Chemistry Research Journal, **2017, 2(6):267-272**

Available online www.chemrj.org

Research Article

ISSN: 2455-8990
CODEN(USA): CRJHA5

Physiochemical and Electrical Properties of Pre-Processed Ester Oils

Mustapha AB*, Ekanem EO, Kolo AM, Boryo DEA, John DS, lawan NM, Barambu AU

Department of chemistry, Faculty of science, Abubakar Tafawa-Balewa University Bauchi, Nigeria

Abstract In this research oils were extracted from *Cassia tora* Seed Oil (CTSO) and *Luffa agyptiaca* seed oil (LASO) and the oils were pre-processed and analyzed for physiochemical and electrical properties of using standard methods. Many researches proved that ester oils are environmentally friendly and biodegradable as compared to crude oil base insulation and lubrication oils. The physiochemical properties of the pre-processed ester oils were; CTSO; LASO, percentage yield, 38.28;29.15 %, colour, yellow; yellowish, moisture content, 4.01;4.17 %, cloud point, 7;5 ^{o}C, pour point, 11;10 ^{o}C, density at 20 ^{o}C, 0.89;0.91 g/ml, viscosity at 40 ^{o}C, 7.51;10.50cSt, viscosity at 100 ^{o}C, 2.0;4.10cSt, Specific gravity at 25 °C, 0.89;0.88J/ kg °C, Smoke point, 201;220^{0}C, Flash point,220;231 ^{0}C,Fire point,243;250 ^{0}C, Biodegradability, readily biodegradable, Iodine value**,** 141;132g iodine/100g of oil, Free fatty acid, 9.01;10.45 %, Acidity 17.93;20.80 mgKOH/g, Peroxide value,220;278 Meq/kg, Corrosive Sulphur, non-corrosive. The results of the electrical properties are Dielectric breakdown voltage (DBV) at 2.5mm gap, 42; 42.5 kV, Oils DBV after 40days 40; 42 kV, Relative permittivity/ dielectric constant @25 ^{0}C, 2.80; 2.75. These results show that the pre-processed oils can serve in some very wide potentials such as biodiesel production, transformer insulating oils, capacitor oils, in turbine engine and as a lubricator in steel casting.

Keywords Pre-processed, dielectric breakdown voltage, biodegradable, triglycerides, glycerin

Introduction

In trying to find an alternative source of environmentally friendly oil, a lot of researches have been carried out to analyze ester oils as substitutes for the non-biodegradable mineral oil. This research analyzes three vegetable oils on their physiochemical and electrical properties after pre-processing. Natural ester oils have been identified as suitable oils since they are biodegradable, non-toxic and have high flash points that ensure more in-service safety [1].

Ester oils biodegrade quickly and completely, and exhibit very low or no toxicity as compared to mineral oils [2]. This is mainly because ester oil dielectric fluids do not contain halogens, polynuclear aromatics, volatile or semi-volatile organics, or other compounds that are present in mineral oils or other dielectric fluids [3]. Ester oils have a much better biodegradation capacity than mineral oil under aerobic as well as anaerobic conditions [4]. Tests carried out by various researchers severally indicate that ester oils undergo about 70-100% biodegradation in a period of 28 days [5]. Significantly, they are environmentally friendly: renewable, nontoxic and biodegradable [2]. Regarding the characteristics for mineral oils and other dielectric liquids, the thermal properties of ester oils appears as equivalent, or better [6].

Natural ester oils are lipid materials and are derive from plants [7]. In plants, they are extracted from numerous oil seed, fruit, or leaf of plants [8]. They can be extracted through three different methods from plants; pressing (expelling), solvent extraction and milling process. Physically, most natural ester oils are liquid at room temperature and are characterize by triglycerides, as contrast to waxes that lack glycerin in their structure [4]. Natural ester oils have good physical characteristics such as color, cloud point, pour point, flash point, ash content, specific gravity, kinematic viscosity, and good chemical characteristics such as iodine value, acid value, free fatty acid, peroxide value, rancidity and Saponification value [9]. For any oil to be used as lubricating oil, it must have an average viscosity index [10]. Natural ester oils have high viscosity index [11]. Viscosity is also connected with the configuration of the double bonds (the *cis* configuration determines lower viscosity than the *trans* configuration) while the position of the double bonds along the hydrocarbon chain has less effect on viscosity [12]. Viscosity of the insulating fluid affects the ability to transfer heat by conduction. Conduction cooling is the main heat removal mechanism in transformers and thus higher viscosity would be required to result in higher temperatures reduction within the transformer. However, the viscosity of an oil affect circulation of oil between the transformer conservator tank and the transformer tank itself, the lower the viscosity, the easier the oil circulates leading to improved heat transfer [13].

Natural ester oils may or may not be edible; examples of inedible natural ester oils include processed linseed oil, tung oil and castor oil [8]. In this research work, inedible natural ester oils were used. Natural ester oils are composed of glycerin in their structure that makes them to serve as lubricants in electronics [9]. The structure of glycerin and triglyceride is as shown in the Figure 1 below.

(a) (b)

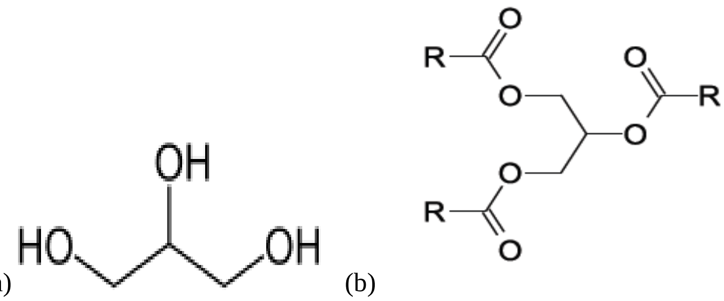

Figure 1: (a) Structure of glycerin and (b) Triglyceride

The water solubility in natural esters oils is around 15 times higher than that in mineral oil [9]. The presence of any little amount of water can cause electrical conductivity in insulating oil thereby making it inefficient. Among the types of natural ester oils considered for best potential application as dielectric insulating fluid in transformers are palm oil and coconut oil [1]. Insulating liquids are used to provide electrical insulation and thermal cooling in high voltage power equipment such as transformer (power, distribution, traction etc.), circuit breaker, capacitor, cable, bushing and load tap changer e.t.c. [14]. This research concentrates only on transformers and capacitor. In Nigeria transformer is one of the important electromagnetic devices used to step down electricity from kV to 240 volts. These 240 volts are use directly by consumers in industries, market places and homes.

Luffa (‘soso’ in Hausa, ‘Kankan’ in Yoruba and ‘Asisa’ in Igbo in Nigeria) is a plant from the cucumber family grown for its multipurpose fruit in many tropical countries [15]. It is an annual climbing or trailing herbaceous species that can be 15 m long [15].

The phytochemicals analysis of the extracts of *Luffa agyptiaca* indicated the presence of some secondary metabolites include cardiac glycosides, flavonoids, saponinis and tannins [16]. It is reported that on a dry matter basis, the oil content of luffa agyptiaca is 19-25% of ground seeds [17].

Cassia tora (“Tafasaa” in Hausa, Nigeria) is a dicot legume known as sickle senna, sickle pod, tora, coffee pod, tovara, chakvad, thakarain malayalam and foetid cassia [18]. The percentage fatty acid composition of *Cassia tora* seed oil was found to be palmitic, 6.70 %; stearic, 7.56 %; lignoceric, 10.05 %; oleic, 39.55 %; and linoleic, 36.14 % [19].

Young leaves of *Cassia tora* can be cooked as a vegetable while the roasted seeds are a good substitute for coffee [18]. It is used as a natural pesticide in organic farms and its powder is most commonly used in the pet food industry [19]. Because of the availability of these plants as weed and other good physical and chemical properties it has more potential to serve in industrial, lubrication and insulation purposes.

Materials and Methods

Seed Sample Collection

Cassia tora seeds were obtained from Maiduguri road, Bauchi and *Luffa aegyptiaca* (Loofah gourd) seeds were collected from fencing of the Federal high court, teacher's street, Bauchi. The matured pods of the seeds were opened; seeds collected in a bowl, the seeds were dried in laboratory at room temperature. The samples were grinded/pulverized using with a blender. The pulverized samples were dried at room temperature for 72 hrs.

Oil Extraction: The oils were extracted using n-hexane in a soxhlet apparatus of 1000 ml size. The solvent was then evaporated from the oil using a rotary evaporator. The percentage oil yield calculated on dry matter bases as shown below;

$$\text{Percentage yield} = \frac{\text{weight of oil}}{\text{weight of sample on dry matter basis}} \times 100$$

Oils pre-processing

a. **Filtration:** All oil samples were fir,st pre-process by filtering three (3) times through a membrane filter with pore size of 0.22 μm in a Buckner filtration apparatus

Figure 2: Buckner Filtration Apparatus

b. **Drying:** All samples were dried for 48 hours in a temperature adjustable oven (Model GENLAB P8HC) at 85^{o}C.

Physiochemical Properties Determinations

Physiochemical properties of the oils; colour, moisture content, cloud point, pour point, viscosity, density, iodine value, free fatty acid, acidity, peroxide value, corrosive Sulphur, smoke point, flash point, fire point and biodegradability were determined using standard methods of the Association of Analytical Chemist (AOAC, 1990) [20]. All the analyses were carried out in triplicate.

Electrical Properties Determinations

Electrical properties of the oils; Dielectric breakdown voltage (DBV), relative permittivity, conductivity and electrical resistivity were determined using standard American standard for testing and material (ASTM) methods.

Results

The results of the physical, chemical and electrical properties of the ester oils are as shown in tables 1-3 below:

Table 1: Physical Properties of the Ester Oils

Test name	CTSO	LASO
Percentage Yield (%)	38.28	29.15
Colour	Yellow	Yellowish green
Presence of particles	Clear and bright	Clear
Moisture content (%)	4.01	4.17
Cloud point (^{0}C)	7	5
Pour point (^{0}C)	11	10

Density at 20 ^{0}C (g/ml)	0.89	0.91
Viscosity at 40^{0}C	7.51	10.50
at 100^{0}C	2.0	4.10
Specific gravity at 25 °C (J/ kg °C)	0.89	0.88
Smoke point (^{0}C)	210	220
Flash point (^{0}C)	220	231
Fire point (^{0}C)	243	250
Biodegradability	RB	RB

Table 2: Chemical Properties of the Ester Oils

Test name	CTSO	LASO
Iodine value (g iodine/100g of oil)	141	132
Free fatty acid (%)	9.01	10.45
Acidity (%) (mgKOH/g)	17.93	20.80
Peroxide value (Meq/kg)	220	278
Corrosive Sulphur	NC	NC

Table 3: Electrical Properties of Ester Oils

Test name	CTSO	LASO
DBV (kV) at 2.5mm gap	42	42.5
Oils DBV after 40days (kV)	40	42
Relative permittivity/ dielectric constant @25 ^{0}C	2.80	2.75

Discussion

The ester oils show higher percentage yield 29.15-38.28 %, this is believed to be because of the season in which the matured samples were collected from their various plants. The samples were carefully selected and collected immediately after raining season in November when the seeds were fully ripe. The ester oils also show brighter colours of the vegetable oil which is one of the requirement for oils that are used as insulating oil in transformer, turbine etc.

The presence of particle which cause a reduction in electrical properties of the ester oils, such as Dielectric breakdown voltage, was reduced by filtering the oil through a membrane filters with porosity of 0.22 µm. The moisture content of the oils, which is a property that describe the water content in the oils, was also reduce to minimum by drying and re-drying of the oils. The result shows a good moisture content which is required in insulating oils. The lower the moisture content in an oil the better its electrical properties. The results of pour point and cloud point in Table 1 shows that the oils can be good lubricators at temperature above 10 ^{o}C. This result also shows the oils can serve as insulating oils in transformer that work in an environment with temperatures above 10 ^{o}C. Viscosity of ester oil determine how easily oil can move or be pump through the working component, filter, and how quickly it drain back to an engine. In oil insulation in medium voltage equipment a lower viscosity is required. The results of viscosity in Table 1 is an indication that the oils can serve for the purpose of biodiesel and lubricating. The good specific gravity shown by the ester oils is an indication that in case of contamination by water, the water will settle at the bottom of any container or tank, which can be easily tap out. Therefore, they can both serve as transformer insulation oil.

For an oil to server as insulation oils a less flammable oil is required, the results of flash point and fire points in this research shows that the oils are less flammable as required by [10].The results of biodegradability of the ester oils shows that the ester oils are all readily biodegradable. It is also an indication that the ester oils are not persistence to the environment as compared to the crude oil base oils which are not readily biodegradable.

The iodine value of the ester oils in this research (Table 2) indicate that the oils are semidrying oil. Plant oils rich in polyunsatured fatty acids have a limited shelf life. In this research, work the results of the acid value and free fatty acid (Table 2) shows that the ester oils have higher acid and free fatty acid value and can be a very good lubricating and insulation agents. Acid value is an indicator of the edibility of oil and its suitability for industrial use [1]. The higher the acidity the lower the edibility of the oil. The results of the acidity show the oils are inedible. The peroxide value of oil state the level of deterioration on the ester oils. Lower peroxide value of ester oil indicates less exposure to oxidation by atmospheric oxygen [1], and the higher their oxidative stability. The results of the peroxide value of the ester oils in this research (Table 2) show that the oils have not been subjected to too much oxidation during extraction and storage and therefore can serve in Biodiesel production and insulation oil.

The results of corrosive Sulphur in Table 2 of this research show that all the ester oils do not contain corrosive Sulphur as required by NIS-IEC 60078-14 (2013), for an oil to be used as insulation oils. Since most electronic device, such as transformer, capacitor, turbine engines, etc, are manufactured with metal both in the body and in the windings.

The result of DBV in table 3 show that the ester oils used in this research have a DBV of higher than 35 kV which shows their can serve as insulation oils in electronic devices like transformers 33 kV rating with three phases, on load tap changer, stepdown distribution. All the ester oils in this research have reached the minimum DBV required by the NIS-IEC 60076-14 (2013). Therefore, the ester oils in this research can serve as insulation oils in transformers and capacitors. The results of the oil contamination due to tank leakage in Table 3 shows that there is a reduction in the DBV of the ester oil when they are exposed to atmospheric oxygen. The reduction in DBV of the ester oils may not be unconnected with the fact that ester oils undergo rancidification when in contact with atmospheric oxygen, which result in formation of moisture that reduces the insulation capabilities of the oils. Both for the purpose of lubrication and insulation the tanks of the devices and engines are seal from atmospheric oxygen

Relative permittivity is an ability of oils to store charge. The results of relative permittivity in in table 3 of this research shows that the ester oils can equally store the charge that other capacitor oils can store.

Conclusion

The good physiochemical and electrical properties exhibited by the ester oils shows that the oils can serve in some very wide potentials such as biodiesel production, transformer insulating oils, capacitor oils, in turbine engine and as a lubricator in steel casting.

References

[1]. Thien Yee Von, Norhafiz Azis, Jasronita Jasni, Mohd Zainal Abidin Ab Kadir, RobiahYunus, Mohd Taufiq Ishak and Zaini Yaakub, (2015). Evaluation on the Lightning Breakdown Voltages of Palm Oil and Coconut Oil under Non-Uniform Field at Small Gap Distances. *J ElectrEng Technol.* 11(1): 1921-718.

[2]. Honary, L. A. T., (2006). Biodegradable/Biobased Lubricants and Greases. Machinery Lubrication Magazine Issue No. 200109, Noria Corporation. www.oilmaintenance.com.

[3]. Howell, S., (2007). Promising Industrial Applications for Soybean Oil in the US. A conference paper presentation pp 43-70. USA.

[4]. Canakci, M., and Sanli, H., (2008). 'Biodiesel Production from Various Feedstocks' and Their Effects on the Fuel Properties'. *Journal of Industrial Microbiology Biot.*5 (35): 431-441.

[5]. Broekhuizen, P., Theodor, D., LeBlanch, K., and Ullmer, S., (2003). Lubrication in Inland and Coastal Water Activities. First edition, pp 2-50. A. A. Balkema Publishers, Tokyo.

[6]. Bertrand, Y., Hoang, L. C., (2004).' Vegetable oils as substitute for mineral insulating oils in medium-voltage equipment'. *Cigrepaper* D1-202.

[7]. Knothe, G., (2001). Historical Perspectives on Vegetable Oil- Based Fuels. International News on Fats, Oils and Related Materials- INFORM; 12(4): 1103-1110.

[8]. McShane, C., P., (2007) 'relative properties of new combustible-resistant vegetable oil-based dielectric coolants for distribution and power transformers'. *IEEE transformer on industrial application*. 37(4): 1132-1139, IEEE.

[9]. Martin, D., Wang, Z.D., Dyer, P., Darwin, A.W., James, I.R., (2007) "A Comparative Study of the Dielectric Strength of Ester Impregnated Cellulose for Use in Large Power Transformers", ICSD Winchester, UK.

[10]. Rycroft M, (2014). Vegetable oil as insulating fluid for transformers.*Electrical Transmission and Distribution*. 2014 edition, pp. 40.

[11]. Chindo, I.Y, Gushit, J.S., Olotu, P.N., Mugana, J., and Takbal, D.N., (2010). 'Comparism of the Quality Parameters of the Seed and Condiment Oil of Adansonia Digitata'. *Journal of American Science.*6 (12)990-994. (ISSN: 1545-1003). Downloaded from http://www.americanscience.org. May 20th 2016.

[12]. Knothe G., Steidley K.R. (2005): "Kinematic viscosity of biodiesel fuel components and related compounds. Influence of compound structure and comparison to petrodiesel fuel components", *fuel.* 84 (2005):1059-1065.

[13]. IEC 60296 (2003). Intenational Standard for mineral insulating oils. Third edition. Reference number IEC 60296:2003(E). available online at www.iec.ch

[14]. Darwin C., (2007). "The use of natural ester fluids in transformers" an online material. http://2011.matpost.org/ matpost2007/docs/MATPOST07_0036_paper. pdf.

[15]. Ichetaonye S. I., Madufor I. C., Yibowei M. E., Ichetaonye D. N. (2015). Physico-Mechanical Properties of *Luffa aegyptiaca* Fiber Reinforced Polymer Matrix Composite. *Open Journal of Composite Materials*. 5 (4): 110-117.

[16]. Mankilik M, Mikailu A., Mhya DH., (2014). Phytochemical Content and Antimicrobial Activities of Luffa Aegyptiaca (Sponge Gourd) Leaves Extracts International Journal of Research in Pharmacy and Biosciences. 1 (1): 1-4.

[17]. Abayeh O.M, Garba I.H, Adamu H.M and Abayeh O.J (2013). Quality Characteristics of *Luffa aegyptiaca* seed oil. *International Journal of Scientific & Engineering Research*. 4 (4): 11-16.

[18]. Wikipedia. *Cassia tora*. An online material Retrived November 2016. *Source:* https://en.wikipedia.org/wiki/cassia_tora

[19]. Tewari J.P., Dixit B.B., Mishra S.S., (1965). Fractionation of Fatty Acids of *Cassia tora* Seed Oil with Urea. *Journal of Pharmaceutical Sciences*. 54(6):923.

[20]. AOAC, 1990, Official Methods of Analysis, 15th edn., The Association of Official Analytical Chemists, Arlington, USA.