Extraction and characterization of bio lubricant properties of breadfruit oil as substitute for mineral oil lubrication of food machines

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ABSTRACT

The suitability of *Treculiaafricana* oil for lubrication was evaluated using the physio-chemical characteristics of extracted oil of roasted African breadfruit seeds. The physiochemical properties of the oil assessed were Relative Density, Acid value, Free fatty, Acid value, Saponification value, Iodine value, Peroxide value and Unsaponifiable matter. Standard methods of analysis were used for the evaluation of physico-chemical properties. Result of the physiochemical properties of the oil were 0.91 Relative density; 2.50 $mgkOHg^{-1}$, Acid value; 0.94% free fatty acid; 257.10 $\mu gKCHg^{-1}$, saponification value; 1.99gKg^{-1}, Unsaponifiable matter; 16.70wijs iodine value; 0.95$mgEkg^{-1}$ Peroxide value. These results compared favourably with mean industrial standards of 0.1 Total Acids; 1.25% free fatty acids, 1.0 $mEqkg^{-1}$ Peroxide value. Iodine (<111.0 wijs) Peroxide (<1.0 MEq) and Unsaponifiable matter (<19.0g) values of *Treculia africana* oil indicated premium quality above industrial specifications. Results revealed the high thermal operation range, applicability under extreme conditions, extended oil drain, improved lubrication with efficient flow characteristics of *Treculia africana* oil. *Treculia africana* seed oil is an important opportunity for exploitation in global bio-degradable oil lubricant solutions.

Keywords: Treculia africana oil, physico-chemicals, lubrication, machine, standard properties.

INTRODUCTION

Lubrication is an important factor in mechanical engineering. One of the cardinal objectives is to reduce friction, reduce or eliminate heat by heat transfers using fluidity, and extension of life of operating machines. In most mechanical operations, moving surfaces are in contact with each other during rotation, leading to friction, evolution of heat and machine wear. In order to manage these developments during engine operation lubricants are applied on the moving parts of engines. Lubricant comprised of base oil and additives [Igawrilow,2004] at the ratio of 90/10. Mineral oils from petroleum or other hydrocarbons and vegetable oils are the major forms of base oil used in the formulation of lubricants. Some of the risks of minerals oils include global warming, acid rains, formation of oxides through reactions with released carbon, nitrogen, sulphur with atmospheric oxygen [Habereder et. at., 2009].These pollutants and other metabolites of mineral oil degradation are detrimental to the environment and human health. In order to check these hazards, vegetable oils with certain advantages over mineral oil are seen as alternatives.

Vegetable oil do not present significant threat to the environment due to their biodegradability and low toxicity advantages. Other advantages of vegetable oil over mineral oils are high viscosity, high lubricity and renewability. The increased pollution awareness and environmental regulations in many developed nations, used for performance and recommendation by occupational experts imply increased demands for vegetable oil by these nations [Erhan,et.al.,2006]. Vegetable oils from soybean, coconuts, sunflower have been used successfully in industrial lubrication, hydraulic press, outboard engines and food machines [Erhan et. al.,2006;Kailis et.al.,2012].

Vegetable oils are less expensive, readily available but have poor oxidation and hydrolytic properties with high thermal sensitivity. Though these limitations exist the cost benefits analysis between mineral and vegetable oils and increased demand for vegetable oil necessitate an extended search for vegetable oils from lesser known sources to satisfy global demands for lubrication. Vegetable oil have long been used for lubrication with different results [Kailis et.al.,2012] These results are associated with some physicochemical properties of oil such as viscosity, viscosity index, relative density, acid value, iodine value, saponification value, peroxide value and unsaponifiable matter.

Treculia africana is a widely distributed food crop tree found in many tropical and subtropical regions of the world. The seeds is a rich source of vegetable oil. Its 9 – 11.50% lipid content [Nwabueze,2009] is higher than 4.78% corn, 1.17.% with minimal toxicity to humans [Enwere,1998] .Though not strictly an oil seed, the proliferation,toxicity and cost benefits of *Treculia africana* underscore the emphasis on its exploitation in lubricant formulations for food processing machines.

This study was aimed at determining the physicochemical properties of *Treculia africana* seed oil and evaluation of lubricating potentials of the oil based on the recommended industrial standards [ME,2006]for lubricating oils. The results of the study is envisaged to promote the utilization potentials and safety of *Treculia africana*oil within the expanding global frontiers of vegetable oils.

MATERIALS AND METHOD

African breadfruit (*Treculia africana*) dry seeds were purchased from Ubani market, Umuahia, Nigeria. The seeds were screened for contaminants such as stones, soils etc and stored in plastic bowls.

Treatment of sample

The dry seeds of African breadfruit were roasted using Fishers scientific oven(Model 635,Fishers scientific, Co UK). The roasted samples were cooled, dehulled, milled, labeled and stored in plastic bowls under ambient ($32\pm.2^0$C) condition for analyses.

Extraction of oil

Batches of twenty (20) gram of milled sample were added into thimbles plugged with cotton wool and placed in 250ml boiling flasks. Fifty(50) ml of solvent (Hexane with 40 – 60^0C boiling point) was added into the flasks. A soxhlet apparatus was set up and mixture refluxed for 6 hours. The thimbles were removed, hexane drained and flask containing oil cooled. Samples of the produced oil were used for physico-chemical properties assay.

Determination of relative density

The relative density of the oil was determined using the recommended methods of analysis of [AOAC,1990; James,1996].

Determination of acid value

Two (2 g) gram of oil was weighed in a tube and 2.5ml of alcohol added to it. The mixture was shaken. 2 drops of phenolphthalein solution was added, vigorously shaken and titrated with 0.1M NaOH until a persistent pink color was observed

$$\text{Acid value (Oleic)} = \frac{\text{Titre (ml)}}{\text{Weight of sample (g)}} \times \frac{5.61}{1}$$

Determination of Free Fatty Acid (FFA)

FFA content was derived from the Acid Value as

$$\text{FFA (oleic)} = \frac{\text{Acid value}}{2}$$

Determination of iodine value

Determination of iodine value employed the Wijis's method as described by [9]. Iodine value was calculated using the formula

$$\text{Iodine value} = \frac{[\text{Titration (blank)} - \text{Titration(sample)}]}{\text{Wt of sample}} \times 1.269$$

Determination of peroxide value

One (1.0) gram of oil was placed into a clean dry boiling tube with 1.0g potassium iodine, 25ml of solvent mixture (2.1 v/v glacial acetic chloroform) and boiled for 30 sec. The content was quickly poured into flask containing 30ml of water and titrated with 0.002N sodium thiosulphate ($Na_2S_2O_3$) using starch indicator

$$PV = \frac{S \times N \text{ (Vol. and Normality of } Na_2S_2O_3)}{\text{Weight of sample}} \times 100$$

Determination of saponification value

Twenty five (25) ml of alcohol potassium hydroxide solution was added to two gram of oil in conical flask attached with reflux condenser. The flask was heated over a water bath, 1ml of phenophtalein (1%) was added and titated against 0.5m HCl. Blank titration had no treatment.

$$\text{Saponifcation value} = \frac{[\text{Titre (blank)} - \text{Titre (sample)}]}{\text{Wt (g) of sample}} \times 28.05$$

Determination of unsaponifiable matter

Titration from saponification was neutralized with 1ml aqueous 3M potassium hydroxide and extracts obtained

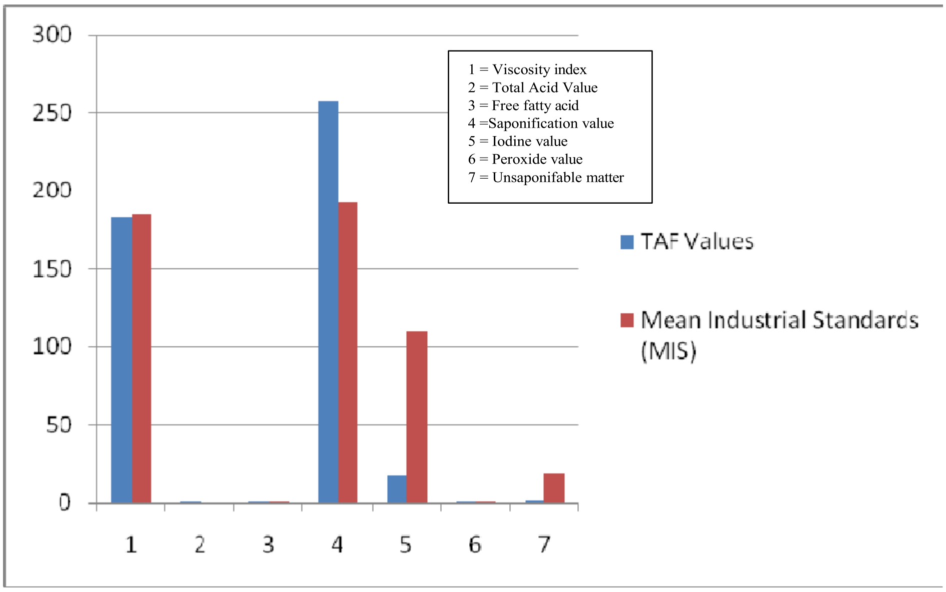

Figure 1. Comparative values of *Treculia africana* oil in standards and industrial standards.

Table 1. Physicochemical properties of *Treculiaafricana* oil

Parameters	Values
Relative Density (20^{0}C)	0.91
Acid value mgKOHg^{-1}	2.50
Free Fatty Acid (%)	0.94
Saponification value µgKCHg^{-1}	257.10
Unsaponifiable matter g Kg^{-1}	1.99
Iodine value wiijs	16.70
Peroxide values mEqKg^{-1}	0.95

with diethyl ether. The ether extract solvent was evaporated and residue in flask dried to constant weight.

Statistical analysis

Data of study was statistically analyzed using Statistical Package for Social Sciences(SPSS) for Analysis of Variance and the 2 tail T-test used to interpret the level of significance at $p<0.05$.

RESULTS AND DISCUSSION

Physicochemical properties of oil samples

The physicochemical characteristics of *Treculia africana* seed oil are shown on Table 1 and Table 2 summarizes the effects of modulated roasting on the evaluated parameters. The relative density (20^{0}C) of raw seeds oil was 0.91. The effect of temperature on Relative Density is shown on Table 2. High temperature roasting of *Treculia africana* seeds results to variations in Relative Density of 0.85 to 0.71. Increase in temperature directly reduces the Relative Density values of *Treculia* oil.

The acid value of *Treculia africana* oil raw seeds oil was 2.50 mgKOHg^{-1}, acid value and indicated stability to thermal treatments.

Free fatty acid value of raw processed oil was 0.94%. Extraction of oil from seeds at 120^{0}C, 140^{0}C, 160^{0}C, 180^{0}C and 200^{0}C resulted in free fatty acids of 0.60%, 0.52%, 0.51%, 0.41% and 0.33% respectively. The difference in values of free fatty acids at extreme temperature (120 – 200^{0}C) was 35.20%. At 0.94% the level of saturation of the oil in relation to industrial standard of 1.0-1.4 was high.

Saponifcated value of the control was 257.10 mgKCHkg-1. Application of heat through roasting increased saponification values to a range of 251.50 to 305.10 mgKCHg-1. Heat positively increased the saponification value of *Treculia africana* oil. This result is in agreement with the report of Onwuka,[2005] and Purseglove [1991] that associated increases in

Table 2. Effects of variation of roasting temperature on physicochemical properties of oil.

Parameters	Temperature (^{0}C)				
	120	**140**	**160**	**180**	**200**
Relative Density (20^{0}C)	0.85	0.82	0.77	0.71	0.66
Acid value mgKOHg^{-1}	2.35	2.33	1.90	1.18	1.04
Free Fatty Acid (%)	0.60	0.52	0.51	0.41	0.33
Saponification value µgKCHg^{-1}	257.50	265	269	290	305.10
Unsaponifiable matter g Kg^{-1}	1.96	1.93	1.60	1.53	1.40
Iodine value wiijs	16.95	16.04	16.20	16.10	15.90
Peroxide values mEqKg^{-1}	0.95	0.78	0.60	0.58	0.44

Table 3. comparison of *Treculia africana* seed oil with Industrial standards for Base-oils

	Indices	Standard Values+
Viscosity index (20^{0}C)	183	170 – 200
Total acid value mgKOHg^{-1}	01.0	0 1 – 1.0
Free Fatty Acid/ Acid numbers %	0.94**	1.1 – 1.4
Saponification value mgKCHg^{-1}	257.10**	186 – 198
Iodine value wiij	16.70**	94 – 126
Peroxide value mEqKg^{-1}	0.95	1.0
Particles (Unsaponifiable matter) g Kg^{-1}	1.99**	19

+ Mechanical Engineering Team. USA.
** Denotes positive significant values of *Treculia* oil over industrial prescribed standards for lubricants

saponification value of oil to hydrolysis of glycosides content of processed seeds.

Iodine value, values of *Treculia africana* oil (Tables 1 and 2) indicated some heat stability in iodine value. The average iodine value is 16.32wijs.

Peroxide values of raw seed oil was 1.04 mEq, 0.95 mEq, 0.78 mEq, 0.60 mEq, 0.58 mEq and 0.44 mEq for oils of seeds roasted at 120^{0}C, 140^{0}C, 160^{0}C, 180^{0}C and 200^{0}C respectively.

The average value for unsaponifiable matter was 1.74gKg^{-1}.

Analysis of Table 2 revealed heat stability of some physicochemical properties of *Treculia africana* oil. Roasting of the seeds at temperature greater than 180^{0}C decreased acid value, fatty acids, peroxide value by about 50% of the raw seed values.

Lubricating potentials of *treculia Africana* seed oil

The potential attributes of *Treculia africana* oil in comparison with industrial standards are presented on Table 3.

The Relative density of the seed oil was 0.91 which decreased to 0.66 at elevated temperature of 200^{0}C.

Viscosity is the most important parameter for lubrication oil. Viscosity of the base oil defines the formation and integrity of the boundary film formed at friction surface. The thickness of the boundary film predicts both lubrication and heat transfer rates [Fellows,2000]. The viscosity of oil is influenced by relative density. Relative density also defines the extent of unsaturation of fatty acids and directly influences the viscosity of oil. Suitable viscosity of oil should not change with temperature changes. Relative density properties of *Treculia africana* oil, as observed is below the maximum (200) standard at 20^{0}C viscosity (170 – 200) for base oil [ME,2006]. The mid viscosity index negates the utilization of the oil as multigrade base oil in a variety of application requiring higher viscosity indices [Igawrilow,2004].

The acid value of raw seeds oil was 2.50 mgKOH/g. Acid value should be low for best lubrication results[Adhavaraya,2004] .High acid values lead to oxidation and formation of gums and sludge. Total acid value specifications vary between 01 to 1.00 over a wide range of application. Heat treatment reduces the acid value to about 1.18. Thus the value is within the standards prescribed for base oil [ME,2006;Meza,2006] and confers stability to decomposition by high temperature during lubrication of machines [Xu et.al.,2014].

The free fatty acid content of the oil was 0.94% which was reduced to 0.33% at extreme (20^{0}C) temperature. The specification for acid number ranged between 1.1 to 1.4. Oil from *Treculia africana* seeds satisfied the free fatty acid requirement for base oil. Free fatty acid and acid value measure the decomposition potential of oil[2006]. Combined analysis of acid value and fatty acids showed decomposition stability of *Treculia africana* oil over a wide lubrication application [Xu et.al.,2014]

The undesirable high level of saturation of the raw seed oil was improved by heat. High degree of saturation promotes the formation of crystals structure leading to the interlocking of triacy glycerol crystals at lower temperature [Igawrilow et.al,2004;Kailis et.al.,2012; Hsu,et.al.,2014]which represents a minus for most vegetable oil used for lubrication.

Free fatty acid, iodine value and unsaponifiable matter were the physicochemical factors that exhibited the best heat facilitation in machine lubrication. *Treculia africana* oil is adjudged to be superior to (Fig 1) mineral oils within the industry specified standards for bio-degradable oils.

Results showed that *Treculia africana* oil has a high (257µKCHg^{-1}) saponification value, which increased with increase in temperature. The standard specification for saponification value for base oil is between 186 – 198 µgKCHg^{-1} [ME,2006]]. High saponification value is a risk factor for the formation of scums by the addition of certain Pour point reducing additives [Habereder et.al.,2009]. The risk factor of high saponification value could be checked by the low unsaponifiable matter (1.53 to 1.99 g Kg^{-1}) value the oil. The high purity of the oil implies efficient heat transfer efficiency and how deposit formation with little need for additives.

The specific standard range for iodine value for base oil is 94 – 126 wiijs. The iodine value of *Treculia africana* seed was 16.70 wiijs. Combined with the peroxide value of 0.95 mEq Kg-1 *Treculia africana* seed oil as lubricant should be very stable to hydrolytic changes [Fox and Stachowiak,2007]. These low indices for iodine and peroxide imply high stability of the oil to temperature induced decomposition and facilitation of low pour point of *Treculia africana* oil during lubrication [Xu et.al.,2014]

CONCLUSION

Treculia africana oil possesses good thermal and oxidation properties and high level of purity essential for premiumlubrication of machines. The evaluated physicochemical properties of *Treculia africana*oil satisfied most of the industrial standards for base oil lubrication. The readily available *Treculia africana*crop points to potentially important contribution of its oil to global stock of bio-lubricants

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