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PERFORMANCE EVALUATION OF NON-EDIBLE VEGETABLE SEED OIL AS CUTTING FLUID IN METAL TURNING OPERATION

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ABSTRACT

In this research work, Oil was extracted from non-edible vegetable seeds (Cocoa seeds CS, Soursop seed SS, and blend of 50%CSO and 50%SSO). The percentage yield of the non-edible vegetable seeds oil was calculated and the result are analysed in pie chat. The physicochemical analysis of all the non-edible vegetable seed oils and mineral cutting fluids were carried out. The non-edible vegetable seeds oils were prepared into cutting fluid with additive (Washing Soap, Tri ethanol Amine, and Distilled Water) used by percentage of volume and blended non-edible vegetable seed oil with difference percentages. The surface turning operation was carried out using Ø30mm diameter mild steel (AISI 1020) as work piece, then the two cutting fluids (non-edible vegetable base cutting fluid NVBCF and mineral cutting fluid MCF) were applied through gravitational method. The temperature, surface roughness, and chip thickness were measured. All the machining output parameters (Interfacial Temperature, Surface Roughness, and Chip thickness) were used for comparison with vegetable based cutting fluids and mineral cutting fluids. The results showed that increase in speed decreased the surface roughness of AISI 1020 steel; and the least surface roughness-value and surface temperature value was 1.7µm, 48.9^{0}C obtained at the spindle speed of 200 rpm for blended of 50%CSO and 50%SSO) oil-based fluids. The NVBCFs of different formulations all showed good lubricant properties which compared favourably with the commercial cutting fluids (CCFs). The non-edible vegetable seeds base cutting fluids (NVSBCFs) formulation that showed the best surface cooling characteristics, lowest roughness, and chip thickness formation was blended of 50%CSO and 50%SSO) Cutting fluids, even better than the commercial cutting fluid (CCFs).

KEYWORDS: Turning Operation, Cutting Fluid, Cocoa Seeds Oil, Soursop Seeds Oil, AISI 1020 Steel.

INTRODUCTION

The productivity in any metal cutting manufacturing sector is influenced by different types of cutting fluids used. Metal cutting fluids is used in all metal cutting processes to eliminate chips, inhibitor of corrosions, lubricate, and provide the cooling effect from the working zone (Mbishida et al, 2018). Cutting fluid was first applied by a man called F. Taylor in 1894, who observed that metal cutting speed can be increased by 33% without limiting the life of tool by applying good amounts of water in the cutting environment (Diniz, A. E., and Micaroni, R., (2007). Metal cutting fluids increase the power of the production systems, tool life, and provide both lubrication and cooling at work surface (Jeevan et al, 2018). There are three main positive effects which cutting fluid generates on the process: lubrication on the interface, heat and chips removal. However, the disadvantages caused by mineral cutting fluid (MCF) include the negative effects they have caused in the environment and worker's health. When discharging inappropriately, cutting fluids may damage and destroy soil and water resources, causing serious environmental problem, respiratory and skin damage (Mannekote e*t al*, 2018). For these cases it is good to develop alternative ways to avoid environmental and heath damage. The use of vegetable plant fluids may give better production in cutting operation combined with good eco- friendliness (Gajrani K. K., and Sankar M. R., 2017. Interest in vegetable plant based-oil cutting fluids is growing rapidly. Vegetable plant based-oil may enhance the cutting performance, reduce the surface roughness and tool life according to industrial study (Somashekaraiahet al 2016). They have many environmental benefits; vegetable plant oils are degradable by oxidation. The correct selection of the vegetable substance, the pH value of the resulting solution and its control are important issues (Obi et al, 2013).

In application of metal turning, grinding, milling and boring, cutting fluids are used throughout. Large machining facilities use central fluid systems with capacities as high as 760 000 litters, and it is estimated that over380 million litters of metalworking fluids are used each year (Ekundayo, 2004.). Depending on the type of machining operation, the cutting fluid needed may be a coolant, a lubricant, or both. Cutting fluids can perform effectively depending on machining operation, work piece materials, tool, cutting speed, and the method of application. Water is an excellent coolant and can reduce effectively the high temperatures developed in the cutting zone. However, water is not an effective lubricant; hence it does not effectively reduce friction. Furthermore, it causes the rusting of work pieces and machine-tool components. On the other hand, effective lubrication is an important factor in machining operations (Kalpakjian and Schmid, 2006), (Cassin, 1967).

From literature reviewed so far, the use of blend of cocoa seed oil (*Theobroma Cacao L*) and soursop seeds oil *(Annona Muricata L.*) as materials for metal cutting fluid production has not been reported. The effect of different volume combination of these materials on the interfacial temperature, surface roughness, and chip thickness will be investigated. The performance results of the produced metal cutting fluid will be compared with the commercial cutting fluids.

MATERIALS AND METHODS

2.1 The Experimental Materials are

1. Non-Edible Vegetable Base Oil: (a) Cocoa Seed Oil (CSO) *(Theobroma Cacao L*), (b) Soursop Oil (SO) *(Annona Muricata L*.), and (c) Mineral Cutting Fluid (MCF).
2. Additive: (a) Washing Soap (b) Tri ethanol Amine (c) Distilled Water.
3. Mild steel (work piece)-AISI 1020.

2.2 Methods of Extraction

The commonest methods used for extraction of oil from seeds and nuts are mechanical extraction, solvent extraction, traditional extraction and super critical fluid extraction. But mechanical extractions were used in this work.

2.2.1 Traditional extraction of seed oil

Traditional method of oil extraction entails oil seed being subjected to thermal treatment, crushed and milled into slurry, water is then added to the slurry and the mixture stirred and kneaded by hand until the oil separates to the top and sides of the utensils being used for the kneading. This is the most usual way oil in being extracted and the process is called water floatation process (Aremu *et al.*, 2015). Traditional method can only be operable on a small scale and difficult in production as compared with other methods of extraction.

2.2.2 Mechanical Extraction of Seed Oil

Mechanical extraction of oils is among the process of vegetable oils extraction in small farmer technology. This is because this type of equipment associates both small scale and low cost when compared to the other methods. Another important advantage is the possibility of using cake resulting from the pressing as fertilizer or animal feed, since it is free of toxic solvents (Bachmann, 2004). Mechanical extraction of oil is gotten in different ways such as reduction in size to produce slurry or pulp, separation in a press. In general, the single-stage operation is more economical, permits higher outputs and has lower capital and operational cost but not suitable for hard nuts as the two stage of expression is more effective. The degree of effectiveness varies with the kind of oilseed and method of oil expression (Akinoso, 2006)

2.2. 3 Extraction of Oil from Cocoa Seed (CS) and Soursop Seed (SS)

The non-edible vegetable plant seeds were washed thoroughly with water and split opened with a sharp kitchen knife in other to remove the pulp from kernel, as shown below Figure 2. The prepared seeds samples were dried at a low temperature for 1 hour. The dried sample was measured to be 3kg and grounded uniformly using a commercial grain mill machine (Ibrahim A.A, 2016), (Akinoso R 2006). However oil from non-edible vegetable seeds was extracted by manual mechanical screw press equipment (Shashidhara Y.M., Jayaram S.R. 2013), (Shashidhara Y.M., Jayaram S.R., 2010), and (Bachmann, J. (2004).

Figure 2: Cocoa Seeds (CS) and Soursop Seeds (SS).

2.3 Formulation of Difference Cutting Fluid Samples

The non-edible vegetable plant seeds oil used were prepared into cutting fluid with different additive (Triethanol amine, Distil Water, and Washing Soap) added. Triethanol amine is used to provide the alkalinity needed to protect against rusting and it acts as an anti-oxidant. It also controls the evaporation rate of water in cutting fluid. Washing soap is an unsaturated fatty acid which is used as an emulsifying or solubilising agent. In preparing these cutting fluids, 200Cl measuring cylinder was used throughout in the Table 2.1 below, to measure out 65% of the vegetable base oil sample used in the experiment. The 65% commercial cutting fluids (CCF) mixed with different additive by (% Vol.), was still used. The formulations are tabulated below.

Table 2.1: Samples Formulations and Mineral Cutting fluid Composition by Volume.

% Composition by Vol.				
MATERIALS	**Base Oil**	**Tri-ethanolamine**	**Distil Water**	**Washin g Soap**
Cocoa Seed Oil (CSO)	65	10	15	10
Soursop Seed Oil (SSO)	65	10	15	10
Blend of 32.5%(CSO) + 32.5% (SSO)	65	10	15	10
Mineral Cutting Fluid (MCF)	65	10	15	10

2.4 Performance Test Criteria

The developed base cutting fluids was investigated through three output parameters: temperature, surface roughness, and chip thickness with the input parameters, cutting speed, cutting depth, and cutting time. Temperature is the key being a measure of the ability of the cutting fluid to remove heat away from the working environment during metal cutting processes. In addition, all the physicochemical analysis of the extracted non-edible vegetable oil was also determined. The metal turning operation was performed on the centre lathe (Brand/Model: No.5226 China) with speeds 80, 150, 200rpm. The speeds in revolution per minute were varied and cutting depth in mm and feed rates in mm/rev were kept constant. The chip thickness of the chips produced was determined through stainless vernier calliper-Brand/ Model: More and Wright NO 712 Range: 0.6 to 1.0 pitch. During the machining process, the interfacial temperature was measured using infra-red thermometer.

Procedure A mild steel smooth rod of 25 mm diameter was machined on a lathe, using the non-edible vegetable cutting fluid and the mineral cutting fluid for performance evaluation. The work piece was inserted on a chuck of lathe machine and surface turning operation was carried out. The oils were used at room temperature. First, the speed (rpm) was varied while the feed rate was kept constant at 0.5 mm/rev and the depth of cut at 2mm. During this phase, the cutting fluids were applied directly on the work piece tool interface by gravitational processes. The temperature variations and time taken were measured using an infra- red thermometer and stop watch (see Figure 2.1). At the end of the three processes the chips collected for each procedure were measured for thickness using a vernier calliper, and surface generated on the work- piece during turning process, was evaluated using a surface roughness tester in (µm).

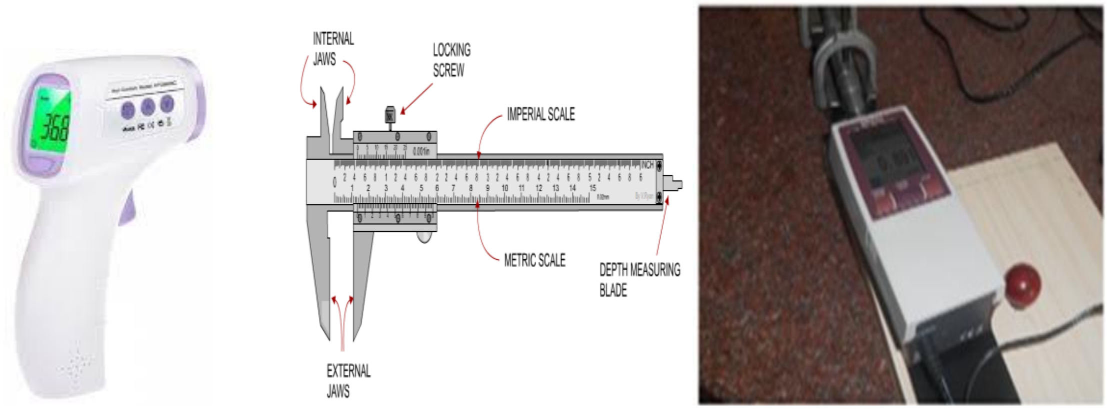

Figure 2.1: Infra-red Thermometer, Vernier Calliper, and Surface Finish Tester.

III. RESULTS AND DISCUSSION

Table 3.1: Percentage Yield of the Vegetable Base Oil.

NON-EDIBLE VEGETABLE SEED BASE OIL	African Pear Seed (CS)	Apricot Kernel (SS)	Blended 1/2(CS) & 1/2(SS)
Weight (W_v) of Vegetable seed before Extraction in Kilogram(Kg)	**3.3**	**3.7**	**3.5**
Weight(W_c) Of Cake After Extraction In Kilogram(kg)	**2.6**	**2.9**	**2.7**
Weight Of Extracted Oil (W_v-W_c)	**0.7**	**0.8**	**0.8**
Percentage Yield (%W_v)	**21.2**	**21.6**	**22.9**
Percentage Yield (%W_c)	**26.9**	**27.6**	**29.6**

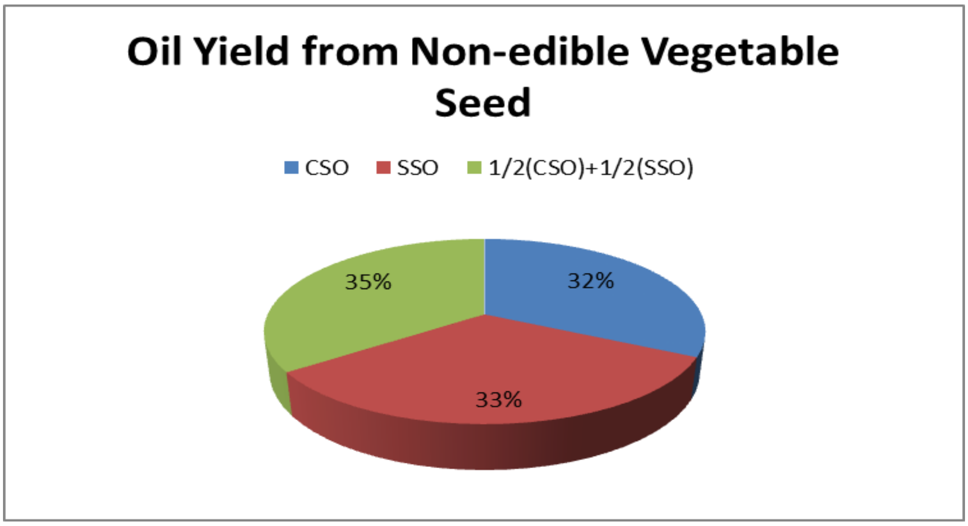

Figure 3.1: Oil Yield from Non-edible Vegetable Seed.

From the observation in Figure 3.1 bleed of ½(CSO) + ½(SSO) seed has the highest oil yield with 35% based on the cake and fresh fruit; followed by Soursop Seed (SS) with 33%, and Cocoa seed (CS) with the least yield value of 32% based on the cake and fresh fruits , respectively. The non-edible vegetable oil produced was based on the formula below:

$$O_v = \frac{Wv - Wc}{Wv} * 100\% \quad (X)$$

$$O_c = \frac{Wv - Wc}{Wc} * 100\% \quad (Y)$$

Table 3.2: Physicochemical Properties of Non-edible Vegetable Seed Oil with Mineral Cutting Fluid.

SEED OIL & MCF	DINAMIC VISCOCITY N-s/m^2	FIRE POINT ^{0}C	FLASH POINT^{0}C	ADHESIVENESS g/m^2	ACID VALUE (mg KOH/g)	pH VALUE	POUR POINT^{0}C
CSO	0.03913	250	251	343	2.737	7.28	-0.199
SSO	0.0454	241	239	401	2.326	7.27	-0.201
41.5%CSO+ 58.5%SSO	0.0402	259	258	305	1.999	7.01	-0.330
72.6%CSO+ 27.4%SSO	0.0278	246	248	277	2.201	6.98	-0.356
50%CSO+ 50%SSO	0.0343	283	263	287	1.971	6.35	-0.411
Mobicut 102MCF	0.0293	253	250	269	2.470	6.87	-0.233

The **viscosity** of the cutting fluids (vegetable plant) and commercial mineral cutting fluids was analyzed (Table 3.2). High viscous fluids produced good lubrication (Noor El-Din, M. R., el tal, 2018), withstand temperature, and reduced friction; but will required more energy for the machine to move freely. The optimum viscosity from Table 3.2 above that will lubricate, reduced temperature and friction was 0.0343N-s/m^2 at 50%CSO+50%SSO.

From Table 3.2, the non-edible vegetable seed oil (50%CSO+50%SSO) possesses high **fire and flash points** of 283°C and 263°C respectively, as it should not catch fire at higher temperatures.

Adhesiveness is the property of a fluid to stick to the surface of work zoon during machining and maintain a later separating both the elements, so that friction is less. Adhesiveness also should be optimum. From the Table 3.2, the blend of non-edible vegetable seed oil (50%CSO+50%SSO) has got an optimum value of 287 g/m^2. So the non-edible vegetable seed oil (50%CSO+50%SSO) is considered as best cutting fluid.

From Table 3.2, it can be observed that the corrosion of the non-edible vegetable seed oil and the cutting fluid can be measured through the value of the acid available in the oil. The lowest **acid value** was 1.971mgKOH/g at the blend of 50%CSO+50%SSO, which gives the optimum performance of machining process.

Low **pH** supports the oil usage in cutting fluids because it is less harmful to machine operators. This means that it is possible for coolant to corrode metal work piece (mile steel). Table 3.2 shows that the non-edible vegetable oil of 50%CSO+50%SSO has a minimum pH of 6.35 that cannot hurt the skin (Ibrahim, 2016**)**; the lower values of the pH, the better for it to be used as metal cutting fluid.

From Table 3.2, the lowest **pour point** was found at the non-edible vegetable seed oil (50%CSO+50%SSO) which was –0.411^{0}C, flow freely without obstruction while the mineral cutting fluid was -0.233^{0}C. Minimum pour point, give better the flow of a fluid, because pour point by definition is the smallest temperature a fluid can flow.

3.1 Cutting Fluids Performance Test Results in Surface Turning Operation

3.1.1 Thermal Conductivity (Temperature) response

Table 3.3: Temperature (^{0}C) with Speed (rpm).

Speed(rpm)	CSO	SSO	50%CSO+ 50%SSO	MCF
80	50.1	57.4	43.5	45.0
150	56.3	67.9	46.2	57.8
200	68.9	72.1	48.9	61.1

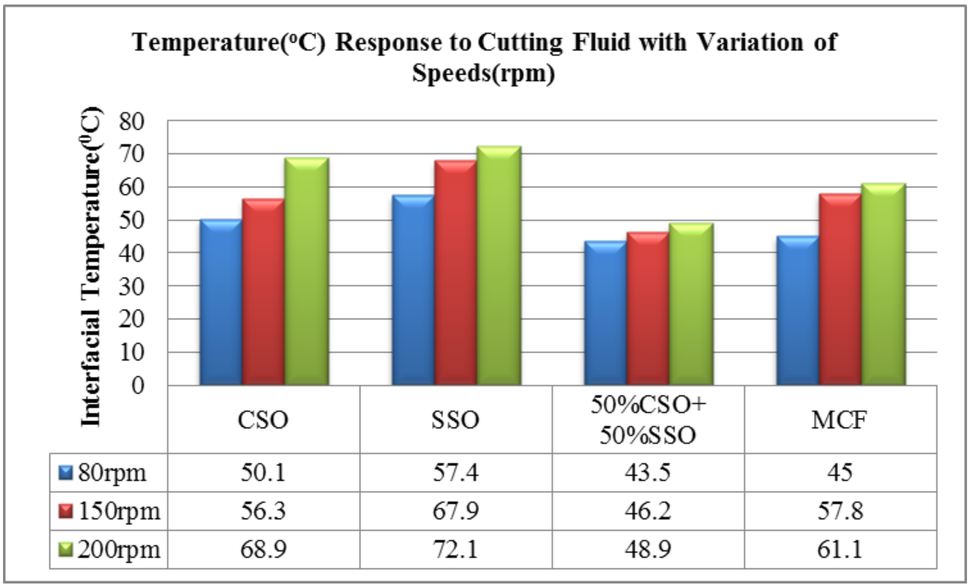

Figure 3.2: Temperatures with Cutting Fluids and Variation of Speeds.

Figures 3.2 shows that increase in speed increases the temperature generated irrespective of the cutting fluid. This is because as the cutting force increase, the cutting speed also increased and since quantity of heat produced is the product of speed and force, it follows that more heat would be generated with an increase in cutting speed. In Figure 3.2 the speed of 90rpm; blended non-edible vegetable seed, 50%CSO and 50%SSO has the lowest temperature of 43.5^{0}C, again at speed of 125rpm blended of 50%CSO and 50%SSO has the lowest temperature of 46.2^{0}C and at the speed of 180rpm, blended of 50%CSO and 50%SSO has the lowest temperature of 48.9^{0}C followed by mineral cutting fluid. When two metals in contact exhibit relative to motion, there is tendency that heat will generate which will increase the interfacial temperature. When friction rises, the temperature will increase and cause surface wearing. However under investigation, the various developed cutting fluids and commercial cutting fluids have their deferent cutting performances. The lowest in all was blended of 50%CSO and 50%SSO which was taken as the best cutting fluid.

3.1.2 Surface Finish (Roughness) Response

Table 3.4: Surface Roughness (µm) with Speed (rpm).

Speed(rpm)	CSO	SSO	50%CSO+50%SSO	MCF
80	2.9	3.0	2.7	2.8
150	2.3	2.4	2.1	2.2
200	1.9	2.1	1.7	2.0

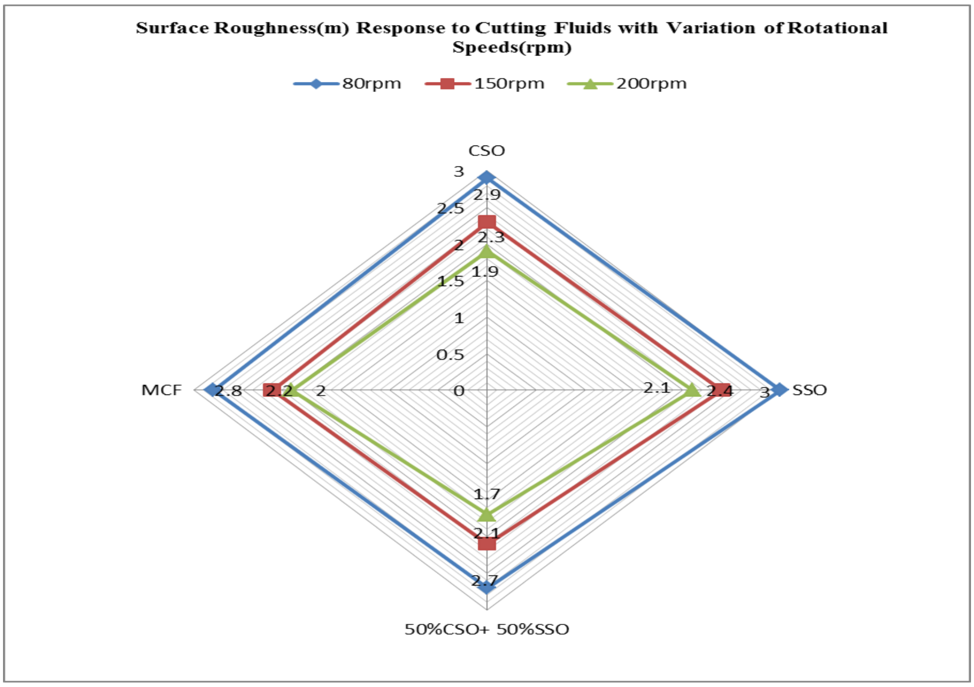

Figure 3.3: Surface Roughness (µm) with Cutting Fluids and Variation of Rotational Speeds (rpm).

The significant factors that affects the surface finish in any metal cutting operation are the cutting fluid, cutting tool, work piece [Eziwhuo et al,]. From figure 3.3, shows that as the cutting speed increased, the surface finish reduced. This is because as the cutting force decrease, the cutting speed increases; because the quantity of heat produced at the interface is the product of speed and force. When head rises, the friction will increase and cause surface wearing. However this research shows that various developed vegetable cutting fluids and commercial cutting fluids have deferent cutting results. In Figure 3.3 at speed of 200rpm, the blended of 50%CSO and 50%SSO has the lowest surface roughness of 1.7µm; followed by cocoa seeds oil (CSO) with values of 1.9µm; commercial cutting fluid (CCF) with values of 2.0µm and soursop seeds oil (SSO) with values of 2.1µm. The optimal value in all is the blended of 50%CSO and 50%SSO which has surface roughness of 1.7µm at 200rpm, 2.1µm at 150rpm and 2.7µm at 80rpm is the best cutting fluid. This is due to the efficacy of the lubricating ability of blended of 50%CSO and 50%SSO based cutting fluid when compared to that of other developed vegetable base cutting fluids and commercial cutting fluid. In conclusion, it is obvious to observe that high lubrication is due to high viscosity which is a property of fluid that functions to prevent wearing of two metals in contact.

3.3.2 Chip thickness Response

Table 4.5: CHIP THICKNESS (mm) WITH SPEED (rpm).

Speed(rpm)	CSO	SSO	50%CSO+ 50%SSO	MCF
80	0.11	0.20	0.21	0.13
150	0.23	0.24	0.30	0.26
200	0.24	0.31	0.38	0.28

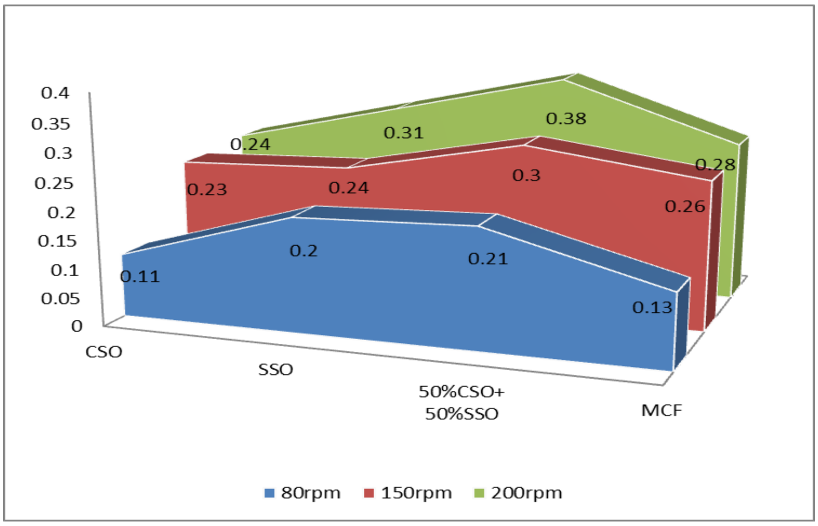

Figure 3.4 Chip thicknesses (mm) with Cutting Fluids and Variation of Rotational Speeds (rpm).

Figures 3.4 shows that increase in speed increase the chip thickness for all the developed vegetable cutting fluids and commercial cutting fluids. This is because a high value of chip thickness gives better rate of metal removal which entails completing the cutting at the given time. It is understood from the chip thickness chart in Figure 3.4 above that blend of ½(CSO) + ½(SSO) has the highest value of 0.38mm at 200rpm follow by SSO with value of 0.31mm at 200rpm and CSO value of 0.32mm at 200rpm. Again at 150rpm and 80rpm, blend of ½(CSO) + ½(SSO) has the highest values of 0.3mm, 0.21mm; followed by soursop seeds oil (SSO) with values of 0.24, 0.2; and the least was cocoa seeds oil (CSO) with values of 0.23mm, 0.11mm respectively.

IV CONCLUSION

1. Non-edible Vegetable based fluids make good lubricants by reducing the temperature and improving the life of the tool, producing good surface finish and performed more than the commercial cutting fluids.
2. The lowest surface finish (roughness) in all is produced by blended 50% of Cocoa Seeds Oil (CSO) with 50% of Soursop Seeds Oil (SSO) which has surface roughness of 1.7μm as the best metal cutting fluid for this experiment. This is due to the superb of the lubricating efficiency of the blended non-edible vegetable based metal cutting fluid when compared to that of other developed unblended base cutting fluids with mineral base cutting fluid. In conclusion, it is obviously observe that high lubrication is a product of increase in viscosity and viscosity being a property of fluid that functions to prevent wearing of two metals relative to motion.
3. It is clearly understood that increase in speed increases the temperature generated for all metal cutting fluid. This is because as cutting force decrease, the rotational speed also increases and since quantity of heat produced is the product of velocity and force, it follows that more heat would be generated with increase in cutting speed. In Figure 3.2, at spindle speed of 80rpm, 150rpm, and 200rpm, blend of 50% of Cocoa Seeds Oil (CSO) with 50% of Soursop Seeds Oil (SSO) has the lowest temperature of 43.5^{0}C, 46.2^{0}C, and 48.9^{0}C. When friction increases, the temperature will increase and cause surface wearing. However under investigation, the various developed vegetable cutting fluids and mineral cutting fluids have their deference cutting performances. The lowest in all is blend of 50% of Cocoa Seeds Oil (CSO) with 50% of Soursop Seeds Oil (SSO) as the best cutting fluid than commercial cutting fluids (CCF).

4. High value of chip thickness gives better rate of metal removal which entails completing the cutting at required minimum time giving (Groover, M.P. (2010). It is clearly understood from chip thickness chart above that blend of 50% of Cocoa Seeds Oil (CSO) and 50% of Soursop Seeds Oil (SSO) has the maximum value of 0.21mm, 0.30mm, and 0.38mm at 80rpm, 150rpm, and 200rpm than commercial cutting fluids.

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