

CHARACTERISATION OF LESS-KNOWN VEGETABLE SEED OILS FOR POTENTIAL FORMULATION OF ECO-FRIENDLY METAL CUTTING FLUIDS

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Abstract: The study was designed to survey the phyto-chemistry, physicochemical and lubricant properties of *Magnifera indica*, *Jatropha curcas* and *Citrullus lanatus* seed oils with the aim of establishing viable parameters for the formulation of a metal cutting fluid. Six litres of vegetable oils were extracted from each of watermelon, jatropha and mango seeds using chemical method. Gas Chromatographic-Mass spectrometric analysis of the extracted seed oils revealed the presence of hexadecanoic acid, 9,12-octadecadienoic acid, cis-vaccenic acid, 1H-indole, cyclopropane, 3-pentadecyl phenol, squalene and 2,6,10,14,18,22-tetracosahexaene. The established physicochemical and lubricant data were oil yield (12.5-54.0%), pH (6.5-9.3), specific gravity (0.833-0.893), refractive index at 20°C (1.4630-2.3000), pour point (5-36°C), flash point (158-178°C), fire point (167-190°C), cloud point (8-39°C), relative density (0.846-0.919 g/cm³), acid value (2.89-5.22 mg KOH/g), saponification value (183-205), iodine value (45.9-104 mg iodine/g), peroxide value (1.35-10.9 mg/g oil), congealing temperature (2-32°C), kinematic and dynamic viscosities between 40-100°C (16.8-39.6 cP) and (17.061-36.400 cP), respectively and viscosity index (170-277). Based on the study, the oil extracts are suitable for a novel formulation of a metal cutting fluid in comparison with available mineral oils.

Keywords: Watermelon oil, Jatropha oil, Mango oil, Lubricant properties, Metal cutting fluids

1. INTRODUCTION

Metal cutting fluids (MWFs) are substances that are introduced between two moving surfaces (i.e. work piece and cutting tool) to reduce friction and wear, thus improving tool life and surface finish of the material being machined. Metal cutting fluids also reduce forces and energy consumption, cool the cutting zone, wash away the chips, and protect the newly machined surfaces from environmental corrosion (Serope, 1997). Approximately 85% of metal cutting fluids being used around the world are mineral based metal cutting fluids (Loredana, 2008). Mineral based metal cutting fluids provide numerous advantages but suffer from serious drawbacks of health and environmental problems. After utilisation, the metal cutting fluids become less effective due to their thermal degradation and contamination by substances in suspension therefore they must be replaced periodically, generating a waste stream called spent cutting oil (Sulaymon and Thuaban, 2010). Generally, spent metal cutting fluids contain tramp oils (adulterant hydraulic and lubricating oil from the machine), greases, biocides, metal fines, other components of original emulsified oil and the products of their degradation. If the spent metal cutting fluids are not well managed, they can appear as environmentally hazardous waste oil. The use of vegetable based metal working fluids is one of the major research and development themes in the manufacturing sector in recent years due to the challenges faced by the use of mineral based metal cutting fluids. Interests in vegetable oil as metal cutting fluids are growing greatly. Some of the promising vegetable oils that have been used in previous researches are sunflower oil (Ansari and kotiveerachary, 2013), canola oil (Krishna et al, 2010), mustard oil (Saleem et al, 2013), rapeseed oil (Itoigawa et al, 2006), coconut oil (Ojolo et al, 2008), palm kernel oil (Ojolo and Ohunakin, 2011), shear butter oil and groundnut oil (Ojolo et al, 2008), cottonseed oil (Lawal et al, 2014), palm oil (Revankar et al 2014), Soybean oil (Shaikh and Sidhu, 2014). The performance of these vegetable oils proves that they are viable for machining operations. Many investigations are still ongoing to develop new vegetable oil based metal cutting fluids from various seeds that are available around the world. Also, as the demand for edible vegetable oils has been on the increase in recent times, production of metal cutting

fluids from edible oils would lead to competition with food grade and industrial oils. Moreover, these oils could be more expensive to be used as bio-lubricant. Hence, more research needs to be carried out on less-known vegetable seed oils which are considered as economically viable sources for the production of bio-lubricant. The study was designed to survey the phytochemical, physicochemical and lubricity properties of *Magnifera indica* (Mango), *Jatropha curcas* (Jatropha) and *Citrullus lanatus* (Watermelon) seed oils with the aim of establishing viable parameters for the formulation of metal cutting fluid.

2. EXPERIMENTAL

2.1. Seeds Collection

The three seeds considered are shown in Fig. 1. Sampling of the different seeds was carried out as follows:

2.1.1. Watermelon Seeds

Watermelon Seeds was purchased dried at Arewa market in Kebbi State, Northern part of Nigeria. The total quantity of seeds purchased was 180 kg. The seeds were ground on the mechanical mill without removing the shell cover.

2.1.2. Jatropha Seeds

Jatropha Seeds were purchased at Ojoo Market, Ibadan, Oyo State, Nigeria. The seeds were bought dried and unshelled manually with pestle. Further drying was carried out in the shade before ground on the mechanical mill.

2.1.3. Mango Seeds

About 170 kg was collected from a Fruit Juice Company in Ibadan, Oyo State, in the South Western part of Nigeria. The seeds were unshelled. The kernels obtained from the seeds were properly ground using mechanical mill.

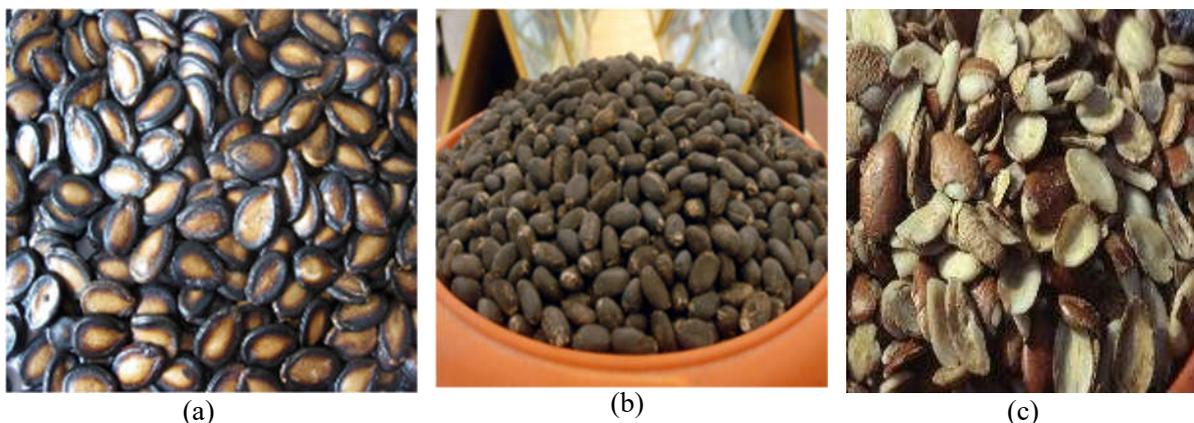


Fig. 1. Seed samples collected for experimentation (a) watermelon seeds (b) jatropha seeds (c) mango seeds

2.2. Extraction of Seed Oils

Seed oils extraction was carried out by chemical means according to AOAC (1975) standard. Crude oil extracts were extracted using 5 liters sized round bottom flask, soxhlet apparatus and analytical grade n-hexane of boiling range between 40-60 °C. The oils obtained were weighed; the yields calculated, labeled and stored appropriately at room temperature for further studies.

2.3. Characterisation of Crude Oil Extracts

Crude oil extracts were characterised to identify physiochemical, phyto-chemistry, and lubricity related properties of watermelon, jatropha and mango seed oils. This was carried out with the aim of establishing viable parameters for the formulation of metal cutting fluids. Several tests were carried out on the crude oils of the samples extracted.

2.3.1. Physio-chemical Characterisation of Crude Oils Extract

The tests determined are oil pH, relative density, oil yield, viscosity (kinematic and dynamic), specific gravity, refractive index, pour point, flash point, fire point, cloud point, acid value, saponification value, iodine value, peroxide value, congealing temperature, appearance at room temperature, oil colour and odour.. Some relevant equations of some measured parameters are given from equation (1) to (5).

2.3.1.1. Determination of pH

The pH of crude oil extracts was carried out using a handheld pH meter at room temperature.

2.3.1.2. Determination of Specific Gravity

The evaluation of specific gravity of the extracted oils was done by using a specific gravity bottle relative to that of distilled water at room temperature.

2.3.1.3. Determination of Acid Value

The acid value of the extracted oil was carried out in triplicate with procedure adopted from (AOAC, 1984) and evaluated using the equation (1):

$$\text{Acid value} = \frac{56.1MV}{W} \quad (1)$$

Where

M = molarity of KOH (M), V = volume of KOH (mL), and W = weight of sample

2.3.1.4. Determination of Saponification Value

The saponification value of the extracted oils was carried out in triplicate with procedure adopted from (AOAC, 1984) and evaluated using the equation (2):

$$\text{Saponification value} = \frac{56.1 M(V_0 - V_i)}{W} \quad (2)$$

Where

M = molarity of HCL (M), V₀ = volume of the blank solution (mL), and W = weight of the sample (g)

2.3.1.5. Determination of Iodine Value

The iodine value of the extracted oils was carried out in triplicate with procedure adopted from (AOAC, 2006) and evaluated using the equation (3):

$$\text{Iodine value} = \frac{12.69M(B-S)}{W} \quad (3)$$

Where

B = blank titre volume (mL), S = sample titre volume (mL), M = molarity of sodium thiosulphate used (M), W = weight of sample (g)

2.3.1.6. Determination of Peroxide Value

The peroxide value of the extracted oils was carried out in triplicate with procedure adopted from (AOAC, 1984) and evaluated using equation (4):

$$\text{Peroxide value} = \frac{1000(V_0 - V_i)}{W} \quad (4)$$

Where V₀ = sample titre volume of thiosulphate (mL), V_i = blank titre volume of thiosulphate (mL), and M = molarity of thiosulphate (M).

2.3.1.7 Determination of Kinematic Viscosity at 40°C and 100°C

Oswald kinematic viscometer was employed in the determination of the kinematic viscosity in the temperature range of 40-100°C and evaluated using the relationship in equation (5):

$$\eta = Adt - \frac{Bd}{t} \quad (5)$$

Where

D = viscosity in centipoises (cP), A, B are constant, d = density in g/cm³, t = time in seconds.

2.3.2. Phytochemical Characterisation of Crude Oils Extract

Oils were extracted, characterised for their functional moieties and phytoconstituents using standard methods. Tests conducted under this process include; (i) Fourier Transform Infra-red (FT-IR) and (ii) Gas Chromatography and Mass Spectra (GC-MS).

2.3.2.1. Fourier Transform Infra-red Analysis

IR spectra of oils were obtained using a FT-IR Perkin Elmer Spectrum, in the range 4000 – 400 cm^{-1} . The resolution was eight and two scans.

2.3.2.2. Gas Chromatography Coupled Mass Spectrometry (GC-MS) Analysis

Samples of oils were separated into their chemical constitutions using a coupled 7890A Agilent Technology GC system with the following column characteristics: HP5MS, 30 m \times 0.320 mm, 0.25 μm thickness, a helium carrier gas with a flow rate of 2.5 mL/min. The column temperature was programmed in the range 80 – 280°C at the rate of 10°C/min. The temperatures of both splitless injector and detector were maintained at 250 and 200°C respectively. The coupled MS system (5975C model, Agilent Technology) was set using a mass selective detector. Identifications of isolated compounds were done by matching the peaks computer Wiley MS libraries and validated by comparing mass spectra with the ones in literature (Brillo and Selvakymari, 2006).

2.3.3. Lubricity Related Properties Characterisation of Crude Oils Extract

2.3.3.1 Determination of Pour Point

ASTM D5853 standard using Stanhope Seta Cloud and Pour Point KT16 8AP Equipment pour was used to determine the pour point of the oil samples.

2.3.3.2. Determination of Flash Point

The flashpoint value was determined using ASTM D93 standard using Cusson technology Manchester M71RH UK electrically heated Pensky Martens serial number P5656/114.

2.3.3.3. Determination of Fire Point

The fire point was evaluated using Pensky Marten's set up and according to ASTM method.

2.3.3.4. Determination of Cloud Point

The cloud points of the oil samples were determined in accordance to ASTM D2500 by using Stanhope Seta Cloud and Pour Point KT16 8AP Equipment.

3.0. RESULTS AND DISCUSSION

3.1. Physicochemical Properties

The physicochemical properties of the oil extracts from watermelon, jatropha and mango oils are shown in Table 1. Colour of the oil seeds are different i.e. watermelon (pale yellow), jatropha (clear yellow), and mango (brown yellow). The condition of the oil extracts at room temperature was generally liquid, except for mango oil extract, which was a semi solid soft fat, a similar observation was reported by Jeyarani et al, (2015). The semi soft solid fat state of mango oil will make it difficult to be used as lubricant.

Oil yield from watermelon and jatropha can be considered economical for commercial production of metal cutting fluids in Nigeria. The oil content in watermelon and jatropha seeds was observed to be 54% and 46% respectively by weight of their seeds. The oil yield of jatropha is similar to that by Pramanik, (2003) which ranges from 45 to 60% by weight of the kernel. That of mango seeds which was 12.5% by weight of its kernel is however very low to be considered as commercial metal cutting fluids, but its use may not be discouraged for machining trials. The fat content of mango seeds is comparable to the ones for some commercial vegetable oils like soybean which ranges from 11 to 25% (Aquino et al., 2013). Moreover,

soybean oil application for machining purpose has been used severally in literatures as metal cutting fluids even with it low oil yield content. The specific gravity of the oil extracts ranged from 0.833 to 0.893. These values are within the range of specific gravities reported for related vegetable oil extracts of some selected tropical seeds (Eze, 2012). The pH of the oil extracts ranges from 6.5 to 9.3. The pH values for watermelon and jatropha are far better than that of mango oil. The pH values less than 7.0 may tend to corrode metal during machining processes. Watermelon and jatropha oils are in the alkaline state while mango oil is acidic.

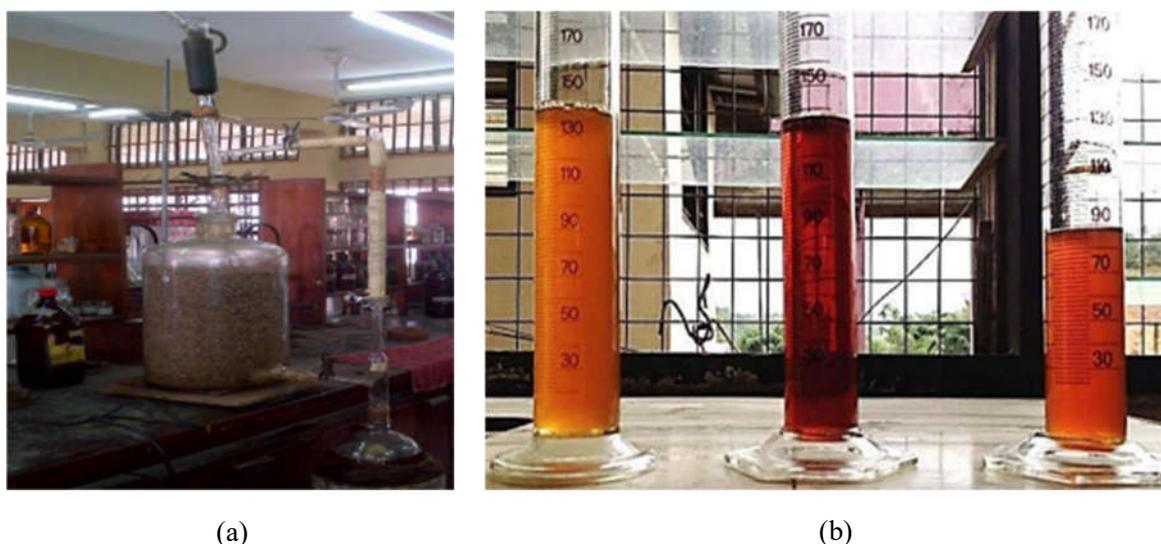


Fig. 2. Seeds oil extraction process (a) soxhlet extraction set-up in the laboratory (b) crude oil extracts
 The refractive index which is the ratio of the velocity of light in vacuum to the velocity of light in a medium is an indication of the level of saturation of the oil (Oderinde et al., 2009). The refractive index analysis shows that none of the oil extracts met the ASTM values that range from 1.476 to 1.479 (ASTM International, 2002). This could be attributed to the presence of some impurities and other components of the crude oil mixture such as the solvent used in the extraction. The refractive index values except for the case of mango oil were similar to that by (Eze, 2012) for pumpkin seed oil. Acid value represents free fatty acid content due to enzymatic activity, and is usually indicative of spoilage. Its maximum acceptable level is 4 mg KOH/g oil (CODEX Alimentarius Commission, 1982), for recommended international standards. Results obtained from this work indicate that the acid value of the oils as determined range from 2.89 mg KOH/g for mango to 5.22 mg KOH/g for jatropha (Table 1). Higher acid value is due to free fatty acid present in the oil. It is least for the mango oil. In addition, all the values fall within the range specified in literature. The acid value is a bit on the high side for jatropha (5.22 mg KOH/g oil). This acid value can be made fit by subjecting the oil to refining and this may also improve its quality for industrial purposes (Oderinde et al., 2009).

Table 1. Physicochemical properties of oil seed samples

Type of Oil Extract

Parameter Measured	Watermelon	Mango	Jatropha
Appearance at Room Temperature	Liquid Form	Semi Soft Solid Fat	Liquid Form
Colour	Pale Yellow	Brown Yellow	Clear Yellow
Odour	Pleasant Odor	Fatty Odor	Slightly Irritating
% Oil Yield	54%	12.5%	46%
pH	8.1	6.5	9.3
Specific Gravity	0.893	0.833	0.89
Refractive Index at 20°C	1.4630	2.3	1.4675
Kinematic Viscosity (cP) at 40°C	39.6	22.4	32.4
Kinematic Viscosity (cP) at 80°C	19.8	16.8	19.2
Dynamic Viscosity (cP) at 40°C	36.4	21.12	29.6
Dynamic Viscosity (cP) at 80°C	20.93	17.061	17.53
Viscosity Index	170	277	176
Relative Density (g/cm ³)	0.919	0.846	0.913
Acid Value (mg KOH/g)	3.24	2.89	5.22
Saponification Value (mg KOH/g)	205	183	203
Iodine Value (mg iodine/g)	104	45.9	98.8
Peroxide Value (mg/g oil)	10.9	3.10	1.35
Congeaing Temperature (°C)	2	32	15

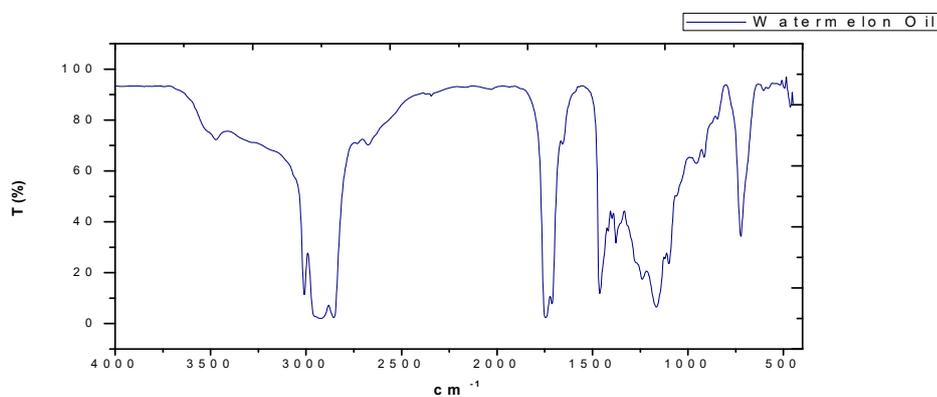
Saponification value measures the average size of fatty acid present in an oil sample which depends upon the molecular weight and percentage concentration of fatty acids components in it. Saponification value will be higher if the oil contains more of saturated fatty acids (such as C14:0, C16:0, C18:0) as it determines the length of carbon chain present in the oil. Saponification values varied significantly among the oils and was highest in watermelon oil (205 mg KOH/g), followed by jatropha oil (203 mg KOH/g) while, the lowest value was in mango oil (183 mg KOH/g). Saponification values had been reported to be inversely related to the average molecular weight of the fatty acids in the oil fractions. In a report by Abayeh et al. (1998), oil fractions with saponification values of 200 mg KOH/g and above will possess low molecular weight fatty acid, which is a preferred range for vegetable-based metal cutting fluids (Shashidhara and Jayaram, 2010). This is understandable because of the relative ease of oxidation of high molecular weight fatty acid. Also, low molecular weight fatty acids are soluble in water during cutting fluid formulation (Jayeoye, 2015). Iodine value is a measure of the degree of unsaturation in an oil, and it is an identity characteristic of native oil. This value could be used to quantify the amount of double bonds present in the oil, which reflects the susceptibility of oil to oxidation (Oderinde et al., 2009). The result obtained for the iodine value for the different oils were shown in Table 1. Higher values show increase in the average degree of unsaturation of the oil, as such, the amount of iodine which can be absorbed by unsaturated acids would be higher. As a result of their agreement with standard, mango and jatropha oils could be classified as non-drying oils; since their iodine values are lower than 100 (gI₂/100g sample). Certainly, those oils whose values are less than 100 (gI₂/100g sample) could be used extensively as lubricants and hydraulic brake fluids (Eze, 2012).

A common way of assessing hydro peroxides is by determination of peroxide value (Gunstone, 2004). The peroxides values for mango and jatropha are very low. The low values of peroxide value are indicative of low levels of oxidative rancidity of the oils and also suggest strong presence or high levels of antioxidant. Moreover, low peroxide value suggests that the oils are fresh and could be stored for a long period of time without getting rancid. Watermelon oil has a very high peroxide value (10.9 mg/g oil) hence; it will be less stable and would easily undergo deterioration when exposed to atmospheric oxygen, a condition which operates during the use of cutting fluid in the course of machining. Viscosity is a measure of the resistance of a fluid to deform under shear stress. It is commonly perceived as thickness, or resistance to pouring.

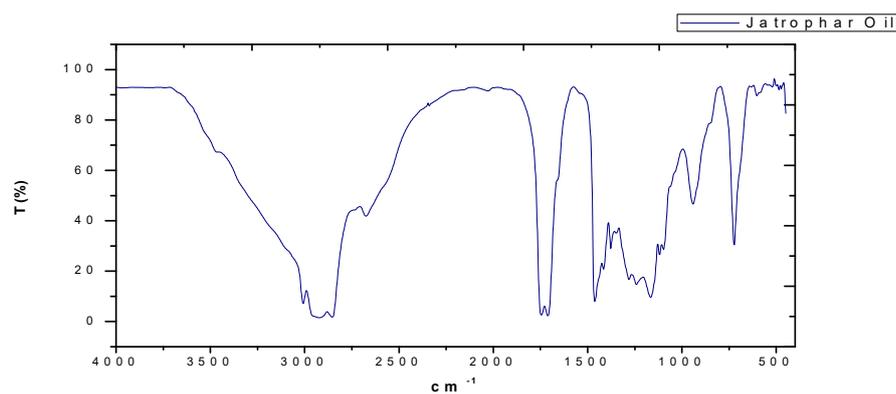
Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction (Nzikou et al., 2010). The viscosity measured at 40-100°C for raw watermelon, mango and jatropha oils are presented in Table 1. As the temperature increase the viscosity of oil reduces. The viscosity of watermelon oil reduces by 2.0 times when temperature raised from 40-80°C. Similarly, the viscosity reduction for mango and jatropha oils was 0.75 and 0.6 times with increase in temperature from 40– 80°C. Another important characteristics measured was the congealing temperature, mango oil had quite a high congealing temperature of 32°C, watermelon oil was the lowest with 2°C and jatropha oil had 15°C. Lower congealing temperature is better; this means the watermelon oil can still be workable at relatively low temperature.

3.2. Fourier Transform Infra-Red (FT-IR)

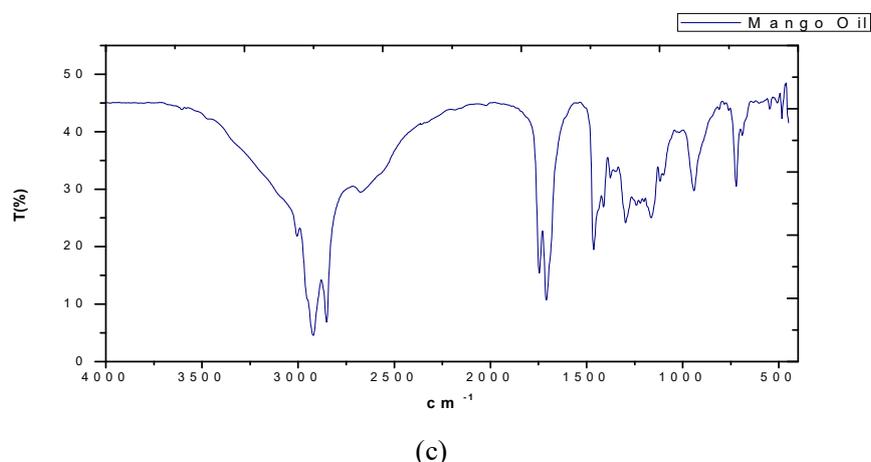
The FT-IR analyses in Fig. 3 justified the basic functional moieties associated with the elucidation of oils. Asymmetry stretching vibration~ 1745 cm^{-1} in the three samples, is diagnostic for the carbonyl moiety of an ester. The presence of both asymmetry and symmetry stretching vibrations in the range 3010–2852 cm^{-1} and their respective bending vibrations in the finger print region, suggests the presence of carbon atoms with 75% and 66.6% p-orbital characteristics. The stretching vibration~ 1657 cm^{-1} in watermelon oil insinuate a carbon atom with a sp^2 signature.



(a)



(b)



(c)
Fig. 3. Fourier transform infra-red for crude (a) watermelon oil (b) jatropha oil (c) mango oil

3.3 Gas Chromatography and Mass Spectra (GC-MS)

The chromatogram obtained from the GC-MS analyses carried out on the oil samples revealed the presence of four phyto-compounds each in watermelon and mango. Three compounds were isolated from sample jatropha. The isolated compounds composed of fatty acids, phenol derivative, and unsaturated hydrocarbon (see Table 2). The extracted oils are bio-based mixtures whose synergistic penetrating capacity could be a better substantial substitute for the mineral-based lubricants with eco-depleting antecedents. *Compound 1* was identified as n-hexadecanoic acid ($C_{16}H_{32}O_2$), M^+ 256 and a diagnostic base peak at m/z 60 owing to McLafferty rearrangement (Okenwa and Donatus, 2013). The compound has numerous applications in soap, cosmetics and release agents. It has not been reported in the application of metal cutting fluids but it can be given a trial because of its application in skin products. The compound is 36.41%, 54.04% and 32.14% by compositions in the three oil samples (Table 2). It is the most abundance quantitatively in watermelon and mango oils. *Compound 2* was identified as cis-vaccenic acid ($C_{18}H_{34}O_2$), M^+ 282 and a base peak observed at m/z 55. This is as a result of an alkyl (butyl) ion fragment. The compound is 0.59% by composition and present in trace amount in mango oil.

Compound 3 was identified as 3-pentadecyl phenol ($C_{21}H_{36}O$), M^+ 304 with a base peak of 108. This depicts a benzyl alcohol radical ion fragment. The compound is 4.18% by composition of the extracted mango oil. *Compound 4* was identified as squalene ($C_{30}H_{50}$), M^+ 410 and a base peak of 69 due to the fragmentation of an alkyl residue (pentyl). The compound is an important intermediate in the biosynthesis of triterpenoids. It is 2.51% by composition of the extracted mango oil. *Compounds 5, 6, 7 and 8* were identified as 9,12-octadecadienoic acid, 1H-indole, cyclopropane and 2,6,10,14,18,22-tetracosahexaene respectively. These compounds represent the chemical compositions of the oil extracts of both watermelon and jatropha. 9,12-octadecadienoic acid is used in making quick-drying oils, which are useful in oil paints and varnishes. 9,12-octadecadienoic acid has become increasingly popular in the beauty products industry because of its beneficial properties on the skin. Research points to 9,12-octadecadienoic acid as anti-inflammatory, acne reductive, and moisture retentive properties when applied topically on the skin (Diezel et al., 1993; Letawe et al., 1998 and Darmstadt et al., 2002). 9,12-octadecadienoic acid in watermelon and jatropha oils will help to eliminate the problems of skin cancer and respiratory challenges especially acne associated with the use of mineral based metal cutting fluids. From Table 2, the oil samples from watermelon and jatropha contain 27.49% and 41.65% respectively of 9, 12-octadecanoic acid in their compositions and this make the two oils suitable for application as metal cutting fluids.

1H-Indole; a solid at room temperature, has a flowery smell at very low concentrations. It is an ingredient of many flower scents (such as orange blossoms) and perfumes. Natural jasmine oil used in the perfume industry, contains around 2.5% of Indole (Leffingwell, 2002). Most of the metal cutting fluids produced industrially contain additives such as corrosion inhibitors, dispersants, biocides, colourants, fragrances etc. In this case, 1H-Indole can serve as an important additive in the production of metal cutting fluids.

Cyclopropane is non-irritating to the respiratory organs and does not depress respiration (Britannica, 2016). Vaccenic acid, also known as (E)-Octadec-11-enoic acid occurs naturally as trans-fatty acid found in the fat of ruminants and in dairy products such as milk, butter, and yogurt. It is also the predominant fatty acid comprising trans-fat in human milk (Precht and J. Molkenkin, 1999; Friesen and S. M. Innis, 2006). A study in 2008 at University of Alberta suggests that vaccenic acid feeding in rats over 16 weeks resulted in lowered total cholesterol, lowered LDL cholesterol and lower triglyceride levels, though studies are ongoing on its effect on humans (AFNS, 2008). Squalene is used in cosmetics, and more recently as an immunologic adjuvant in vaccines. Also, dietary gains through squalene intake are not fully explored, though it is regarded as providing some resistance against certain types of cancer (Smith, 2000; Owen et al., 2004).

Table 2. Gas chromatography analysis of phyto-compounds isolated from watermelon, mango and jatropha oils

Oil Sample	Chromatography Peak	Compound Nomenclature	Molecular Formula	Molecular Weight	Retention Time (min)	Percentage Content (%)
Watermelon	1	n-hexadecanoic acid	C ₁₆ H ₃₂ O ₂	256	18.247	57.87
	2	acid	C ₁₈ H ₃₂ O ₂	280	19.747	27.49
	3	9,12-octadecadienoic acid	C ₁₈ H ₃₂ O ₂	280	22.859	3.73
	4	1H-indole Cyclopropane	C ₃ H ₆	42	25.783	11.36
Mango	1	n-hexadecanoic acid	C ₁₆ H ₃₂ O ₂	256	17.627	38.76
	2	acid	C ₁₈ H ₃₄ O ₂	282	19.822	55.28
	3	cis-vaccenic acid	C ₂₁ H ₃₆ O	304	26.488	4.18
	4	3-pentadecyl phenol Squalene	C ₃₀ H ₅₀	410	29.898	2.51
Jatropha	1	n-hexadecanoic acid	C ₁₆ H ₃₂ O ₂	256	17.881	35.06
	2	9,12-octadecadienoic acid	C ₁₈ H ₃₂ O ₂	280	19.758	41.65
	3	2,6,10,14,18,22 tetracosahexane	C ₂₄ H ₃₈	326	30.075	23.29

3.4. Lubricity Related Properties Characterisation

The lubricity related properties of the oil extracts from watermelon, jatropha and mango oils are as shown in Table 3. Pour point for mango oil, 36°C, was the highest, followed by jatropha oil, 17°C, and watermelon oil with 5°C. This means that watermelon oil may still maintain its fluidity at relatively low temperature. Therefore, watermelon oil the lowest pour point is the best amongst the three oils; it will not congeal on time. The flash point is used to describe flammable and combustible liquids. Mango oil exhibited the lowest flash point of 158°C, while watermelon and mango oil were 178°C and 165°C respectively. The ease of storage makes watermelon oil with the highest flash point better (it will not flash and ignite on time).

Fire point are used to indicate the fire hazard of oil and evaporation loses under high temperature loses. Mango oil with the least fire point, 167°C, is the most highly inflammable amongst the three oils. While that of jatropha and watermelon oils were 178°C and 190°C respectively. The fire point of any substance hugely affects its application. Higher fire point is better and provides safer application; such oil will not

burn on time. Vapour will not come out of the liquid on time. Mango oil exhibited a relatively high cloud point at 39°C; Watermelon oil was the lowest with 8°C, while jatropha oil has a cloud point of 20°C. Lower cloud point is better; Oil will not congeal on time.

Increasing governmental regulations and awareness in the society is forcing industrialists to reduce the use of mineral oil-based metal cutting fluids as metal cutting fluid due to their environmental and health impacts. Metal working fluids have been used extensively in metal cutting operations for the last 200 years. Earlier, metal working consisted of simple oils applied with brushes to lubricate and cool the machine tool. As cutting operations became more severe, metal working formulations became more complex (Lawal et al., 2012). Higher difficulties are expected when machining with mineral based oil due to its negative effects to the operators.

Table 3. Lubricity related properties of oil extracts

Parameter Measured	Type of Oil Seed		
	Watermelon	Mango	Jatropha
Cloud Point	8	39	20
Pour Point	5	36	17
Fire Point	190	167	178
Flash Point	178	158	165

Metal cutting fluids are complex mixtures of oils, detergents, surfactants, biocides, lubricants, anti-corrosive agents, and other potentially toxic ingredients (OSHA 1999). Research on occupational exposures to metal cutting fluids has suggested that operators in machining workshops are at risk of developing allergenic disorders and diseases. Skin and airborne exposures to MWFs have been implicated in health problems including irritation of the skin, lungs, eyes, nose and throat. Conditions such as dermatitis, acne, asthma, hypersensitivity pneumonitis, irritation of the upper respiratory tract, and a variety of cancers have been associated with exposure to MWFs (Saleem et al, 2013). The severity of health problems is dependent on a variety of factors such as the kind of fluid, the degree and type of contamination, and the level and duration of the exposure. Respiratory irritation involves some type of chemical interaction between the MWF and the human respiratory system. The inhalation of MWF mist or aerosol may cause irritation of the lungs, throat, and nose. On the other hand, skin contact with metal cutting fluid occurs when the operator dips his hands into the fluid or handles parts, tools, and equipment covered with fluid without the use of personal protective equipment, such as gloves and aprons. Skin contact may also result from fluid splashing onto the employee from the machine if guarding is absent or inadequate.

Consequently, vegetable oil based metal cutting fluids has some superior features compared to the petroleum based metal cutting fluids. These are reduced overall volume of fluids due to higher viscosity, minimized health risk to workers and minimized bio-contamination. Biodegradability of vegetable oils is the strongest point in their consideration for use as potential metal cutting fluids. With growing concerns about the environmental impact of the use of industrial fuels and lubricants, vegetable oils offer in theory the most plausible solution to the issue of obtaining renewable and eco-friendly lubricants and fuels. Furthermore, their applications as skin and perfume products show that they possess an important characteristic which makes them safer for potential use in metal cutting.

4.0. CONCLUSION

Indigenous Nigerian less-known seed oils of three varieties namely watermelon, jatropha and mango seeds were analysed with respect to their physicochemical, phytochemical and thermal properties. Various oil properties of the seeds were determined using AOAC and ASTM standards. The fatty acid methyl esters (FAME) prepared from the seed oils were analyzed by GC-MS and FT-IR. The GC-MS confirmed the presence of fatty acids such as n-hexadecanoic acid, 9, 12- octadecadienoic acid, 1H- indole, cyclopropane, cis-vaccenic acid, 3-pentadecyl phenol, squalene and 2,6,10,14,18,22 tetracosahexaene in the three oil seeds considered. Hexadecanoic acid was the most abundant compound in watermelon and mango oil while 9, 12- octadecadienoic acid is the most abundant for jatropha oil. Fatty acids content in mango, watermelon and jatropha oils have great applications as vegetable oils and could be utilized for lubricating purpose. The bio-based oils compositions' impact on the environment is acceptable and meets current and anticipated future industrial regulations related to the presence of volatile organic compounds. The oil compositions as described herein may be diluted with additives to provide metal cutting oil product to enhance lubricity properties and rust or corrosion resistance.

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