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Formulation Of Soluble Cutting Fluids And To Determine Its Physico-Chemical Properties (Groundnut, Cotton And Neem Oils)

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Abstract
Mineral oil-based cutting fluids have adverse effects on the machine operators and the environment and hence the need to develop safe, environmentally friendly and efficient metal cutting fluids. The physico-chemical properties of the formulated oils determined shows that the acid value of groundnut, neem and cotton oils are 3.927, 1.122 and 0.3927mgKOH/g respectively. The saponification values show that cotton oil has the highest value (214.5825mgKOH/g) followed by groundnut oil (201.9600 mgKOH/g) and neem oil (196.3500 mgKOH/g), the density values indicate that neem oil has the highest value (1.00 g/cm^3), whereas cotton and groundnut oils have 0.995 g/cm^3 and 0.960 g/cm^3 respectively. The iodine test results show that cotton, groundnut, and neem oils have iodine values of 119.02, 102.84, and 83.78 g/I$_2$/g respectively whereas, the kinematic viscosity values are 5.39, 6.50 and 7.08 mm^2/s for cotton, neem and groundnut oils respectively. Further study on other locally sourced vegetable-based oils should also be investigated.

Keywords: *Vegetable oils, Acid, Saponification, Density, kinematic viscosity, Iodine, Phosphorus, Phenol, Emulsifier*

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I. Introduction

The challenge of modern machining industries is mainly focused on the achievement of high quality in terms of work piece, chip formation, surface finish, high production rate, less wear on the cutting tools, effective management of cutting fluids and work piece. It is necessary to determine optimal cutting parameters like speed, feed rate and depth of cut and also tool geometry and type of the cutting fluids (Deshayes, 2003).

Cutting fluids are used to reduce the negative effects of heat and friction on both tool and work piece. Cutting fluids produce three positive effects on cutting process: heat removal, lubrication on the chip–tool interface and chip removal (Lopez de Lacalle *et al.,* 2006). However, the advantages of cutting fluids have been questioned lately, due to the several negative effects they have caused to the environment and workers health. Inappropriate discharge of cutting fluids may damage soil and water resources, causing serious environmental impact. On the shop floor, machine operators may be affected by negative effects of cutting fluids, such as skin and respiratory problems (Lopez de Lacalle *et al*., 2006).

In order to make the machining process more ecologically friendly, a near-dry application of lubricant have been accepted because of its environmentally friendly characteristics. However, in some machining process, it is practically impossible to drastically reduced or eliminate the use of cutting fluids (Sokovic and Mijanovic, 2001, Dhar *et al*., 2006 and Suda *et al.*, 2004).

The use of vegetable oils may make possible the development of a new generation of cutting fluids of high performance in machining combined with good environmental friendliness. Interest in vegetable oil-based cutting fluids is growing according to industrial study. Compared with mineral oil, vegetable oil may enhance the cutting performance, extend tool life and improve the surface finish. Although, they have many environmental benefits, vegetable oils are more susceptible to degradation by oxidation or hydrolytic reactions. Therefore, the correct selection of vegetable substance, pH of the resulting solution and its control are important issues (Woods, 2005).

Vegetable oils (palm oil, groundnut oil, shear butter oil and cotton seed oil) have been used as lubricants in the turning operation of aluminum under varying spindle speeds, feed rates and depths of cut in the

Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Kaduna State, Nigeria. The parameters investigated were chip thickness ratio, surface finish and surface temperature. Vegetable oils reduced chip thickness ratio, improved surface finish and exhibited good cooling behaviour at the work piece-tool interface. This performance is due to their high viscosities and the presence of surface-active agents such as *stearic* acid and halogens, such as chlorine which help to reduce surface energy of a liquid and increase its wetting ability or oiliness (Obi *et al.*, 2013).

The credibility of lubricants can be determined by measuring the chip thickness ratio defined as the ratio of chip thickness size to that of the chip. In an earlier investigation (Childs, 2000), it was observed that chip thickness is strongly influenced by lubrication. In an air atmosphere the chip formed was thick but adding a lubricant caused the chip to become thinner and curled. That is, adding lubricant caused the friction between chip and tool to reduce.

Amrita *et al.* (2014) machined metals under dry conditions and made the following observations. The air surrounding the work piece acts as the cooling agent. Since air has low thermal conductivity, it acts as a poor coolant. High temperatures at tool-work piece interface causes failure of cutting tools, formation of micro cracks and surface roughness of work piece is compromised. In wet cutting, the work piece is machined under wet conditions. Most cutting fluids constitute ninety five percent of water and five percent of cutting oil. Usage of cutting fluids have shown significant changes in thermal properties, tool wear, surface roughness and cutting forces on tool and work piece respectively. Uncontrolled microbial contamination of metal working fluids represents both economic and health risk. Minimum quantity lubrication (MQL) is alternative to this problem which uses minute amount of cutting fluids which is about three or four times less than that of the amount commonly used in a flood cooling condition. MQL requires a fluid with high heat carrying and lubricating properties. The primary work was to prepare a cutting fluid by including 0.3 wt% of nano particles and to check its stability, as dispersion of nano particles in base fluid is a challenging process. Inclusions were applied at a flow rate of 10ml per minute while performing turning operation under constant cutting conditions. Performance of cutting fluids were evaluated by measuring cutting forces, cutting temperature near chip –tool interface, tool wear and surface roughness for each turn. The results were compared with dry and MQL application with emulsifier oil without nanoinclusions.

Shafaradeen and Jamiu (2013) investigated vegetable oils to serve as a possible replacement for non-biodegradable mineral oils, which are currently being used as base oil in cutting fluids during machining processes. In the study, the performances of palm oil and groundnut oil were compared with that of mineral oil-based cutting fluid during machining operation of mild steel. Temperature of the workpieces as well as their chip formation rates while using these vegetable oils as cutting fluids under different cutting speed (rev/min), feed rate (mm/rev) and depth of cut (mm) were compared with that of mineral oil and dry machining. The average temperatures of the workpieces were obtained at different depths of cut; 5mm, 10mm and 15mm under different cutting conditions. The temperature of the workpiece when groundnut oil was used as the cutting fluid was very close to that of the conventional oil, which was the lowest. Palm oil gave the overall highest chip thickness of 0.27 mm probably due to its better lubricating property. This was followed by that of the groundnut oil and the conventional oil as compared with dry machining of 0.17 mm thickness. Vitamin-C- rich-lemon fruit extract was used as an antioxidant to improve the oxidative stability of the vegetable oils. Viscosities of the various fluids were also analysed, and lowest average viscosity value of 28.0 mm^2/s was obtained using groundnut oil. This shows that groundnut oil possesses better fluidity and faster cooling capacity than other oil samples. Samples lubricated with mineral-oil based fluid show fine microstructures, similar to what obtained using groundnut oil-based cutting fluid. Fine surface morphology indicates improved surface roughness compared to using other cutting fluids. Based on these results, groundnut oil and palm oil where recommended as viable alternative lubricants to the mineral oil during machining of mild steel.

Paul and Pal (2011) investigated the performance of different types of cutting fluids (karanja oil, neem oil, conventional fluid) as compared to dry cutting condition during turning of mild steel. The use of vegetable based cutting fluid improves surface quality as compared to dry turning and conventional cutting fluid. They explained the reason for the lower temperature of neem vegetable oil and that of karanja vegetable oil and also, the lower viscosity of neem oil to that of karanja oil. Their performances when compared with conventional soluble oil have shown that they can perform the same function as the conventional oil in the machining of aluminum. They reduced chip thickness ratio, improves surface finish and exhibit good cooling behavior at the work piece tool interface.

Kuram *et al.* (2010) studied three different vegetable-based cutting fluids developed from raw and refined sunflower oil and two commercial types (vegetable and mineral based cutting oils), which were used to determine thrust force and surface roughness during drilling of AISI 304 austenitic stainless steel with HSSE tool. The ability of these vegetable cutting oils was investigated in terms of reducing thrust force and improving surface finish at different spindle speeds and feed rates during drilling. In the experiments, spindle speed, feed rate and drilling depth were considered as machining parameters.

II. Materials And Methods

Cutting Fluid Preparation

The oils sample used in this work was prepared into cutting fluid using the methods given by Lawal *et al.* (2007). In preparing each sample of cutting fluid, 500 ml of fixed oil was measured (using a 1-litre measuring beaker) and mixed with water in oil to water ratio of 1:10. This mixture was, thereafter, blended with 4% ordinary soap, 4% phosphorus, and 2% phenol all at room temperature. The formulations are tabulated in Table 4. The samples of cutting fluid used for the experiments were labeled samples A, B and C and their fixed oil constituents are as follows:

Sample A: Cotton oil (From Afcot oil Ngurore Area, Adamawa State)
Sample B: Groundnut oil (From Hong Local Government Area, Adamawa State)
Sample C: Neem oil (From Michika Local Government Area, Adamawa State)
Each of the cutting fluid developed had the composition given in Table 1.

Table 1: Cutting fluid composition

Material	Function	Content (% volume/volume of fixed oil)
Vegetable oil	Base oil	90
Washing soap (Cameroun)	Emulsifier	4
Phenol (benzyl alcohol)	Disinfectant	2
Phosphorus	Extreme pressure agent	4

Methods of determining the Physico-chemical Properties

Saponification Value

A mass of 0.5g of the oil was accurately weighed in 250ml conical flask litted in an air condenser. 10ml of absolute (100%) alcohol (ethanol) was added to dissolve the oil and 2.5M KOH solution was later added. The flask was reflux on a sand bath for about two (2) hours and was allowed to cool, few drops of phenolphthalein indicator was added. The unreacted potassium hydroxide was titrated against a standard 1M oxalic acid until the pink colour disappears. The saponification value was calculated using equation 6 (Association of Analytical Chemist, [AOAC], 2000).

$$\text{Saponification value} = \frac{56 \times (V_1 - V_2) \times 1000}{2000} \quad (1)$$

Where;

V_1= volume of 1mol oxalic acid used for blank (control) (cm^3)
V_2 = volume of 1mol oxalic acid used for sample (cm^3)

Iodine Value

A mass of 1g of the oil was accurately weight and dissolved in 25ml of chloroform in a 500ml conical flask. 25-50ml of Wij's solution (standard) was added to enable about 75% of the reagent to remain unreacted. The flask was corked and shaken and it was allowed to stand in the dark for about an hour with occasional shaking. 20-40ml of potassium iodide solution and 100ml of water was added. The liberated iodine was titrated against standard 0.1M sodium thiosulphate solution using starch indicator. Also perform a blank (control) experiment.

The iodine value was calculated using equation 7 (AOAC, 2000).

$$\text{Iodine value} = \frac{(V_1 - V_2) \times M \times 127 \times 100}{W \times 1000} \quad (2)$$

Where;

W = Weight of oil sample (g)
M = Molarity of sodium thiosulphate (g/cm^3)
V_1= Volume of sodium thiosulphate used for blank (control) (cm^3)
V_2 = Volume of sodium thiosulphate used for sample (cm^3)

Acid Value

The oil was thoroughly mixed and 2g of the melted oil was accurately weighed in a 250ml conical flask containing 50ml of freshly neutralized hot ethyl alcohol and about 1ml of phenolphthalein indicator solution. The mixture was heated for about fifteen minutes in water bath (75-80^oC). The mixture was titrated while hot against standard alkali solution shaking vigorously during the titration. Colour changes from colourless to light pink indicate the end point of the titration. The acid value was calculated using equation 8 (AOAC, 2000).

$$\text{Acid Value} = \frac{56.1 \times V \times N}{W} \quad (3)$$

Where;

W = Weight of oil sample (g)
N = Normality of KOH solution (g/cm^3)
V= Volume of standard KOH solution (cm^3)

Density

The weight of an empty density bottle was measured then it was filled to mark with the oil and its weight was again measured. The former weight was subtracted from the later to know the actual weight of the oil. Since the volume of the bottle is known, therefore density of the oil was calculated using equation 9 (AOAC, 2000).

$$\text{Density} = \frac{\text{Mass of the oil}}{\text{Volume of the bottle}} \quad (4)$$

Where;

D = Density (g/cm^3)
M = Mass of the oil (g)
V= Volume of the bottle (cm^3)

Viscosity

Twelve (12) balls were placed into a petridish, the diameter of each ball and the probable mass of the petridish together with the balls were determined. The mass of the petridish and the balls were also determined separately. 30ml of the oil was measured into a measuring cylinder and two rubber rings were placed between the walls of the measuring cylinder. The balls (one at a time) were dropped into the measuring cylinder containing the oil. The time of fall of each ball between the upper and the lower rubber ring were measured using a stop watch. The biggest and the smallest values were eliminated and the density was measured. The viscosity of the oil was calculated using equation 10 (AOAC, 2000).

$$\mu = \frac{2}{9} g r^2 (\rho\text{ball} - \rho) \quad (5)$$

Where;

g = acceleration due to the gravity (m/s^2)
r = radius of the ball (m)
ρball = density of the material of the ball (kg/m^3)
ρ = density of the investigated oil (kg/m^3)
Δt = time of the free fall of the ball between the two rings placed at the distance ΔL

III. Results And Discussion

Physico-chemical Properties of Cotton, Neem and Groundnut Oils

The results of physico-chemical analysis of cotton, groundnut and neem oils are presented in Table 5. The experimental results of acid value (of cotton, groundnut and neem oils) which is a measure of the amount of free fatty acid present in fats/oil are presented in Figure 2, which indicates that the acid value of groundnut oil (3.927 mgKOH/g) was greater than that of neem oil (1.122 mgKOH/g) and cotton oil (0.3817 mgKOH/g) which is low signifying that the oils are edible and can stay for a long time without getting rancid. Standard values ranges from (0.3 – 4 mgKOH/g) and the values obtained are in agreement with the report that acid value of oils suitable for edible purpose should not exceed 4 mgKOH/g (Tan *et al.*, 2002). The results obtained are similar to the results obtained by Soetaredjo *et al.* (2008).

The saponification value which is the measure of the mean molecular weight of the fatty acids present in fats is presented in Figure 3. Figure 3 shows that cotton oil has the highest value (214.5825 mgKOH/g) followed by groundnut oil (201.9600 mgKOH/g) and neem oil (196.3500 mgKOH/g). Standard values ranges from (188- 196 mgKOH/g) for most oil plant origins (Odeomelam, 2005). It is reported that oils with low free fatty acid usually have high saponification value (Orhevba and Efomah, 2012) as such cotton and groundnut seed oils are good for soap production.

Density values of the oils were determined and presented in Figure 4. It is the ratio of the mass of individual oil to the volume it occupied. Figure 4.3 indicates that neem oil has the highest value (1.00 g/cm^3), whereas cotton and groundnut oils have 0.995 g/cm^3 and 0.960 g/cm^3, respectively. The results obtained are similar to the results obtained by Kuram *et al.* (2010).

Iodine value as the proportion of unsaturated acids present in a certain volume of oil is one of the properties of unsaturated organic compounds. Iodine has the ability to form double bonds with halogens. Figure 5 presents the experimental results. The figure shows that iodine value is higher in cotton oil (119.02 g/I_2/g) than in groundnut oil (102.84 g/I_2/g). The iodine value classifies cotton and groundnut oils as drying. Orhevba and Efomah (2012), proposed that iodine value above 100 g/I_2/g makes an oil to be classified as drying, while below 100 g/I_2/g is non-drying. Therefore, neem oil with 83.78 g/I_2/g which is below 100 g/I_2/g is non-drying. The higher the iodine value the more the double bonds present, which consequently reflects the reactivity of the oil. i.e. the oil becomes more susceptible to oxidation and rancidification and the lower the iodine value the lesser the number of unsaturated bonds, thus the lower the susceptibility of such oil to oxidative rancidity (Kochhar, 1998). The iodine values of groundnut and neem oils are low enough to avoid the oils drying out easily with oxidation and thus are good for cutting oil.

Table 2: Physico-chemical Properties

Parameters	Values		
	Cotton Oil	Groundnut Oil	Neem Oil
Acid Value (mgKOH/g)	0.3817	3.927	1.122
Saponification Value (mgKOH/g)	214.5825	201.960	196.350
Density (g/cm^3)	0.995	0.960	1.000
Iodine Value (g/I_2/g)	119.02	102.84	83.78
Kinematic Viscosity (mm^2/s)	5.39	7.08	6.50

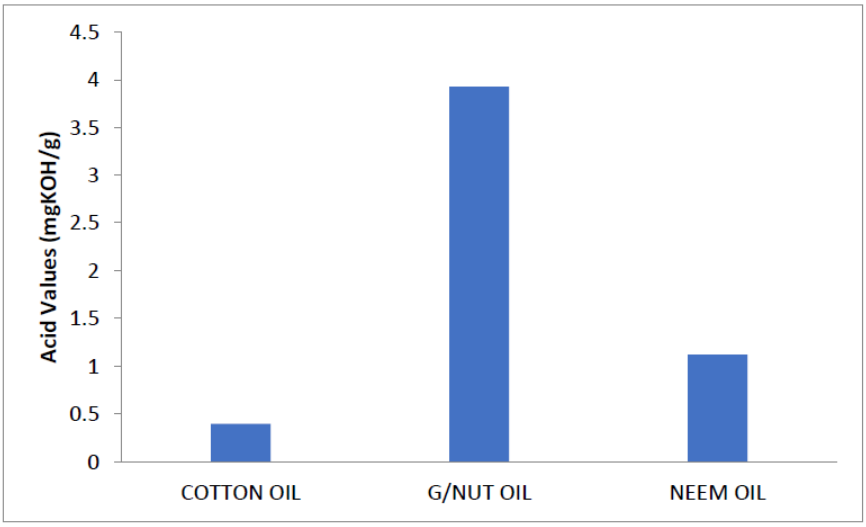

Figure 1: Comparison of Acid Values of the Cutting Oils

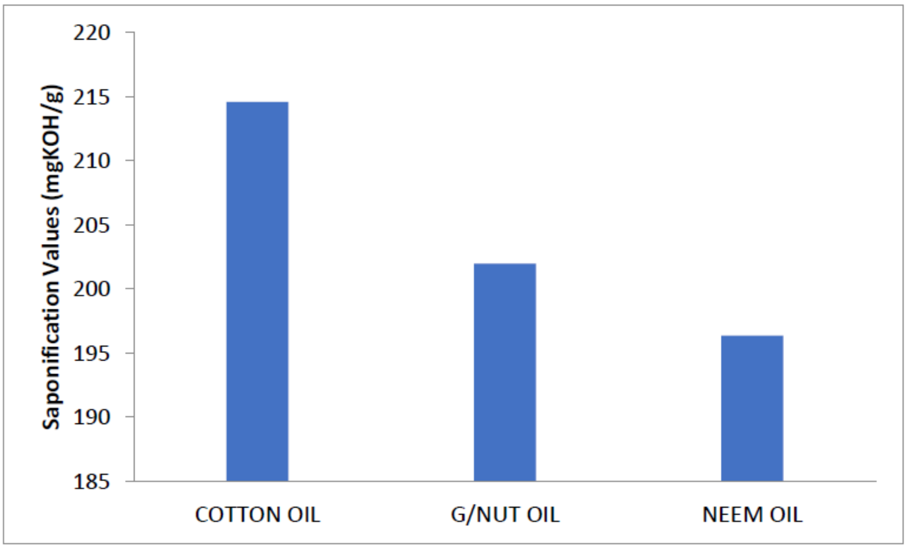

Figure 2: Comparison of Saponification Values of the Cutting Oils

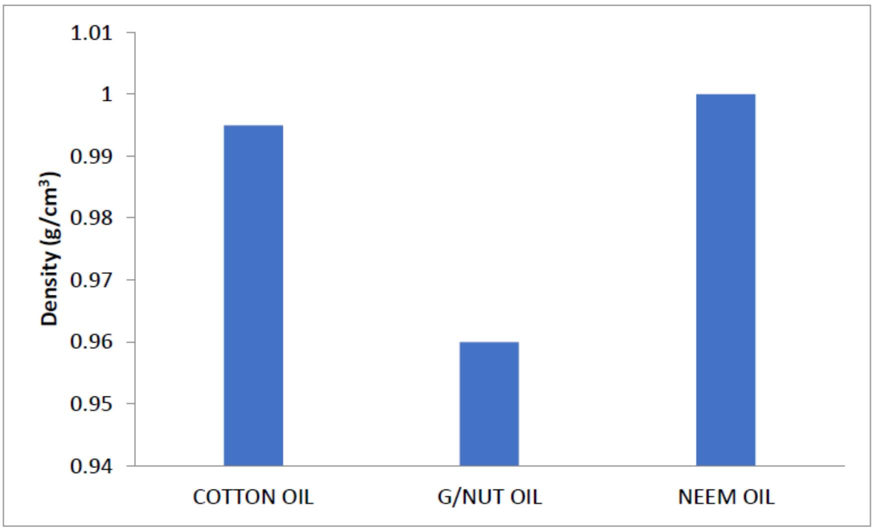

Figure 3: Comparison of Density Values of the Cutting Oils

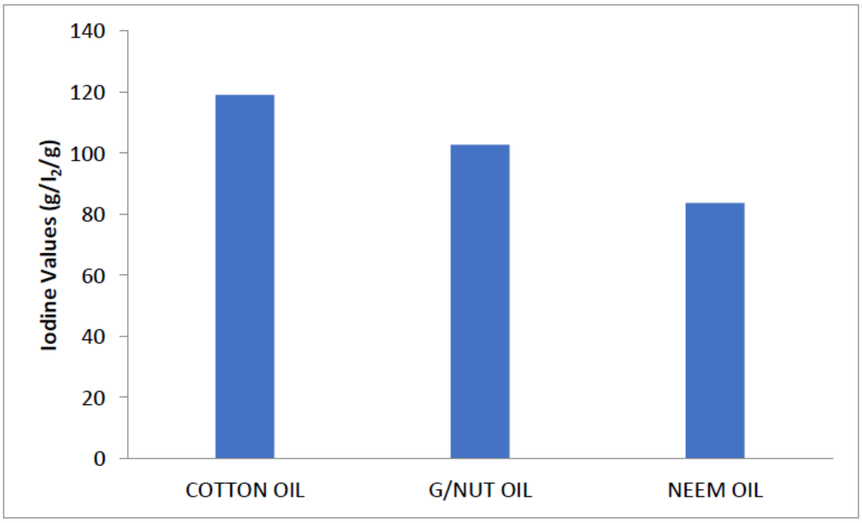

Figure 4: Comparison of Iodine Values of the Cutting Oils

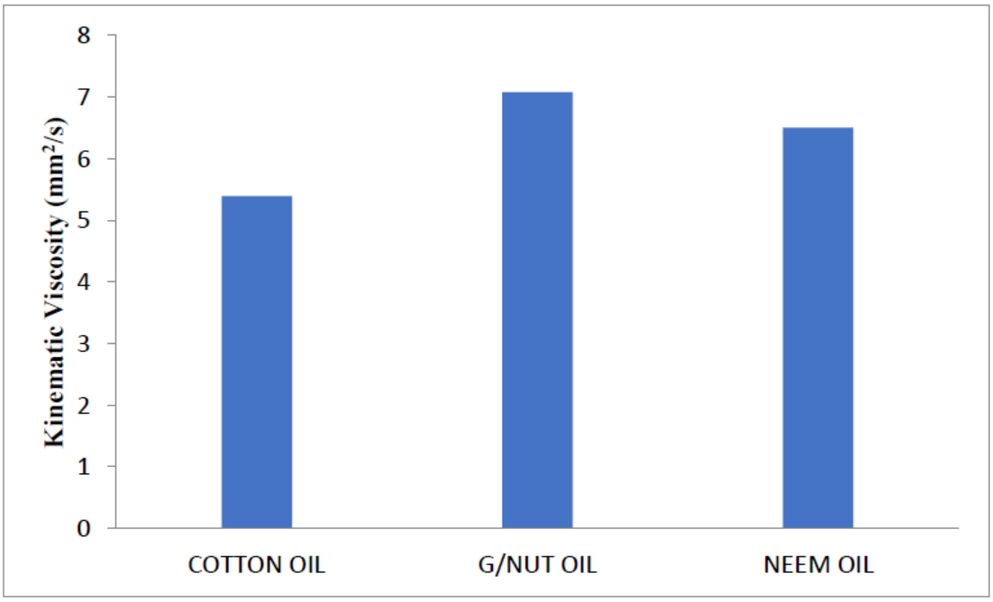

Figure 5: Comparison of Kinematic Viscosity of the Cutting Oils

The kinematic viscosity trend in Figure 5 shows that cotton oil has the lowest value (5.39 mm^2/s) while groundnut oil has the highest value (7.08 mm^2/s) all at 40 ^oC. The viscosity was significantly lower than viscosities (8.80, 8.67, 8.50, 8.46, 8.65, 8.50 and 26.50 mm^2/s) for Rapeseed, Canola, Soy bean, Crambe and Waste Vegetable oils, respectively all at 40^oC reported by Thompson and He (2006).

The specified standard limits for viscosity of oils at 100 ^oC are 5- 100 mm^2/s. The result of this study is within the range of international standard organization (ISO) as reported by Tobinson and Jinn (2014). Low viscosity of the oil samples indicates a low resistance to flow on the other hand, high viscosity implies a high resistance to flow. A good cutting fluid is expected to have a moderate viscosity to allow for low resistance to flow as well as enhancing good lubricity.

IV. Conclusions

Three vegetable cutting fluids have been formulated from cotton, groundnut and neem oils. The formulated cutting fluids contain 90% base oil, 4% washing soap as emulsifier, 2% benzyl alchohol as disinfectant and 4% phosphorus as extreme pressure agent.

The physico-chemical properties of the cutting oils determined include; acid value, saponification value, iodine value and density. The acid values for cotton, groundnut and neem oils were 0.3817, 3.927 and 1.122 mgKOH/g, respectively. Cotton, groundnut and neem oils have saponification values 214.5825, 201.960 and 196.350 mgKOH/g, respectively.

Density values for cotton, groundnut and neem cutting fluids were 0.995 g/ml, 0.960 g/ml, and 1.000 g/ml, respectively. While iodine values for cotton, groundnut and neem oils were 119.02, 102.84, and 83.78 $g/I_2/g$ and kinematic viscosity are 5.39, 7.08 and 6.50 mm^2/s, respectively.

V. Recommendations

1. Groundnut cutting fluid is recommended as a better cutting fluid with a relatively moderate viscosity which enhances the lubricity of the fluid and the relatively low iodine value which does not allow the fluid to oxidize and dry during machining.
2. Flash points of groundnut cutting fluid, cotton cutting fluid, and neem cutting fluidshould be determined to ascertain their safety for machining.
3. Further studies on other locally sourced vegetable-based oil should be carried out.

References

[1]. Amrita, M., Shariq, S.A., and Charan, C. (2014). Experimental investigation on application of emulsifier oil-based nano cutting fluids in metal cutting process, 12th Global Congress on Manufacturing and Management (GCMM), 2014. Procedia Engineering, vol. 97, pp.115-124.

[2]. Deshayes, L. (2003). Cutting methodology study, Link between couple work piece tool and Machine Tool work piece system (Methodologiedtude de la coupe, liaison entre couple outilMatierealet Piece outil Machine)", Insa de Lyon, 271p.

[3]. Kochhar, S. L. (1998). Economic Botany in the Tropics. 2nd Edition, Macmillan India Ltd, pp. 354 – 355.

[4]. Kuram, E., Ozcelik, B., Demirbas, E.,and Sik, E. (2010). Effects of the cutting fluid types and cutting parameters on surface roughness and thrust force, Proceedings of the World Congress on Engineering (WCE) 2010, London, UK, vol. II, June 30–July 2, pp. 1-5.
[5]. Lawal, S.A., Abolarin, S.M., Ugheoke, B.I., and Oneche, E.O. (2007). Performance evaluation of cutting fluids developed from mixed oils, Leonado Electronic Journal of Practice and Technologies ISSN 1583-1078 Issue 10, pp. 137-144.
[6]. Lopez de Lacalle, L. N., Ângulo, C., Lamikiz, A. and Sanchez, J. A. (2006). Experimental and numerical investigation of the effect of spray cutting fluids in high-speed milling. Journal of Materials Processing Technology, Vol.172, No.1, p.11-15.
[7]. Obi A. I., Alabi, A. A., Suleiman, R. B. O., and Anafi, F. O. (2013). Verification of some vegetable oil in cutting fluid for aluminum, Nigerian Journal of Technological Development, Vol.10, No.1, pp. 7-12.
[8]. Odoemelam, S.A. (2005). Proximate Composition and Selected Physico-chemical Properties of the Seeds of African Oil Bean (Pentaclethramarcrophylla). Pakistan Journal of Nutrition, Vol.4, No.6, pp. 382-383.
[9]. Orhevba, B. A., and Efomah, A. N., (2012). Extraction and Characterization of Cotton seed (Gossypium) Oil. International journal of basic and applied science. Vol.1, No. 2,pp. 398 – 402.
[10]. Paul, S.O., and Pal, P.K. (2011). Study of surface quality during high speed machining using eco-friendly cutting fluid.Machine of technology materials Vol. 73, No.4, pp 24-28.
[11]. Sharafadeen, K. K., and Jamiu, K. O., (2013). Performance evaluation of vegetable oil- based cutting fluid in mild steel machining. Chemistry and Materials Research. Vol.3, No. 9, pp. 35 – 46.
[12]. Soetaredjo, F.E., Budijanto, G.M., Prasetyo, R.I., and Indraswati, N. (2008). Effects of pre treatment condition on yield and quality of Neem oil obtained by mechanical pressing. Journal of Engineering and Applied Sciences Vol.3. pp. 45–49.
[13]. Suda, S.,Wakabayashi, T., Inasaki, I and Yolota, H., (2004). Multifunctional Application of a Synthetic Ester to Machine Tool Lubrication Base on MQL Machining Lubricants. Annals of CIRP Vol.53, No.1, pp. 61-64.
[14]. Thompson, J. C. and He, B. B. (2006) Characterization of crude glycerol from biodiesel production from multiple feed stocks, Applied Engineering in Agriculture, Vol. 22, pp. 261-265.
[15]. Tobinson B., And Jinn, V. (2014). Determination of Suitability of Groundnut Oil as a Hydraulic Fluid. European Journal of Mechanical Engineering Research Vol.1, No.1, pp.1-13.
[16]. Woods, S. (2005). Going Green. Cutting Tool Engineering Vol.57, No.2, pp. 48-51.