



EVALUATION OF YELLOW OLEANDER (*thevetia peruviana*) SEED OIL BY BASIC PHYSICOCHEMICAL PROPERTIES FOR METAL CUTTING LUBRICATION USAGE

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Abstract

Development of cutting fluids from the widely available material resources requires meticulous tests and analyses to ensure that, in the first place, these fluids meet basic properties in their pure or modified forms. Research is now being focused on plant extracts for use in metal cutting due to their generally excellent environmental friendliness and lower risk to personnel's health. Yellow Oleander (YO) seed oil as a vegetable oil can be environmentally friendly and sustainably abundantly extracted in many parts of the world, like Nigeria. The potential of using the seed oil for metal cutting lubrication or the development of metal cutting lubricants has been rudimentarily investigated through analyses of its acid value, iodine value, saponification value, peroxide value, refractive index, and percentage foam capacity relative to the commonly and widely used soluble oil. Results show that YO seed oil has acid value, iodine value, peroxide value, saponification value, refractive index, and percentage foam capacities of 31.23 mgKOH/g, 62.82 mg Iodine/g, 12.61 mgKOH/g, 213.01 mgKOH/g, 1.310, and 1.2%, respectively. The corresponding results obtained with soluble oil were 20.10 mgKOH/g, 18.10 mg Iodine/g, 11.23061 mgKOH/g, 223.08 mgKOH/g, 1.458, and 1.51%, respectively. Comparative analyses of the results indicate that: YO seed oil can be a little more corrosive than soluble oil but insignificant in corrosivity to deteriorate components in contact with it; YO seed oil can be non-drying and non-rancid like soluble oil but with the better of the two from soluble oil; YO seed oil is non-oxidizing like soluble oil, so its lubricating ability and cooling efficiency would not significantly reduce in usage; and YO seed oil can have comparable consistency to soluble oil but with better biodegradability than soluble oil.

Keywords— Assessment, availability extents, desirable properties, indexes, metal cutting lubricants, plant extracts, Yellow oleander plant.

Introduction

A variety of cutting fluids have been developed to assist in the machining of various metals such as steel and aluminum by turning, boring, drilling, grinding, and other methods, with ongoing searches for better ones in terms of properties, costs, mechanical performance, and environmental and personnel health effects because there is no all-purpose cutting fluid. Water, straight oils, synthetic fluids, and semi-synthetic fluids are all utilized in cutting fluids, although soluble oils are the largest, most frequently used, and most commonly used form. Soluble oils are commonly used on general-purpose machines that only require mild cutting operations and low metal removal rates (Sales *et al.*, 2001; Isik, 2013; Mbishida *et al.*, 2018). However, issues with the use of soluble oils and all fluids made from mineral oils include negative effects on habitat biological life, non-biodegradability issues, soil contamination, and health effects on personnel, such as toxic substances from the oil mist penetrating the

human body through the respiratory system and skin, which can cause adverse changes in the lungs, liver, kidney, adrenal glands, and heart, to name a few (Olisakwe *et al.*, 2011; Naje *et al.*, 2021; Nasirudeen *et al.*, 2019). Due to all these and other undesirable characteristics of mineral oils or their formulations as cutting fluids, research is now focusing on the use of plant extracts as cutting fluids because of their overall excellent environmental friendliness and lower risk to personnel health (Adler *et al.*, 2006; Shah *et al.*, 2014). Development of cutting fluids from widely available resources, however, requires painstaking engineering tests and analyses to ensure that, in the first place, the fluids in pure or modified form meet properties such as non-toxicity, biodegradability, non-foaming, non-smokiness, non-stickiness, non-corrosiveness, non-drying, high resistance to oxidation, non-rancidity, atmospheric stability, consistency, and perennial high quality. Acid value, iodine value, saponification value, peroxide value, refractive index, and percentage foam

capacity are commonly used physicochemical properties for evaluating the rudimentary quality of fluids for metal cutting applications (Jayeoye *et al.*, 2015).

The creation of fatty acids occurs when oil is hydrolyzed or oxidized by air moisture, resulting in acidity. The number of milligrams of potassium hydroxide required to neutralize the free fatty acids in 1.0 g of oil is known as the acid value of the oil. Greater emulsification of cutting fluid with stronger corrosion tendencies is facilitated by higher acid values (Sharma and Jain, 2015). The saponification value of oil is the mass of potassium hydroxide in milligrams required to neutralize fatty acids obtained by complete hydrolysis of one gram of the oil. Higher saponification values of oil indicate that the oil has a shorter fatty acid chain and a lower molecular weight, while a low saponification value of oil indicates that the oil has a longer fatty acid chain and a higher molecular weight (Bart *et al.*, 2010; Jayeoye *et al.*, 2015). 'A cutting fluid's peroxide value is used to indicate the extent to which the fluid can be or has been damaged by free radicals that can give rise to aldehydes and ketones that can cause it to smell musty and rancid.' In this regard, cutting fluids with lower peroxide values are better (Jayeoye *et al.*, 2015). The iodine value of oil is the mass of iodine in grams that is required to saturate fatty acids present in an oil sample of mass of 100 g. The iodine value is frequently used to determine the extent of un-saturation in cutting oil. Un-saturation in oil occurs in the form of double bonds that are reactive to iodine compounds. A higher iodine value of oil indicates a greater number of C–C chemical bonds present in the oil, resulting in more un-saturation and susceptibility to oxidation drying (Jayeoye *et al.*, 2015; Ebong, 2019). The refractive index of oil is the ratio of the speed of light in a vacuum to the speed of light in the oil. For practical measurements, the scales of standard instruments indicate refractive indexes with respect to air rather than vacuum. Oil's refractive index is a particular property that each type of oil has within specified limits. It is linked to the degree of unsaturation, but it is also influenced by other factors such as the presence of free fatty acids, oxidation, and heat treatment (Clark *et al.*, 2021). Foaming is an undesired effect that can occur in metal cutting fluid as a result of microscopic air bubbles collecting and accumulating on the fluid's surface. This can cause severe oil oxidation, decreased lubricating ability and cooling efficiency, increased cavitation corrosivity, deterioration of the machined surface, and hydraulic failure of the oil-containing system. Many factors can cause oil to foam, including impurities such as water, grease, and particles; mechanical difficulties that produce excessive aeration of the oil; and incorrect amounts and types of additives in the oil (Acculube.com, 2021).

Yellow Oleander (YO) seed is an evergreen shrub or small tree that grows 3–8 meters tall

with a short bole. It is relatively biodegradable and is abundantly available in many parts of the world. The plant has been widely used in folk medicine in Central and South America and Southeast Asia. It is also a household remedy for several ailments in the Philippines and India. It grows widely but is sometimes cultivated for medicinal use and sold in local markets or grown as an ornamental hedge, being valued for its floral display. The oil extracted from YO seed has been in study for over ten years now for various uses in engineering, such as an environmentally friendly biodiesel alternative to petroleum diesel, which has adverse environmental effects. YO is a small tree or shrub with yellow, bell-shaped flowers. The Mediterranean regions of Southern Europe and South-West Asia are home to YO (Gajrani and Sankar, 2014). The plant grows naturally in Nigeria and can be grown for horticultural purposes in almost every part of the country due to its lovely flowering habit. It blooms all year, but most prominently in the summer. The plant grows quickly and blooms all year, with fruiting taking one to three years. To thrive, the plant requires a slightly acidic or alkaline soil pH of 6.6-7.5 or 7.6-7.8. The plant's seed has around 60% oil, while its defatted cake contains about 37% protein.

The significance of the YO plant has mostly been based on clinical, toxicological, and pharmacological considerations (Gajrani and Sankar, 2014; Sharma and Sharma, 2014). YO plants can be grown in arid zones as well as in higher rainfall zones and even on land with thin soil cover. It can be a good plantation material for eco-restoration in all types of wasteland. It grows readily from plant cuttings or seeds up to a height of 3–4 m. However, YO suffers from certain limiting factors that need to be known while dealing with it. These factors are its inability to grow on water-logged lands and its high toxicity through large amounts of inhalation or consumption (Everest *et al.*, 2005).

The object of this research paper is to present a rudimentary assessment of the suitability level of YO seed oil for use as a metal cutting lubricant or the development of metal cutting lubricants through analyses of its acid value, iodine value, saponification value, peroxide value, refractive index, and percentage foam capacity relative to the conventionally used soluble oil.

Materials and Methods

Materials

The materials used in the research were extracted YO seeds; ethanol; and Mobilcut 100 commercial soluble oil, which was purchased and mixed with water in accordance with the manufacturer's specifications for cutting various ferrous and non-ferrous metals in the production workshop of the Department of Mechanical Engineering at the Nigerian Defence Academy, Kaduna, Nigeria.

The facilities used include: a very accurate weighing balance with a sensitivity of 0.001 g, beakers of various sizes, a spatula, a Soxhlet oil extractor together with the extraction thimble and heating mantle, a round bottom flask, and an Abbey refractometer.

Extraction of the YO Seed Oil

The ripe fruit of YO seed was handpicked around Nuhu Bamalli Polytechnic and Barewa College in Zaria, Kaduna State, Nigeria, and allowed to dry. The fruit seeds were manually separated from the fruits. The oil was extracted from the seeds using the Soxhlet extraction technique, which is a higher-yielding, quicker, and less expensive technique. The seeds were first dried and ground into a paste using a grinding

stone. The resulting paste from the seeds was as shown in Figure 1. A filter paper was folded into a thimble shape and placed in the holder for the extraction thimble. After inserting the thimble into the Soxhlet extractor, 250 ml of petroleum ether was added to the paste using a glass funnel and heated by putting it on the extractor's heating mantle. Water was permitted to flow continuously from the inlet into the condenser. In the condenser, the vapor was gradually cooled and collected in the thimble. This was done until the solvent turned colorless, signaling that the extraction was finished. Figure 2 shows how a mixture of petroleum ether and oil was heated to facilitate evaporation and collection of the petroleum ether in the condenser, while Figure 3 shows how the oil was left at the bottom of the flask. 10 liters of oil were extracted.

A portion of the produced YO seed paste in a container



Figure 1: The ground paste of YO seeds



Figure 2: The heating mantle

The extracted YO seed oil in a glass container



Figure 3: Part of the processed YO seed oil

Determination of the Physicochemical Properties of YO Seed Oil and Soluble Oil

The acid value (AV) of the YO seed oil and then that of soluble oil was calculated using the standard method of the American Oil Chemists Society (AOCS) (AOCS Cd 3d-63, 2017). To begin, 125 mL of toluene and isopropyl alcohol reagents were measured and poured into a 500-mL flask using graduated laboratory cylinders. A syringe was used to draw 2 mL of 1 percent phenolphthalein in isopropyl alcohol and discharge it into the mixture, which was then agitated for about 10 seconds to homogenize the mixture. The initial neutralization was achieved in this way. A mL of 0.1 mL-1 KOH solution was gradually added to the glass container with a burette until a pink color appeared and remained for 30 seconds. A 10g-oil sample was pipetted into the solution, and 1 mL of KOH solution was titrated drop by drop through the burette while vigorously shaking the flask. The titration endpoint was indicated by a consistent pink color that lasted at least 30 seconds. Equation 1 was used to evaluate the AV. For more accurate results, the method was repeated three times for each oil type, with the average value obtained in each case and reported as the AV of the oil (AOCS, 2017; Zhang *et al.*, 2019).

$$AV = \frac{(A - B) \times C \times 56.1}{M} \text{ (mgKOH)g}^{-1} \quad (1)$$

Where: A was the required KOH solution in mL for the oil sample titration, B was the required KOH solution in mL for the blank solvent titration, and C was the molarity of the KOH solution, which was 0.1. M was the oil sample quantity (10g) used, and 56.1 g mol⁻¹ is the molecular weight of KOH.

The saponification values of the YO oil and soluble oil were determined in accordance with the AOCS method cd 3-25 (AOCS, 1993a). An oil sample of 2 g was first measured in a volumetric flask. After that, 25 mL of 0.1 mL of alcoholic KOH was drawn in a pipette and allowed to drain for about 60 seconds into the flask. The mixed sample was allowed to boil gradually and steadily for 45 minutes for proper saponification by connecting a condenser to the flask. The condenser and the flask were then cooled but not to the extent of gel formation. About 1 mL of distilled water was used to wash down the inside of the condenser. After disconnecting the condenser, 1 mL of phenolphthalein indicator was added to the mixture. The resulting solution was titrated with 0.5 mL-1 hydrochloric acid (HCL) until the pink color of the solution just disappeared. A blank determination was run concurrently with the sample. The saponification value (SV) of the oil was thence determined from Equation 2 (AOCS, 1993; Odoom and Edusei, 2015).

$$SV = \frac{56.1 \times (V_2 - V_1) \times N}{M} \quad (2)$$

where; N denoted the normality of the HCl used, V denoted the volumes in mL of the HCl used in the test and the blank, and M denoted the sample's mass in grams.

The AOCS method Cd 1-25 was used to determine the iodine value of the oil sample (AOCS, 1993b). An oil sample with a mass of 0.001 kg was determined using the technique and put into a 500 mL flask. To ensure full dissolution, 15mL of carbon tetrachloride was added to the oil sample in the flask and swirled. Using a pipette, 25mL of Wijs solution was dispensed into the flask containing the sample. To ensure complete mixing, the flask was swirled. The sample was then placed in the dark for 30 minutes at room temperature. The flask was removed from storage and 20 mL of 10% potassium iodide (KI) solution was added, followed by 150 mL of distilled water. The mixture was gradually titrated with a 0.1 mL⁻¹ thiosulfate (Na₂S₂O₃) solution, with constant and vigorous shaking until the yellow color had almost disappeared. A 1.5 mL volume of starch indicator solution was added and the titration was continued until the blue color disappeared. A blank determination was conducted simultaneously. The iodine value was then evaluated from Equation 3 (AOCS, 1993b; Odoom and Edusei, 2015).

$$\text{Iodine Value} = \frac{12.69 \times (V_2 - V_1) \times N}{M} \quad (3)$$

where; N is the thiosulphate solution's normalcy, V is the volume of thiosulphate solution used in the test, V is the volume of thiosulphate solution used in the blank, and M is the sample's mass.

A modified American Oil Chemists' Society standard method, Cd 8-53, was used to determine the peroxide values of the YO seed and soluble oils (AOCS, 1997). An oil sample of around 5 mL was deposited on a standard test paper made according to US Patent 4098575. A 10-ml amount of water was added to the paper after the determined oil quantity was gently placed on it.

By comparing the intensity of the blue color that appeared on the test paper with the intensities of standard colors of the paper which denoted various peroxide values of oils, the peroxide value of the test oil was determined (AOCS, 1997; Akinoso *et al.*, 2010).

The Abbes refractometer was used to estimate the refractive index of specific oil in laboratory daylight conditions, in accordance with the instrument's manual and the AOCS Cc 7-25 standard procedure for determining the refractive indexes of normal oils and liquid fats (AOCS, 2017). The refractometer's screw head was used to open the double prism. One of the prisms was filled with a drop of oil whose refractive index was to be determined, and the prisms were tightly closed by tightening their screw heads. The instrument was operated to circulate water inside it by its functional capability. After that, the instrument was permitted to stand for around two minutes to verify that the oil sample and the instrument were both at the same temperature at 30°C. The refractive index of each given oil sample was read directly on display from the

instrument's scale. An ethyl alcohol-soaked cotton pad was used to clean the prisms by properly wiping any oil left on them and allowing them to dry completely before the next test (AOCS, 2017).

The percentage foam capacity (%FC) of each separate oil was determined in accordance with the method used by Chandra et al (2015). By the method, a YO oil sample of 1.0 g was determined and added to 50 mL of distilled water that was maintained at 30.2 °C in a graduated test tube. The suspension was then

mixed and vigorously shaken for 5 minutes for any foaming. 30s after the whipping, a foam height was formed proportional to the volume

$$(\%FC) = \frac{(H_{AW} - H_{BW})}{H_{BW}} \quad (4)$$

Where H_{AW} was the height of the oil obtained after whipping, and H_{BW} was the height of the oil obtained before whipping.

Results and Discussion

The Physicochemical Properties

Results of the determined physicochemical properties of YO seed oil and soluble oil were as shown in Table 1.

Table 1: Determined Physicochemical Properties of YO Seed Oil and Soluble Oil

S/No	Parameter	YO seed oil	Soluble oil
1	Saponification value (mgKOH/g)	213.01	223.08
2	Acid value (mgKOH/g)	0.3123	0.2062
3	Peroxide value (mgKOH/g)	12.610	11.230
4	Iodine value (Wijs) (mg/g)	62.82	18.10
5	Foam Capacity (%)	1.21	1.53
6	Refractive index at 30°C	1.310	1.458

From Table 1, it can be seen that the saponification value of the YO seed oil is 213.01 mgKOH/g and is less than but in close range to the value of 223.08 mgKOH/g for soluble oil. According to Rahman *et al.* (2017), the saponification value is inversely proportional to the average molecular weight or chain length of fatty acids present in oil and generally ranges between 168 mg KOH/g and 179 mg KOH/g. The higher the saponification value of oil, the better the oil is as a cutting fluid. Thus, soluble oil can be a little better than YO seed oil as a cutting lubricant. Results of titrimetrically analyzed saponification values of selected rapeseed oils in raw and dried form have also been reported by Rahman *et al.* (2017). The report showed that the saponification values in mgKOH/g of raw forms of mustard (wild), mustard (hybrid), rai (wild), and rai (hybrid) were 171.1, 176.71, 172.22, and 178.56, respectively, while the saponification values for their fried forms were 174.65, 177.56, 173.91, and 179.52, respectively. Rahman *et al.* (2017) also found that canola oils have the lowest saponification values of 168.3 (raw) and 171.1 (fried) when compared to the corresponding values for mustard and rai, and canola oils' values significantly differed from those of all varieties of rapeseed, which indicates a better oil quality. From their results, the saponification value was found to be higher in fried samples than in raw form. From their obtained saponification values, it can be judged that YO seed oil and soluble oil are better materials for metal cutting lubrication than rapeseed.

Table 1 show that YO seed oil has an acid value of 0.3123 mg KOH/g and soluble oil has an acid value of 0.2062 mg KOH/g. According to Rahman *et al.* (2017), normal acid value of oil varies between the band of 0.36 and 1.5 mg KOH/g. Moreover, cutting fluids with acid values greater than 0.1 mg KOH/g are known to be corrosive to metals, with the possibility of forming gum and sludge in service applications (Sharma and Jain, 2015). The lower acid value of soluble oil puts it ahead of YO seed oil for metal cutting lubrication of common and corrodible metals like carbon steel. Acid values in mgKOH/g of some oils obtained by Vitz *et al.* (2020) are canola 0.071, maize 0.223, soya 0.6, virgin olive oil 6.6, used frying oil 31, and bee wax 17-36. From this, it is evident that both YO seed oil and soluble oil has very low acid values compared to olive oil and bee wax. The extent to which both YO seed and soluble oils can influence metallic corrosion is also seen to be insignificant considering their low acid values, and bee wax extract, with a much higher acid value, is not reportedly known to be detrimentally corrosive to metals like stainless steel but is inhibitory to its corrosion in an acid environment, according to Gapsari *et al.* (2015).

Oil with a high proportion of highly unsaturated fatty acids will rapidly absorb oxygen and oxidize when exposed to air, and the oxidized oil will create a hard film or skin. These oils are referred to as "dry oils," because they are often ineffective lubricants.

The iodine value of the oil is the physiochemical feature that defines its appropriateness for metal cutting in this case. Metal cutting oil with a lower iodine value is less drying and has better lubrication performance. Generally, the iodine values of oils range between 94 and 105 mg/g (Rahman *et al.*, 2017). Oils having relatively high iodine values of around 190 mg/g are classified as drying oils. Semi-drying oils have iodine levels of around 130 mg/g. Iodine levels in non-drying oils, such as olive oil used in soap production and food items, are typically less than 80 mg/g. Table 1 shows that YO seed oil, which has an iodine value of 62.82 mg/g, and soluble oil, which has an iodine value of 18.10 mg/g, are both non-drying oils because their iodine levels are all less than 80 mg/g. Accordingly, both YO seed oil and soluble oil cannot harden when exposed to air (Ebong, 2019). However, soluble oil is a better non-drying oil than YO seed oil, and other non-drying oils such as groundnut oil, olive oil, palm oil, and palm kernel oil with iodine values in mg/g of 86.00, 81.01, 53.91, and 36.74, respectively, as obtained by Ebong, (2019).

The peroxide value is a chemical method of determining the oxidative deterioration and rancidity of oils, notably metal cutting oils. A higher peroxide value indicates increased oxidative damage or the potential for oxidative deterioration. When the peroxide levels in oils reach 30 to 40 mgKOH/g, they are considered rancid (Godswill *et al.*, 2018). As indicated in Table 1, YO seed oil has a peroxide value of 12.610 milli-Eq./kg of oil, which is approximately equivalent to the value of 11.230 mgKOH/g for soluble oil. This shows that both oils have excellent peroxide values, which also indicates that they will not be rancid in use or storage.

A refractive index is used to express the distinct quality or identity of oil. It indicates the possible chances of rancidity developing in oil. The higher the refractive index of oil, the less biodegradable it is and the higher the chance of its spoilage due to oxidation. The refractive indexes of some house oils at room temperature as reported by Clark *et al.* (2021) are mineral oil (1.47-1.48), olive oil (1.44-1.47), soybean oil (1.47-1.48), palm oil (1.44-1.46), water (1.33), coconut oil (1.43-1.46), eucalyptus oil (1.46-1.47), castor oil (1.47-1.48), cod liver oil (1.47-1.48), ethyl alcohol (1.33), and corn oil (1.47-1.48) (Clark *et al.*, 2021). All these oils or fluids except water are also known to be biodegradable with better biodegradation properties than soluble oil (Clark *et al.*, 2021). From these backdrops, it can be seen that YO seed oil and soluble oil are comparable with one another and such other vegetable oils or fluids by the duo's refractive indexes of 1.310 and 1.458, respectively, as can be seen from Table 1. This indicates that YO seed oil as a vegetable would be better than soluble oil in biodegradation properties if used as a lubricant, but comparable to soluble oil in rancidity level (Clark *et al.*, 2021).

Foam is an undesirable but inevitable property of a cutting lubricant. The greater the presence of foaming and its stability in a cutting fluid, the less desirable the cutting fluid due to its ability to cause severe oil oxidation, decrease lubricating ability and cooling efficiency, and increase cavitation corrosivity, among other things (Acculube.com, 2021). From this property and fact, it is evident from Table 1, that the YO seed oil with a foam capacity of 1.21% can be a little better cutting lubricant than soluble oil with a foam capacity of 1.53%.

Conclusion

Extracted oil from Yellow Oleander (YO) seed has been rudimentarily investigated for metal cutting lubrication in terms of its acid value, iodine value, saponification value, peroxide value, refractive index, and percentage foam capacity relative to the commonly and widely used soluble oil. Results indicate that: YO seed oil is comparable in corrosivity level with soluble oil, so it can minimally deteriorate structures in contact with it; YO seed oil would be non-drying and non-rancid in usage or storage like soluble oil but less in these properties than soluble oil; YO seed oil is non-oxidizing like soluble oil, so its lubricating ability and cooling efficiency would be minimally reduced in usage; and YO seed oil can have comparable consistency to soluble oil but better biodegradability properties than soluble oil. Moreover, YO seed oil can have a sustainable and abundant extraction in many parts of the world, such as Nigeria, where the YO plant grows naturally in abundance or can be abundantly grown agriculturally, and cheap methods of extracting its seed oil are available. The presented information contributes to any consideration in the use of YO seed oil for metal cutting lubrication or as a component in developing metal cutting lubricants.

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