FORMULATION AND INVESTIGATION OF SUITABILITY OF JATHROPHA VEGETABLE OIL AS A CUTTING FLUID

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ABSTRACT

The need to lubricate and cool tool-chip interface during machining operations; to minimise friction and heat as well as take away the heat from cutting tool and workpiece by means of applying cutting fluids have been in use for over a century. The most common among the cutting fluid in use is mineral oil. However, mineral oil has been found to be eco-unfriendly. Consequently, the need to search for eco-friendly cutting fluids. This paper provides an overview of some of the existing types of cutting fluids, with their respective advantages and disadvantages clearly enumerated. Detailed investigation of suitability of Jathropha vegetable oil as a cutting fluid is also investigated. The fatty acid composition (FAC) profile of Jathropha vegetable oil was investigated via GC-MS test and it was found to be unsaturated in nature, hence suitable for formulation of cutting fluid. The procedure involved in the formulation of the Jathropha vegetable oil -based and mineral oil- based cutting fluids are clearly explained. The formulated mineral oil and Jathropha vegetable oil-based cutting fluids were then characterized and mineral oil-based cutting fluid was found to have a viscosity of 1.00mm^2/s and pH value of 8.9 while Jathripha vegetable oil-based cutting fluid have a viscosity of 2.32mm^2/s and pH value of 8.65. Both cutting fluids are corrosion resistant, milky in colour and of acceptable stability. Jathropha vegetable oil-based cutting fluids, in view of its environmental friendliness and biodegradability is consequently recommended as a suitable alternative cutting fluid to mineral oil-based cutting fluids for machining of metallic workpieces.

Keywords: Vegetable oil, mineral oil, cutting fluid, eco-friendliness, cooling, lubrication

1.0 INTRODUCTION

In machining operations, cutting fluids are essential to reduce friction and heat brought about by tribological action between the cutting tool and workpiece materials. The tribological action results in shortening of tool's life and deterioration of surface finish and dimensional accuracy of the workpiece [1]. To mitigate the negative effect of the tribological action between the cutting tool and the workpiece, cutting fluids are used. The use of cutting fluids for machining processes has been in existence for many centuries [2]. Cutting fluids cool and lubricate the cutting tools and workpieces in machining processes and their use can bring about among others, the following advantages:

1. Elongation of tool's life which results in reduction of tool cost.
2. Increased cutting speed becomes possible as friction and heat are minimised
3. Reduction of labour cost. This is possible due to longer tools life and reduction in regrinding times of the tool. Hence, reducing cost per component machined.
4. Reduction of energy cost, since friction is reduced by a cutting fluid, less energy and power are required in machining operations, resulting in corresponding savings in energy and power costs.

According to [3], the advantages and disadvantages of existing types of cutting fluid are presented in Table 1.

Table 1: Advantages and disadvantages of various cutting fluids

S/NO	CUTTING FLUIDS	ADVANTAGES	DISADVANTAGES
1.	Straight Cutting Oils	Excellent lubricity, good rust protection, good sump life, easy maintenance and rancid resistance.	Poor heat dissipation, increased risk of fire, smoking and misting. Oily film on workpiece, limited to low speed and severe cutting operation.
2.	Soluble Oil	Good lubrication, improved cooling capabilities, good rust protection, general purpose from light to heavy duty operations.	More susceptible to rust, bacteria growth, tramp oil contamination and evaporation losses, increased maintenance costs and may form precipitates on machine; misting, oily film on workpiece.
3	Synthetics	Excellent microbial control and resistance to rancidity, relatively nontoxic, transparent, non-flammable/non-smoking, good corrosion control, superior cooling qualities, reduced misting/foaming; easily separated from workpiece/chips, good settling/cleaning properties, easy maintenance and long service life. It is used for a wide range of applications.	Reduced lubrication property, may cause misting; foaming and dermatitis. It may emulsify tramp oil, may form residues and easily contaminated by other machine fluids.
4	Semi synthetics	Good microbial control and resistance to rancidity, relatively non-toxic, non-flammable, good corrosion control, good cooling and lubrication properties, reduced misting/foaming, easily separated from workpiece/chips, good settling/cleaning properties, easy	Stability being affected by water hardness, may cause misting; foaming and dermatitis, may emulsify tramp oil, may form residues and easily contaminated by

		maintenance and long service life. It is used for a wide range of machining applications.	other machine fluids.

Most of the commercially available cutting fluids are mineral oil with chemically synthesised emulsifiers and additives as basic ingredients [2]. However, due to poor biodegradability of mineral oil, it is becoming a source of environmental pollution. Inappropriate disposal of mineral oil results in surface water and ground water contamination, soil contamination and air pollution [3]. Consequently, it brings about Agricultural and food contamination [4]. Mineral oils come from one of the limited resources on earth; fossil fuels [5]. However, there are now multitudinal challenges posed by using mineral oils as lubricants in most applications nowadays. Environmental concern ranging from renewability, biodegradability, safety and health of operators which are on the increase, need serious attention [6]. Therefore, it becomes necessary to adopt sustainable product design technique. The alkalinity of the cutting fluid promotes the selective growth of many pathogenic micro-organisms. Many incomplete oxidation products of anaerobic micro-organism will produce unpleasant odours after a period of stagnation. The microbial toxins and enzymes produced in water soluble cutting fluids, as well as chemical biocides that are often used to kill micro-organisms are carcinogenic and may cause cancer [7]. Scientists and tribologists have developed various alternatives to overcome the limitations of mineral oil based cutting fluids. Currently in use are synthetic lubricants, tallow and solid lubricants. Since vegetable is renewable, it is another attractive alternative to mineral oil; in view of its environmental friendliness, biodegradability and its relative non-toxic nature [7]. The ongoing research shall seek to formulate Jathropha vegetable oil based and mineral oil based cutting fluids. The physiochemical properties of Jathropha vegetable oil from the existing literature is provided, its Fatty Acid Composition (FAC) via Gas Chromatograph and Mass Spectrometer was carried out and the characteristics of both mineral oil-based and Jathropha vegetable oil based cutting fluids were investigated. Vegetable oils are the esters of glycerol and fatty acids. Advantages of vegetable oils includes good solvency, high lubricity, low volatility, high load carrying capacity, low emission of hydrocarbon, higher fire resistance and good thermal properties [8] and [9].

2.0 MATERIALS AND METHODS

2.1 Fatty Acid Composition (FAC) Analysis

The Jathropha vegetable oil was subjected to fatty acid composition analysis (FAC) using gas chromatograph interfaced to a mass spectrometer (GC-MS) instrument. The machine condition used are as shown in Table 2.

Table 2: Machine condition for GC-MS test

Column over temperature	70.0^0C
Injection temperature	250.0^0C
Column flow	1.8mL/min
Total flow	40.8mL/min
Linear velocity	49.2cm/sec
Pressure	116.9 KPa

The GC-MS test was conducted at Federal Institute of Industrial Research Oshodi (FIIRO), Lagos. The result of Fatty Acid Composition (FAC) analysis is presented in Table 3.

Plate I: GC-MS machine

The Physiochemical properties of Jathripha vegetable oil is presented in Table 2.

Table 3: **Physiochemical Properties of Jathropha Vegetable Oil (Source: [7])**

S/N	Parameter	Value
1.	Specific gravity	0.916
2.	Acid value (mg/100g)	7.85
3.	Free Fatty Acid (mg/100g)	3.93
4	Saponification value (mgKOH/g)	189.33
5	Flash point (^{0}C)	219
6.	Pour point (^{0}C)	-7
7.	Moisture content (%)	0.89
8.	pH value	5.09
9.	Iodine value g/100g of KOH	113.4
10.	Viscosity@ 25^{0}C (mm^2/s	32

2.2 Formulation of emulsion cutting fluids from Mineral oil and Jathropha vegetable oil Oils.

Mineral soluble oil (CMO) Mobil Met 424 was sourced from Osogbo (Lat 7.7827^{0}N, Long 4,5418^{0}E) in Osun State, Nigeria. Jathropha curcas vegetable oil designated as JVO in this study was sourced from Zaria (Lat 11.0855^{0}N, Long 7.7199^{0}E), Kaduna state, Nigeria.

Additives for the cutting fluid

In formulation of cutting fluids, additives are very important components. These are substances which confer special desired qualities to cutting fluids. According to [10], the composition of additives in any cutting fluid may vary between 25 to 30%. The common additives used while formulating the cutting fluids include emulsifier, anti-oxidant, biocide and anti-corrosion. In this study, these additives were used in the formulation of vegetable oil-based cutting fluid. Description of the additives applied in the formulation is shown in Table 4.

Table 4: Description of additives for formulation of vegetable oil cutting fluid.

Additives	**Composition**	**Source**
Emulsifier	0.5M sodium lauryl sulphate + sodium tripoly phosphate + sulphuric acid + calcium carbonate in 5 litres of water.	Prepared in Chemical Engineering Laboratory of Federal University of Technology, Minna-Nigeria.
Anti-Oxidant agent	It contains equal concentration of 0.5M zinc chloride + peroxide + calcium carbonate solution	Prepared in Chemical Engineering Laboratory, Federal University of Technology, Minna, Nigeria.
Biocide	Mixture of equal concentration of 0.5M hypo chloride + phenolic solution + tris (hydroxymethyl) nitro methane calcium carbonate solution	Prepared in Chemical Engineering Laboratory of Federal University of Technology, Minna, Nigeria.
Anti-corrosion agent	Banana plant juice	Sourced locally from Minna, Niger State, Nigeria.

Basic water quality required in formulating cutting fluid

The basic need in the formulation of oil-based emulsion cutting fluids is water quality as it affects performance and stability. Water hardness is ascertained by the quantity of magnesium and calcium salts it contains as they have effects on the quantity of emulsifier in the process of formulating the oil-based cutting fluid. Soft water enhances unneeded bubbling but formation of water insoluble soap is promoted by hard water which consequently reduces quantity of emulsifier used. Consequently, the quality required of drinking water has been recognised and certified as meeting the demand in formulating oil-based cutting fluids. This is because the level of micro-organisms such as yeast, fungi, bacteria and others for the emulsion can be stabilised. [11], revealed that drinking water of good quality has an average pH value of 7.72 and average hardness level of 65mg $CaCO_3$/L. World Health organization, (WHO) standard for good drinking water specifies pH value of 6.8 – 8.5 and maximum hardness level of 400mg/L [12] .The water for this research work is distilled water sourced from the Water resources, Aquaculture and Fisheries Technology (WAFT) department's laboratory in the School of Agriculture at Federal University of Technology, Minna, Niger State. The water for formulation of the cutting fluids used in this experiment satisfies the World Health Organisation (WHO) standard for good drinking water. Percentage ratio of oil to (water + additives) of 1:9 is the basis for preparation of oil in water emulsion metal working fluids. The method used is the one followed by [13] and [14]. The method involves controlled addition of the additives to the oil. A magnetic stirrer (Magnetic stirrer with hot plate 79-1) was used to stir the mixture at a speed of 1400 rpm for 15 minutes at ambient temperature. Various additives as shown in Figure 2, were added to the vegetable oil. The additives are emulsifier, anti-oxidant, biocide and anticorrosion agent, which were added in different percentages, and mixed thoroughly with mechanical stirrer. Water was then added to 90% by volume in order to make the emulsion ratio of 1:9 of base oil (mineral oil or vegetable oil) and water. The percentage ratio of additives applied by [15] was used for the formulation, which goes thus: - emulsifier 11.81%, anti-oxidant 0.76%, biocide 0.64% and anti-corrosive agent 3.67%. The idea behind adoption of the ratio applied by [15] was due to the observed properties of the vegetable oil (Jathropha) especially the fatty acid composition, which is revealed by GC-MS test on Jathropha oil. It is having higher percentage of unsaturated fatty acid as shown on Table 4. The formulation involves the mixture of oil and additives and stirred to form a homogenous liquid before adding water to make up for the balance of the required volume. The algorithm for the formulation is shown in Figure. 1 and figure 2 for mineral oil based and vegetable oil-based cutting fluids respectively.

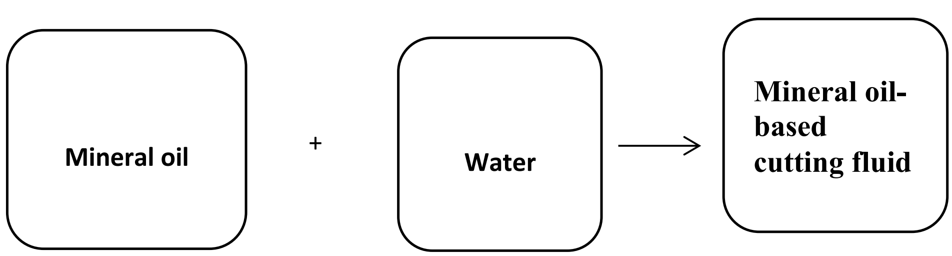


Figure 1: Formulation of mineral oil-based cutting fluid.

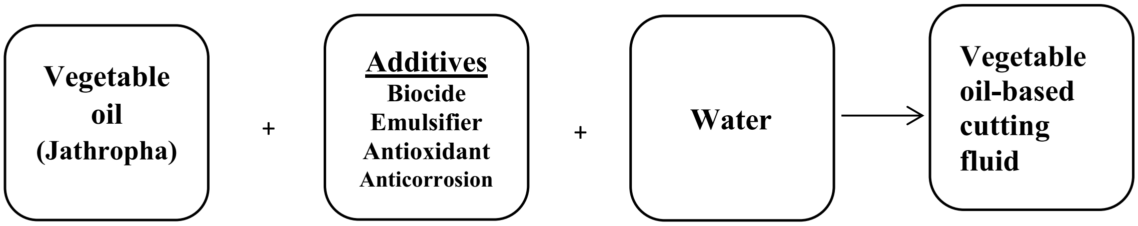


Figure 2: Formulation of vegetable oil-based cutting fluid

In preparation of one litre (1000ml) of mineral oil based cutting fluid, the soluble oil concentrate was mixed with water in ratio 1: 9.

However, in preparation of one litre (1000 ml) of vegetable oil-based cutting fluid, the following calculation was applied to obtain the appropriate volume of each component.

1. 10% of oil in 1000 = 100mL
2. 11.81% emulsifier in 1000 = 118.1mL
3. 0.76% Anti-oxidant in 1000 = 7.6mL
4. 0.64% biocide in 1000 = 6.4mL
5. 3.67% Anti corrosive in 1000 = 36.7mL
6. Balance (73.12%) water value) = 731.2mL (Distilled water of 7.35 pH

3.2. Characterisation of formulated cutting fluids

(a) pH Value

An indication of the general condition of a fluid's acidity or alkalinity is its pH value. Reduction of a cutting fluid's pH value reflects a fall in its performance. When the pH value of a fluid becomes very high or very low, it becomes very dangerous to machine operators and problematic to dispose. Microbial contamination of cutting fluid occur in acidic medium rather than an alkaline medium. Consequently, and in accordance with [16], a higher pH value enhances the fluid's resistance to microbial attack. According to [17], pH value range of 9 to11 has been suggested. It has been proved that an acidic (low pH value) will cut-down the corrosion protection of the workpiece and machine components; and consequently, cut-down their life stability. However, if the cutting fluid is strongly alkaline (high pH value), it will have the tendency to cause skin irritation to the operator and other users.

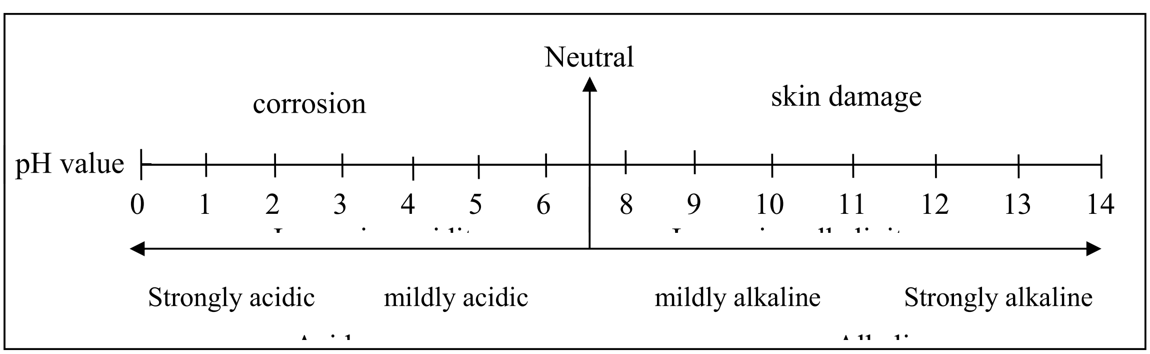


Figure 3: Effects of pH value on workers' health and materials.
Source: [17]

pH meter was used in determining the pH values of the cutting fluids in the Chemical Engineering Laboratory of Lagos State Polytechnic, Ikorodu, Lagos State, Nigeria. Before using the pH meter, it was first calibrated using buffer solution. After every reading, the electrode was cleaned with distilled water before another reading was taken. The results obtained is presented in Table 4.4.

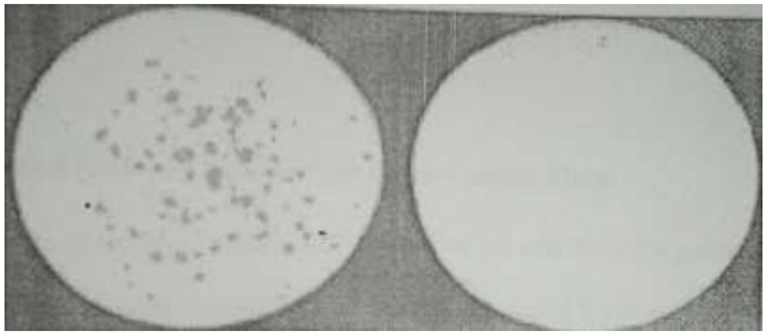
Plate II: pH meter

(b) Viscosity

Viscosity is the measure of internal flow in liquids, semi-liquid or semi-solid substance. It is a measure of resistance of a liquid to flow. It is also the ratio of shear stress to the rate of shear during flow [14]. For effective evaluation of the lubricating property of a cutting fluid, one of the deciding parameters in kinematic viscosity. According to Rao *et al,* [13](2007), the lubricating property of a cutting fluid increases with an increase in its kinematic viscosity. ASTM D445 method was used in determining the viscosity of formulated cutting fluids at the Chemical Engineering Laboratory, Federal University of Technology Minna, Niger State, Nigeria.

(c) Corrosion Level Test

Definition of corrosion is given as the deterioration of the surface layer of a metal due to chemical reactions between it and the environment surrounding it. The chemical reaction results in conversion of the useful materials such as metals and their oxides into useless oxides. The procedure used by Alves and Oliveira [15] (2006) was used in determination of the corrosion level of the formulated cutting fluids. The test was carried out to examine the number of corrosion spots on a test filter paper resulting from the corrosive actions of the formulated vegetable oil-based cutting fluids. The procedure involves measuring 1g of cast Iron chips onto a filter paper placed on a petri dish. Then 2ml of the cutting fluid (mineral oil or vegetable oil) collected with a pipette was applied in wetting the iron chips placed on the filter paper in a petri dish. It was then covered for two hours. The iron chips were later thrown away and the filter paper properly rinsed away with pipe born water. Acetone was then used to treat the paper and then dried at ambient temperature. The corrosion level was then evaluated by visual inspection.



Before After

Plate II: Corrosion level test of cutting fluid

(d) Stability

Stability evaluation of the cutting fluids formulated was done on the basis of visual transparency within 24 hours period at ambient temperatures (26^{o}C) as to separation of water and oil in a graduated 100mL measuring cylinder.

Plate III: Stability test of emulsion cutting fluids

4.0 RESULTS

4.1 Analysis of GC-MS

The graph of GC-MS is presented in Figure 4.1

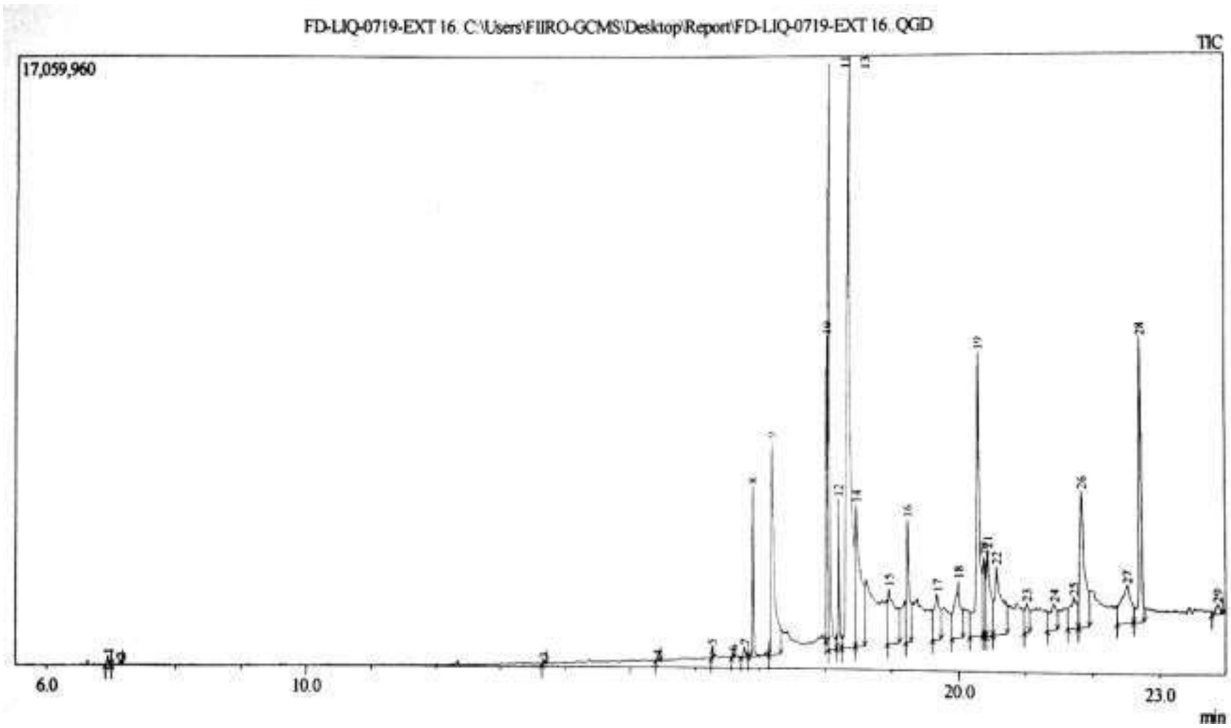


Figure 4.1: Graph of GC-MS of the Jathropha vegetable oil

Interpretation of GC-MS was done using the data base of Nigerian Institution of Science and Technology, (NIST), having very large patterns in the Library that is built into the GC-MS machine. Tables 4.2 show the Fatty Acid composition results of jathropha seed oil. From the results, unsaturated acid has the highest values of 77.02 %. This implies that the selected vegetable oil – Jathropha is liquid at room temperature and consequently fit for formulation of cutting fluid. Table 4. shows the fatty acid composition of the Jathropha vegetable oil used while the fatty acid profile is presented on Table 5.

Table 5: Jathropha Seed Oil's Fatty Acid Composition

S/N	IUPAC name	chemical formula	fatty acid	type of fatty acid	value (%)
1.	Hexadecanoic	$C_{17}H_{34}O_2$	Palmitic	Saturated	2.20
2.	n-Hexadecadienoic	$C_{16}H_{32}O_2$	Palmitic	Saturated	6.21
3.	Octadecadeinoic	$C_{19}H_{34}O_2$	Linoleic	Poly-unsaturated	3.64
4.	11-octadecenoic	$C_{19}H_{36}O_2$	Elaidic	Unsaturated	7.39
5.	Methyl stearate	$C_{19}H_{38}O_2$	Stearic	Saturated	1.72
6.	Cis-vacenic	$C_{18}H_{34}O_2$	Oleic	Mono-unsaturated	20.71
7.	Oleic	$C_{18}H_{34}O_2$	Oleic	Mono-	6.48

				unsaturated	
8.	9-Octadecenal (z)	$C_{18}H_{34}O$	Linoleic	Poly-unsaturated	3.94
9.	15-Hydroxypentadecenoic	$C_{15}H_{30}O_3$	Palmitic	Saturated	2.85
10.	17-Octadecynoic	$C_{18}H_{32}O_2$	Stearic	Saturated	2.34
11.	9-Octadecenoic (z)	$C_{21}H_{40}O_4$	Oleic	Saturated	3.17
12.	Cis-9-Hexadecenal	$C_{16}H_{30}O$	Linoleic	Poly-unsaturated	8.48
13.	8-Hexadecenal	$C_{18}H_{34}O$	Linoleic	Poly-unsaturated	1.80
14.	Cis-9-Hexadecenal	$C_{16}H_{30}O$	Linoleic	Poly-unsaturated	2.85
15.	Hexadecanoic	$C_{19}H_{35}O_4$	Palmitic	Saturated	4.64
16.	13-Tetradecenal	$C_{14}H_{26}O$	Myristoleic	Mono-unsaturated	1.77
17.	17-Octadecynoic	$C_{18}H_{32}O_2$	Stearic	Saturated	1.70
18.	16-Dieporydexadecanol	$C_{16}H_{30}O_4$	Oleic	Poly-unsaturated	1.95
19.	9-octadecanoic	$C_{21}H_{40}O_4$	Oleic	Mono-unsaturated	5.90
20.	13-Octadecedien	$C_{18}H_{34}O$	Oleic	Mono-unsaturated	3.49
21.	Squalene	$C_{30}H_{50}$	Linoleic	Poly-unsaturated	6.07
22.	sum of fatty acids with insignificant values				0.68

Table 6: Jathropha vegetable oil's

S/n	Acid	Form	Value (%)
1.	Myrinstoleic	C 18:1	1.17
2.	Oleic	C18:1	39.75
3.	Palmitic	C16:0	15.90
4.	Stearic	C18.0	5.96
5.	Linoleic	C 18:2	28.73
6.	Elaidic	C 18: 1	7.37
7.	Others	-	1.12
	TOTAL		100.00

From Table 6, it can be deduced that

$\sum$ Saturated Fatty acid = 21.86%

∑ Unsaturated Fatty acid = 77.02%

∑ Others = 1.12%

Grand Total = 100%

This result agrees with the findings of [18] and also compares favourably with findings of [19] which reported that Jathropha oil is made of high quantity of about 78 – 84% unsaturated Fatty acid. The ratio of Unsaturated acid: Saturated acid: Others is approximately 7:2:1. This implies that the oil is unsaturated in nature; it will remain liquid at room temperature and is consequently suitable to formulate cutting fluids for machining. Jathropha oil belongs to the non-edible category of vegetable oil and its impact on food chain system is minimal [20].

Table 7: Characteristics of various cutting fluids.

S/N	Pproperty	Value	
		Mineral oil	**Vegetable oil**
1.	Colour	Milky	Milky
2.	Stability	Stable	Stable
3.	Viscosity (mm^2/s)	1.00	2.315
4.	pH value	8.9	8.65
5.	Corrosion level	Corrosion resistant	Corrosion resistant

The methodology adopted in carrying out the above tests for the characteristics of the cutting fluids is comparable to that of [3].

5.0 CONCLUSIONS

This study has captured investigation of suitability of Jathropha vegetable oil as a cutting fluid for machining operations. In view of its eco-friendliness, stability as well as confirming that its characteristics as a cutting fluid lies within the acceptable range, its suitability as a cutting fluid is confirmed. It is consequently recommended for use as a cutting fluid in machining of metallic workpieces.

6.0 RECOMMENDATIONS FOR FURTHER STUDIES

The following recommendations for further studies are made;

1. Suitability of other vegetable oils such as neem oil and others should be investigated.
2. The effect of Jathropha vegetable oil-based cutting fluid on surface roughness of various workpiece materials should be investigated.
3. The effect of Jathropha vegetable oil-based cutting fluid on tool life of various cutting tool materials should be investigated.

REFERENCES

[1] Mamid, V.K., and Xaviour, M.A., (2012), "A Review in Selection of Cutting Fluids", National monthly refereed Journal of Research in Science and Technology, Volume no 1, Issue no.5, pp 2 – 19.

[2] Krar, S.F. and Check, A.F. (1997), "Technology of Macnine Tools, Glencoe/McGraw, New York, USA.

[3] Somashekariah, R., Suvin, P.S., Granadhas, D.P., Kailas, S.V., Chacravotty, D. (2016), "Eco-friendly, None toxic cutting fluid for Sustainable manufacturing and machining processes", Tribology online, Japanese society of Tribologies, 11,5, pp556 – 567.

[4] Adhvanju, A., Liu, Z. and Erhan, S.Z. (2005), "Synthesis of Novel Alcoxylated Trycyglycerols and their lubricant base oils properties", Industrial crops and products, 21, 113-119.

[5] Sorovic, M. and Mijanovic, K. (2001), Ecological aspects of cutting fluids and its influence on Quantifiable parameters of the cutting processes, Journal of materials processing Technology, 109, 181 – 189.

[6] Kolawole, S.K., Odusote, J.K., (2013), "Performance evaluation of Vegetable oil-based Cutting Fluids on Mild Steel Machining", Chemistry and Materials Research Gate, Vol 3, No 9, Research gate, www.jiste.org.

[7] Olaiya, K.A. (2021), "Investigation of Energy consumption in Orthogonal turning of AISI 304 Alloy Steel using Formulated Vegetable oil based cutting fluid", Unpublished PhD thesis submitted to the Mechanical Engineering Department, School of Infrastructure, Process Engineering and Technology, Federal University of Technology, Minna, Niger State, Nigeria.

[8] ASTM D3707, (2010) "Test method for Storage Stability of Water-in-Oil Emulsion by Oven Test method", ASTM International.

[9] Lawal, S.A., Chouldhury, I.A. and Nukman, Y. (2012), "Application of Vegetable oil-based Metal working Fluids in Machining Ferrous metals – A Review", International Journal of Machine Tools and Manufacture, 52, 1 – 12.

[10] Alves, S.M., and Oliveira, J.F.G. (2008), Vegetable based cutting fluids – An environmental alternative to grinding process, 15th CIRP International Conference on Life Cycle Enineering.

[11] Ong, C., Ibrahim, S., Gupta, B.S. (2007), A survey of tap water quality in Kuala Lampur, Urban water Journal, 4, (1), 29 – 41.

[12] WHO (2011), World Health Organization, Guidelines for Drinking Water Quality. Fourth Edition.

[13] Muniz, C.A.S., Data T.N.C., Moura E.F., Dantas – Neto, A.A and gurgel, A (2008), Novel Formulations of cutting fluids using Naphtemic basic oil, Brazilian journal of petroleum and gas 2(4), 143 – 153.

[14] Onuoha, O.J. (2015), Suitability of Vegetable oil in Orthogonal turning of AISI 1330 carbon steel using Taguchi method, Unpublished thesis submitted to the Mechanical Engineering Department, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Niger State, Nigeria.

[15] Lawal, S.A., Choudhury, I.A., and Nukman, Y. (2014),), Experimental Evaluation and Optimization of flank wear during turning of AISI 4340 steel with coated carbide inserts using different cutting fluids, Journal of the institution of engineers (India): Series C, 1-8.

[16] Rao, D.N., Srikant, R.R., and Rao C. S (2007), Influence of emulsifier content on properties and durability of cutting fluid, Journal of Engineering, the Brazilian society

of Mechanical, Science and Engineering, Vol xxix, No 4, October to December, 2007, pp 396 – 400.

[17] Alves, S.M., and Oliveira, J.F.G. (2008), Vegetable based cutting fluids – An environmental alternative to grinding process, 15th CIRP International Conference on Life Cycle Enineering.

[18] Heller, J. (1996), Physic nut (Jathropha curcas L): Promoting the conservation and use of underutilised and neglected crop, Institute of Plant genetics and crop plant research, International plant genetic unit, Rome.

[19] Sayak, B.S. and Patel, K.N. (2010), Physiochemical Characterisation of Seed and Seed oil of Jathropha curcas L. collected from Bardoli (South Gurat), Sains Mallasiana, 33: 955-959.

[20] Walaki, J.B.,Vishal, M., Gautam, V., Vijay, P., and Pruthvirajsinh, R.(2014), "Begetable oil based metal cutting fluids for sustainable machining process", International Journal of Emerging Technologies and Applications in Engineering, Technology and Sciences(IJ-ETA-ETS), Volume 7, Issue 1, Special issue.