noteworthy that the acidic nature of RLSO was owing to the occurrence of free fatty acid while that of TMO was due to its sulphur content. The acid values of RLSO and TMO were found to be 0.08 and 0.14 mg KOH g⁻¹ oil respectively which both exceeded the ASTM standard of 0.01–0.03 mg KOH g⁻¹ oil. The FFA of both RLSO and TMO of 0.0718 and 0.0421 mg KOH g⁻¹ oil respectively also exceeded the ASTM specification of 0.01–0.08 mg KOH g⁻¹ oil. Both the acid value and the FFA of RLSO compares well with that of Transformer mineral oil.

Iodine value is a degree of the reactivity and unsaturation of oil. Oils with high value of iodine possesses greater degree of unsaturation. The iodine value for RLSO was establish to be 57.87 g 100 g⁻¹ oil and higher than TMO which was found to be 28.178 g 100 g⁻¹ oil, as presented in Table

1. The value obtained is lower than 100 hence the oil is classified as non-dry oil and it also falls within minimum ASTM requirement of 55–120 g100/g (ASTM, 2013). The value obtained for RLSO is greater than that of 51.27 g 100 g⁻¹ oil obtained for *Jatropha curcas* seed oil [23]. Similarly, the value signifies the decrease in unsaturation of oil [34], hence a benefit since lower unsaturation of oils, the superior is the oxidation stability. The Saponification value of RLSO was found to be 158.03 mgKOH/g oil as shown in Table 1 and is within the ASTM specification. The value obtained is higher than that of TMO which was found to be 151.48 mgKOH/g oil. A high saponification value shows a great presences of low molecular mass fatty acids [35]. This is indicating soap formation and problems in separation of products if exploited for bio-transformer syntheses. Peroxide value is a sign of rancidity level of an oil [10]. RLSO peroxide value was found to be 4.61meq g⁻¹ oil while that of TMO was 4.44 the values are slightly lower than the ASTM recommended value of 5 -10 meq g⁻¹ oil as revealed in Table 1 signifying that the oil is good because of its lower level of rancidity. A lower peroxide value improves the appropriateness of the oil for storing for a long-time as a result of lower level of lipolytic and oxidative activities. The refining process carried out also aided in decreasing the peroxide value of RLSO.

The flash point of RLSO was found to be 151°C higher than 137°C for TMO and was above the least ASTM recommended range of 140°C thus possess no threat to fire outbreaks should accidents occurs. EL-Sayed et al., [36] noted that flash point is an essential requirement for safety during handling, storage and transportation. The flash point obtained for RLSO revealed that RLSO can safely be utilized even where the temperature is high. The low temperature performance standard for oil are cloud and pour points. The lowest temperature at which oil can flow is termed cloud point. RLSO cloud point is 13°C higher than 7°C for TMO and it falls within the ASTM specification of 7 - 15°C as shown in Table 1. This suggested that the oil can perform appropriately in cold climatic conditions. The RLSO pour point is 3°C, higher than -7°C for TMO and higher than upper limit for ASTM specification of -6. A higher pour point habitually confines the usage of oils in cold climatic conditions. Achten et al. [34] emphases for low pour point for oil to keep on flowing, even at low temperature. Wax precipitates in oil losing its flow properties instigating the wax to chunk the fuel supply line and filters when the pour point is higher than the ambient temperature. The boiling point of RLSO was found to be 153°C higher than 135°C for TMO it also falls within the ASTM specification of 120 - 230°C.

Table 1. Physio-chemical properties of Refined *Luffa cylindrica* seed oil (RLSO) with the ASTM standard specification for transformer oil and Purchased transformer mineral oil (TMO).

Properties	TMO	RLSO	ASTM specification
Density at 29.5°C (g/cm ³) 27°C	0.889	0.85	0.55-0.89
Viscosity at 27°C (cst)	9.03	8.81	9.3–27
Cloud point (°C)	7	13	7–15
Pour point (°C)	-7	3	-8– (-6)
Flash point (°C)	137	151	140–155
Acid value (mgKOH/g oil)	0.08	0.14	0.01–0.03
Boiling point (°C)	134	153	120–230°C
pH		5.23	5.5–8.2
Specific gravity at 20°C	0.8909	0.8847	0.89–0.91
Saponification value (mgKOH/g oil)	151.472	157	150–244
Peroxide value (meq/g oil)	4.44	4.61	5–10
Iodine value (g100/g)	28.178	57.87	55–120
Free fatty acid (mgKOH/g oil)	0.042	0.071	0.01–0.08
Appearance	Yellow tint	Yellow tint	White / yellow tint

3.2. Electrical Properties of RLSO and TMO

The DBV result of the fresh RLSO as displaced in Table 2 shows that the oil has a DBV than 35.22 kV though lower than that of TMO of 40.48 kV. The results met the ASTM specification of 25 – 40 kV. The result of RLSO indicate that it can serve as insulation oils in transformer of 33 kV rating with three phases. The results of RLSO after forty days as shown on Table 2 reveals that there is a decrease in the DBV to 33.64 kV. The relative decrease in DBV of RLSO compared to TMO is because oils ester undergo rancidified when they come in contact with atmospheric oxygen, resulting in formation of moisture which decreases the insulating ability of the oil. The relative permittivity results in Table 2 infers that the ester oil will be able to store the charge other capacitor oils will store.

Table 2. Electrical Properties of Ester Oils

Properties	TMO	RLSO	ASTM specification
Dielectric strength (kV)	40.48	35.22	25–40
Oil DBV after 40 days (kV)	40.46	33.64	-
Relative permittivity dielectric constant	2.23	2.51	

The measurement of Breakdown voltage were carried out at a number of temperatures level, extending from room temperature 25°C to 120°C. For every level, six measurements were conducted, with the mean value displaced in Figure 1. Breakdown voltage of RLSO increased considerably with temperature up to 70°C. This result due to relative reduction of water content of RLSO. This is because the insulating fluid breakdown voltage is inversely proportional to its relative water content [37, 38]. Increasing temperature resulted in substantial decrease in the relative water content of the oil. Accordingly, raising the breakdown voltage of the oil. A similar trend was testified by Rajab et al., [38], who carried out a research on breakdown voltage analysis on mineral, palm oil and synthetic types insulating liquid under temperature variation.

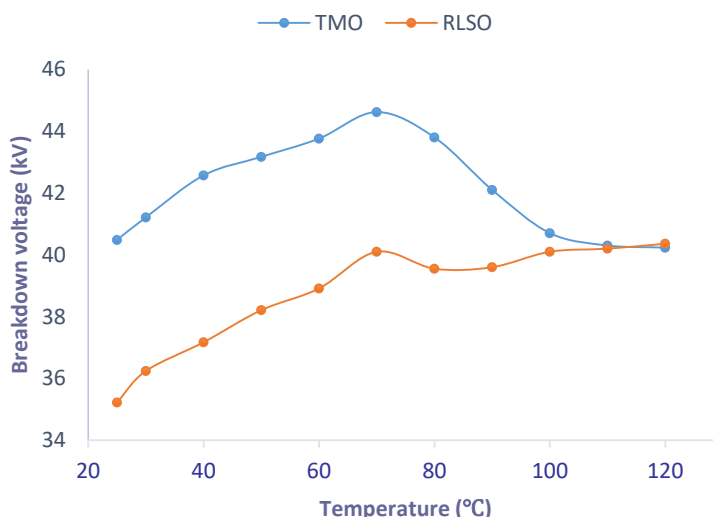


Figure 1. The Mean value of breakdown voltage of RLSO and TMO

4. Conclusions

Transformer oil produced from luffa cylindrica seed oil have been characterized. The characteristics of the refined luffa cylindrica seed oil indications that the refined seed oil is of worthy quality, because most of properties tested are reasonable in agreement with those obtained for transformer mineral oil used in this study, the and also meeting the ASTM specifications. The use of mineral oil

in transformer brings a lot of problem through outflow when in operation and the oil becoming a pollutant to the environment as a result of its less biodegradable attributes. Consequently, luffa cylindrica seed oil like other vegetable oil has been known as good quality substitute material for transformer oil attributable to its high-quality biodegradability characteristic, low pour point, high flash point, and high solubility. The experimental results reveals that refined luffa cylindrica seed oil also has good breakdown strength. The use of RLSO as transformer oil will shows conceivable savings for utilities since it will simplify the remediation and cleanup processes. Nonetheless, the actual savings are appreciated in areas of spill or leakage. Which is a fact for utilities in ecologically delicate parts where spills or leaks are identified as peril to marine life.

Acknowledgments

We would like to thank Prof. B. O. Bolaji of Mechanical Engineering Department, Federal University Oye-Ekiti for his valuable advice.

Authors' Contributions

Oyelaran designed the study. Sanusi, Borisade and Abioye carried out the experimental work, the theoretical calculations, in collaboration with Olumoroti,. Oyelaran wrote the paper is the overall supervisor of the project.

Both authors read and approved the final manuscript.

Competing Interests

The authors declare that they have no competing interests.

Refereneces

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