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Comperative Peformance of Neem Seed, Water Melon Seed and Soluble Oils as Metal Cutting Fluids

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Abstract The comparative performance of soluble oil, Neem oil and water melon oils were investigated for application as Cutting fluids in a turning operation using Mild steel and spindle speeds of 250 rpm, 710 rpm and 180 rpm; depth of cut of 1 mm, 0.5 mm and 0.75 mm were used respectively, automatic feed rate and an ambient temperature of 34°C. Some physicochemical properties relating to cutting fluids were also investigated. Results shows that the Specific gravity of Neem seed oil was 0.9304 and Water Melon seed oil was 0.9324. The flash point for Neem seed oil was obtained as 157°C, Water melon seed oil 117°C. Viscosities were obtained as follows; Neem seed oil 8.08 cSt, Water melon seed oil 8.56 cSt. Pour point for Neem seed oil was +8, Water melon seed oil -8. % Wt of Sulphur was found to be 0.0293 for Neem seed oil, Water melon had -0.0081. pH for Neem seed was 3.6 and Water melon seed oil 5.5. Machining results shows that at 100 % oils, Water melon seed oil produced (54.66°C) and Conventional cutting oil (53°C) are not good as lubricant for metal cutting operations as the temperatures obtained using these oils exceeded the temperature obtained during dry machining at 50°C. The least temperature of 37.33°C was obtained while machining with 25 % Neem seed oil and 75 % water emulsion. All the oils – water emulsion ratios were effective as coolants and comparable to the Conventional cutting oil tested. How ever, the best surface finish was obtained from the dry machined sample. Amongst the oils tested, 100 % water Melon seed oil produce the best surface finish.

Keywords: *comparative, cutting fluid, conventional, Neem oil, water melon, soluble oil*

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1. Introduction

The trend in renewable lubricant technology is now in-reversible, this is driven by global warming, dwindling reserves and high cost of oil, ethical corporate policies and government strategies to encourage biomaterial use. The interest in Vegetable oils based Metal working fluids (MWFs) is growing. People are interested in the protection of the environment, protecting health and safety of employees and supporting the government economy and making many societies less dependent on oil [11]. Modern metal working fluids are quite effective if environmental issues are not considered. In wet cutting applications the fluids have historically reduced the unit cost of machined products by amount greater than purchase cost of fluid resulting in net profit/saving to manufacturer. Cost reductions are achieved through increase performance in areas that include tool life, surface texture of the machined product and increased cutting process speed and feeds [8]. Vegetable oil based metal working fluids can be used in same operations as mineral-based or petroleum based fluid. However, when compared to mineral oil, vegetable oil can enhance cutting performance, extend tool life and improve surface finish. Environmental benefits though important, are secondary [11]. However, increasing demand for environmental acceptable lubricant has led researchers to look to vegetable oil as the closest alternative [15]. Hence the need for more research in use of vegetable oil as alternative to mineral, petroleum or synthetic based oils.

Cutting fluids are very important in machining processes. This is because they carry away the heat generated there by cooling the work and also help to give good surface finish in addition to other auxiliary functions like rust prevention etc. There is a wide variety of cutting fluids available today. Many new coolants have been developed to meet the needs of new materials, new cutting tools, new coatings on cutting tools and wetting techniques. The goals of machining operations are to improve productivity and accuracy at reduced cost. This is accomplished by machining at the highest practical speed while maintaining practical tool life, reducing scrap and producing parts with the desired surface finish or quality. During machining, heat is generated and this has adverse effects on the work piece surface finish and dimensional accuracy, tool wear and life, as well as production rate (Sunday, 2003). This heat must be removed from the process, justifying the need for metal working fluids. Sunday et al (2003) used different cutting fluids emulsions of about 10% concentrations developed as cutting fluids from fix oils, the performance of each was evaluated using cooling and lubrication capacities or indices as determinant. A comparison of the results with those of purchased conventional cutting fluid was conducted. In evaluation process, a 2mm/min feed rate using straight turning operation on the lathe at equal time interval of 10 minutes at various cutting speeds. It was found that cutting fluids developed from groundnut oil, performed better as coolant at all the experimental speeds at a maximum temperature of 60.5°C at the working zone as against 71.39°C observed for conventional oil. The viscosity, 10.76cSt of groundnut oil was however higher than those of the control sample oil 4.79cSt and 6.20cSt for palm kernel oil.

Investigation of the effect of cutting speed, feed rate, depth of cut and rake angle on main cutting force during the cylindrical turning of mild steel, brass and aluminium rods, using high speed steel (HSS) cutting tool and palm kernel oil as cutting fluid was carried out by Ojolo & Ohunakin [9]. Impact of lubrication on coefficient of friction between the chip and rake angle face during turning operation, assuming a negligible friction between flank and cut surface was measured. Experimental results showed that aluminium at cutting speed of 4.15m/s and rake angle of 9^0 gave 33.3% reduction in coefficient of friction, brass and mild steel gave 7.9% and 13.8% increase in coefficient of friction respectively. Finding at speed of 4.15m/s; 1.5mm depth of cut, gave 9.79% reduction for aluminum, 46.7% and 20.8% increase in coefficients of friction for brass and mild steel respectively. Cutting speed of 4.15m/s and feed rate of 1.8mm/rev gave 9.2% reduction for aluminum, 30.4 and 14.5% increase in coefficient of friction for brass and mild steel respectively. Similar trend was observed after varying cutting conditions on the work parts through different selected values. They concluded that the effect of palm kernel oil as a metal cutting fluid or lubricant was more pronounced on aluminium than in brass and mild steel. Experimental investigation using vegetable oil, through minimum quantity lubrication in end milling AISI 420 hardened stainless steel, with uncoated carbide tool, was carried out by Safin, Hisyam, and Aman, (2009). Results on tool life and tool wear were compared against other coolant techniques using emulsions. Machining trials were performed at constant cutting speed of 60m/min and feed rate of 0.03 mm/tooth. The radial and axial depth of cut was maintained at 12 mm and 0.6 mm respectively. Result showed that MQL with vegetable oil based lubricant, out performed other coolant techniques in terms of tool life. Dry cutting condition recorded the shortest tool life. Maximum flank wear and chippings were dominant tool failure mode under all tested coolant conditions. They concluded that both the coolant techniques and the type of lubricant used, significantly affected tool life and tool wear of cutting tool. Metal machining involves generation of final surface by metal removal in form of chips. Thus any phenomenon that affects metal cutting, chip formation and removal mechanism will significantly affect characteristic features of final surface (Ramalinga et al 2012). In turning, higher cutting parameter value offer opportunities for increasing productivity but also with greater risk of deterioration in surface quality and tool life.

2. Research Methodology

2.1. Oil Extraction Procedures

About 2209.2g (2.209Kg) of Water melon seeds samples were obtained from the fruit market along the new Kano road junction, Dogarawa Zaria. The seeds were sun dried so that the seed coat was separated from the seeds. Winnowing was then carried out to separate and obtain clean seeds. The clean seed were then poured in a mortar and a pestle used to pound and crushed the seeds to a paste-like form. The paste-like melon was transferred to a stainless steel bowl and about 0.2 liters (200ml) of boiling water was added into the paste and then mixing was done by hand. Water melon paste was then placed in an oven (Volcan laboratory furnace) and the temperature was set at between 120°C and 140°C and heating was carried out for approximately 10 minutes. This was aim at enhancing the flow of oil during pressing. Oven heated paste of melon was then transferred to sieving cloth of very fine sieve grade. The edges of the sieving cloth were gathered and tied. The sieving cloth with the melon paste was then placed in a Mechanical Press that is locally fabricated and consists of a Jack to achieve pressing, Mild steel frame and a means for collecting of the oil. The Jack was continuously used to apply pressure to the paste at intervals so that oil was continuously squeezed out of the paste. This was done until no more oil was oozing out of melon paste. A laboratory flask was use for the collection of the oil. The same procedure was used to extracted oil from the Neem seeds.

2.2. Oil Properties Test Procedure

The Pour Point of the oils was tested according to ASTM D 97 and Relative Densities (Specific Gravity) by Hydrometer Method (ASTM D 1298) while the Flash-point by pensky-martens closed cup tester ASTM D93. Kinematic Viscosity was tested according to ASTM D 445 and Sulphur tested using the Horiba apparatus model SLFA2800 Sulphur in oil analyzer by X-ray machine. PH was tested using the PH meter, model and serial No 7010/1886.

2.3. Machining Procedure

Each work piece was mounted on a three jaw self centering chuck of a TEX TRENCIN Lathe machine model SN40B and properly secured using the chuck key. A high speed steel (HSS) cutting tool (12 X 200) was then mounted on the lathe tool post or tool holder after it has been grounded to the correct clearance and rake angles. The tool post was adjusted until approximately perpendicular to the work piece. The prop of a thermocouple wire was set so that it just touched the work piece at a point very close to cutting zone. The thermocouple was then connected to STEL digital electronic temperature indicating Regulator model TED-2001 with a range of between 0°C - 400°C. This read the temperature or heat generated at cutting zone. Dry machining (that is, turning without lubricant) was carried out on a single work piece made of mild steel using a spindle speeds of 250, 180rpm and 710rpm and depth of cut 1mm, 0.75mm and 0.5mm respectively with an automatic feed rate.

Temperature measurement was carried out at the end of turning just went the machine is about to be stop. Readings were taken three times so that average temperature was obtained. One vegetable oil (Neem oil) being tested was poured into water bottle used as the applicator and turning was carried out with oil applied from water bottle at speed of 250 with 1mm depth of cut. Turning operation was repeated with the Neem oil as coolant but at speed of 180rpm, depth of cut 0.75mm and 710rpm, depth of cut 0.5mm the same as in the dry machining. Three readings were also taken. The oil was then mixed with water at a 50% to 50% ratio and used to machine another work piece using the same parameters stated above and equally taking three readings. The Neem oil was again mixed with water at a ratio of 25% Neem oil to 75% water and the same procedure was repeated in carrying out the machining and recording. The turning operation was repeated with vegetable oils from the remaining five oils being tested using the same procedure and parameters as was in the previous cases.

2.4. Surface Roughness Test Measurement

Mild steel specimens were machined on TEX TRENCIN Lathe machine model SN40B and surface roughness indices obtained from a digital INSIZE SURFACE ROUGHNESS TESTER (code – ISR-16) measuring instrument, Serial No 1510090001. The prop of instrument was place on the turned surface along the direction of the tool travel. The prop was then allowed to travel to and fro on turned surfaces through a length of about 5mm and the instrument then displays roughness value instantly.

3. Presentation of Results

3.1. Results of Physicochemical Analysis

Table 1. Results of physicochemical analysis of the two selected vegetable oil

Properties Analyzed	Neem seed oil	Water Melon seed oil
Specific Gravity 15/40°C	0.9304	0.9324
Flash point °C	157	117
Pour Point °C	+8	-8
Kinematic Viscosity (100°)	8.08	8.56
% Wt Sulphur	0.0293	nil
P H	5.6	5.5

3.2. Turning Operation Results

Table 2. Temperatures in °C obtained machining with 100% straight oils and dry sample

S/No	Oils	Averaged Machining reading
1	100 % Conventional oil	53
2	Dry sample	50
3	100 % Neem oil	45
4	100 % Water melon oil	54.66

Ambient Tempt. = 34°C
Spindle speed = 250 rpm/min
Depth of cut = 1mm.

Table 3. Temperatures (°C) at machining with 50% oil/50% H_2O emulsion and dry sample

S/No	Oil	Averaged Machined Reading
1	50 % Conventional oil	40.33
2	Dry sample	50
3	50 % Neem oil	39.66
4	50 % Water melon oil	42.66

Ambient Tempt. = 34°C
Spindle speed = 250 rpm/min
Depth of cut = 1mm.

Table 4. Temperatures in °C obtained machining with 25% oil – 75% H_2O ratios and dry sample

S/No	Oil	Averaged Machined reading
1	25 % Conventional oil	38.33
2	Dry sample	50
3	25 % Neem oil	37.33
4	25 % Water melon oil	41.33

The ambient environmental Temperature during the machining period was 34°C
Spindle speed = 250 rpm/min
Depth of cut = 1mm.

Table 5. Temperatures in °C obtained machining with 100% straight oils and dry sample

S/No	Oils	Averaged Machined reading
1	100 % Conventional oil	52.66
2	Dry sample	57.33
3	100 % Neem oil	45
4	100 % Water melon oil	52

The ambient environmental Temperature during the machining period was 34°C
Spindle speed = 710 rpm/min
Depth of cut = 0.50mm.

Table 6. Temperatures in °C at machining with 50% oil – 50% H_2O ratios and dry sample

S/No	Oils	Averaged Machined reading
1	50 % Conventional oil	44.33
2	Dry sample	57.33
3	50 % Neem oil	45.66
4	50 % Water melon oil	47.66

The ambient environmental Temperature during the machining period was 34°C
Spindle speed = 710 rpm/min
Depth of cut = 0.5mm.

Table 7. Temperatures in °C at machining with 25% oil – 75% H_2O ratios and dry sample

S/No	Oils	Averaged Machined reading
1	25 % Conventional oil	41.33
2	Dry sample	57.33
3	25 % Neem oil	43
4	25 % Water melon oil	41

The ambient environmental Temperature during the machining period was 34°C
Spindle speed = 710 rpm/min
Depth of cut = 0.5mm.

Table 8. Temperatures in °C obtained machining with 100% straight oil and dry sample

S/No	Oils	Averaged Machined reading
1	100 % Conventional oil	50
2	Dry sample	54.66
3	100 % Neem oil	45.33
4	100 % Water melon oil	54.66

The ambient environmental Temperature during the machining period was 34°C
Spindle speed = 180 rpm/min
Depth of cut = 0.75mm.

Table 9. Temperatures in °C at machining with 50% oil – 50% H_2O ratios and dry sample

S/No	Oils	Averaged Machined reading
6	50 % Conventional oil	44.33
7	Dry sample	54.66
3	50 % Neem oil	45
4	50 % Water melon oil	47.66

The ambient environmental Temperature during the machining period was 34°C
Spindle speed = 180 rpm/min
Depth of cut = 0.75mm.

Table 10. Temperatures in °C at machining with 25% oil – 75% H_2O ratios and dry sample

S/No	Oils	Averaged Machined reading
6	25 % Conventional oil	43.66
7	Dry sample	54.66
3	25 % Neem oil	42.66
4	25 % Water melon oil	43.66

The ambient environmental Temperature during the machining period was 34° C
Spindle speed = 180 rpm/min
Depth of cut = 0.75mm.

4. Discussion of Results

4.1. Oils Properties

For the properties that were tested, the results obtained agree mostly with the results of other works carried out by different researchers. Kinematic Viscosity; The results obtained at 100°C shows that the viscosity of Neem seed oil is 8.08 which compares favorably with literature [1] but differ with Niraj [3] with 3.8. Water Melon had viscosity of 8.56. All results agreed with available literature on viscosities of oils. Viscosity plays a significant role on ability of oil to flow and also to remain stable at particular temperatures for a period of time. See Table 1. Below in Figure 1 shows the plot of the kinematic viscosities of the two oils tested.

Pour Point: The pour point obtained for all the oil shows that the oils can be poured relatively easily and hence, flow was not a problem. Neem had the least pour point of +8°C (A K Singh and A K Gupta, +9); [3] and Flemming et al (2011) +8°C while Water Melon had the best result at -8°C. The standard maximum pour point for emulsifiable oils use as cutting fluids is 1.67°C (35°F). Since Nigeria is situated in the tropical region of the world were temperature hardly drop to 8°C, the oils are suitable for use as coolants as they can be poured. Figure 2 shows pour points of two oils. **Flash point:** Those of two oil (neem and water melon) were 157 and 117 respectively (Table 1). The oil permits higher metal cutting temperature. Figure 3 below shows a plot of flash point of the oils.

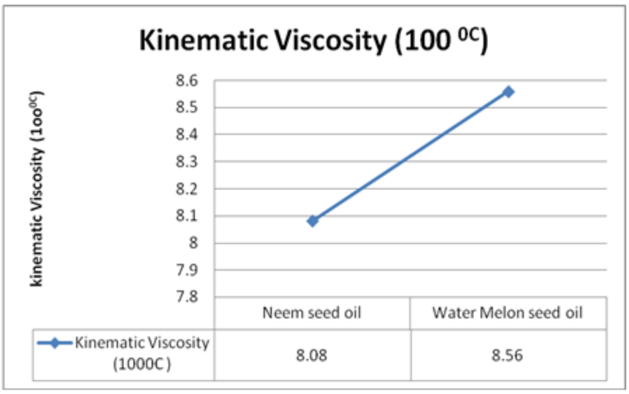

Figure 1. plot of kinematic viscosities

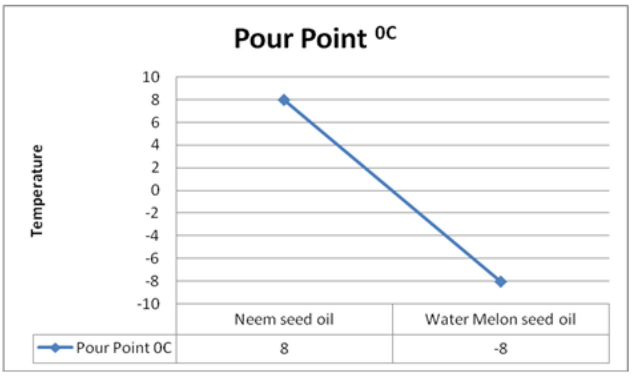

Figure 2. plot of oils pour point

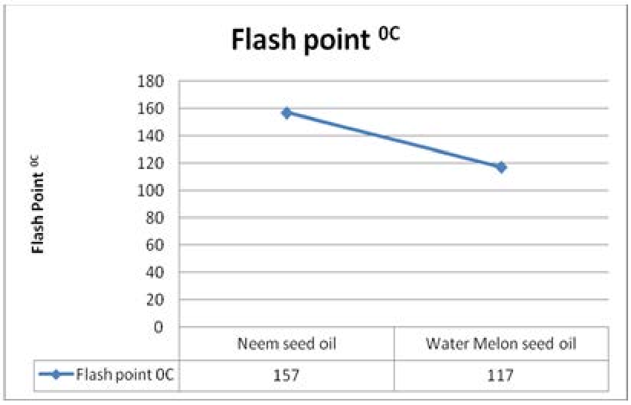

Figure 3. Plot of oils Flash Points

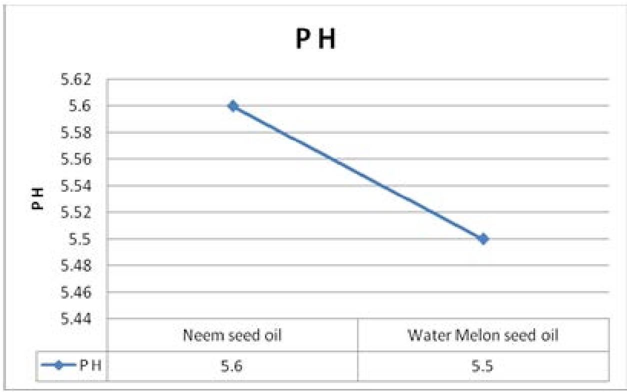

Figure 4. Plot of oils PH

PH: The pH of all the oils shows some level of acidity Neem oil had a pH of 5.6 which compares favorably with the result obtained by Kovo (undated) and the pH of Water Melon was found to be 5.5. The low pH values support use of oils as cutting fluids as they are harmful to machine operators and people within vicinity of machine operations. Also, this means that there is less likely hood of coolant corroding metal work pieces or machine itself. However pH of 6-8 favors bacterial growth and 4.75- 9.75 is acceptable to the skin. Figure 4 above shows the plot of the oils PH values. Sulphur %wt; Table 2 shows the quantity of Sulphur in all the oil samples were low. Neem oil with 0.0293 %Sulphur which differs from 0.48 % obtained by Niraj [3] and water melon %Sulphur was nil. The negative sign indicates that the level of Sulphur in these oils is so low and not within the range of apparatus to dictate. Sulphur was used as an extreme pressure additive in lubricants and cutting fluids [7]. Figure 5 shows a plot of the two oils tested. Since % Sulphur was low in oil samples. It is recommended that sulphur addition be made in the oils to improve this function.

Specific gravity (relative density): Table 2 shows relative densities of oil using ASTM D94 standard test procedure. Relative density result of water melon oil used was 0.9324. This compared favorably with 0.91 obtained by Oyeleke et al, 0.864 obtained by Odjoba et al with difference of 0.0684 and 0.86- 0.92 reported by Taiwo [12]. Neem oil had relative density of 0.9304 which compares to 0.927 obtained by Kovo (undated) and Niraj [3] obtained 0.9619. Figure 6 shows a plot of the specific gravity of the tested oils.

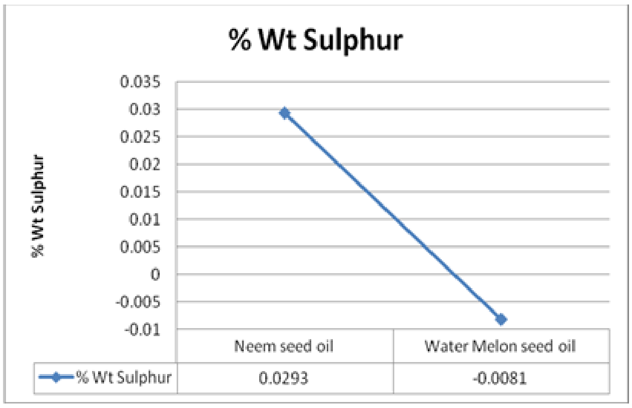

Figure 5. Plot of Vegetable oils %Wt Sulphur

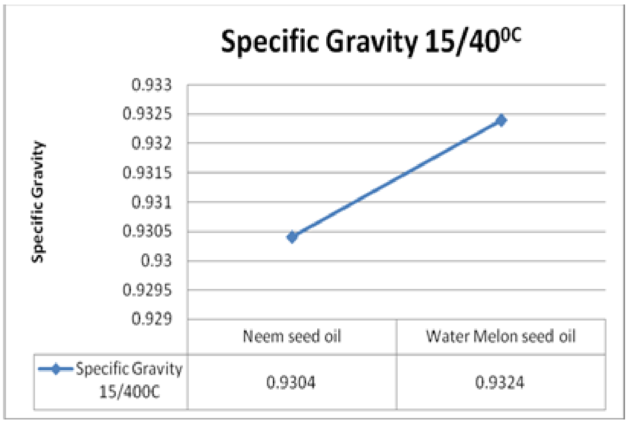

Figure 6. Plot of vegetable oils Specific Gravity

4.2. Observations during the Machining Operations

During machining process, straight Neem oil (100 % oil) produce a pungent, irritating and chocking smoke that is almost unbearable to the machinist and Water melon oil produced less smoke at 100 % oil but at other ratios with water, the quantity of smoke produced increased. At 50 % oil and 50 % water emulsion the oils became slightly thicker than the straight oil with Neem being more soluble and at 25 % oil and 75 % water, water melon seed oil was more soluble than Neem. At 50 % oil -50 % water emulsion and 25 % oil–water emulsion ratios, Neem seed oil moderate solubility.

4.3. Temperatures (Cooling Effect)

Table 2 shows the temperatures obtained machining at 100% straight oils,250rpm and depth of cut 1mm. Neem seed oil produced the best cooling effect with average temperature rise of 45°C. Result of water melon seed oil was 54.66°C averaged. This exceeded temperature obtained while machining dry sample at 50°C. Conventional cutting oil had average temperature rise of 53°C which was comparable to that of water melon seed oil. Figure 7 shows a plot of average temperatures obtained.

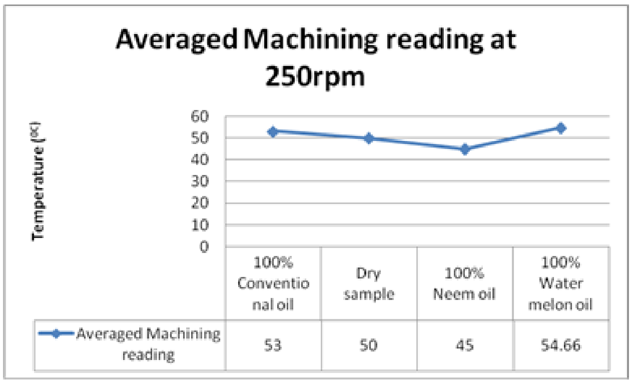

Figure 7. Plot of Average temperature at 250rpm, 1mm depth of cut

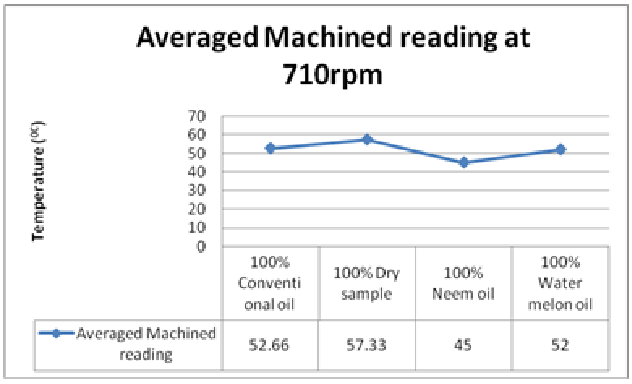

Figure 8. Plot of Temperatures at 710rpm, 0.5mm depth of cut

Table 5 presented average temperatures with 100 % oil at 710 rpm, depth of cut 0.5 mm. The best average cooling effect was obtained machining with Neem seed oil at 44°C and followed by Water melon seed oil at 52°C and the dry machined sample at 57.33°C. Conventional cutting oil gave an average temperature 52.66°C. Table 8 shows results of temperatures obtained at 180 rpm, depth of cut 0.75 mm with 100% oil. Conventional cutting oil gave an average of 50°C. Neem oil performed better than conventional cutting oil while water melon with 54.66°C was the same as dry machined sample. Figure 8 and Figure 9 show plots of the average temperatures obtained at 710 rpm and 180 rpm respectively with temperatures on the Y axis and oils on the X axis.

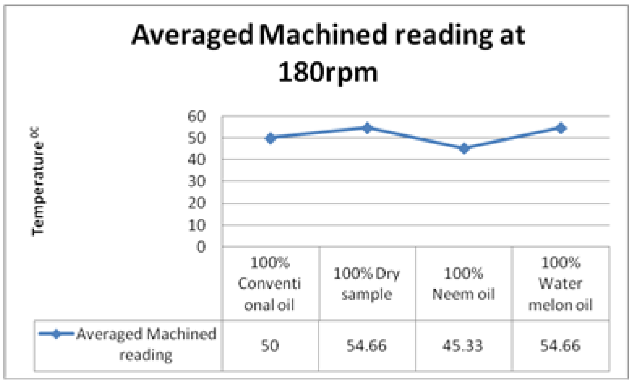

Figure 9. Plot of Temperatures at 180rpm, 0.75mm depth of cut

This result shows that machining with 100 % Neem oil being tested was better than machining with 100% conventional cutting oil at 180 rpm, depth of cut 0.75 mm, at 250 rpm, depth of cut 1 mm and 710 rpm, depth of cut 0.5 mm. This result, also means that machining at 250 rpm, depth of cut 1mm, pure water melon seed oil and Conventional cutting oil inhibit even the natural air from cooling the work piece but however, acts as corrosion inhibitors since they crate an interface between the work piece and air hence preventing oxygen from reaching or reacting with metal work piece. The second negative draw back of these pure oils is that led to high temperatures during the machining process. This in turn led to softening of the tool and its ability to cut effectively.

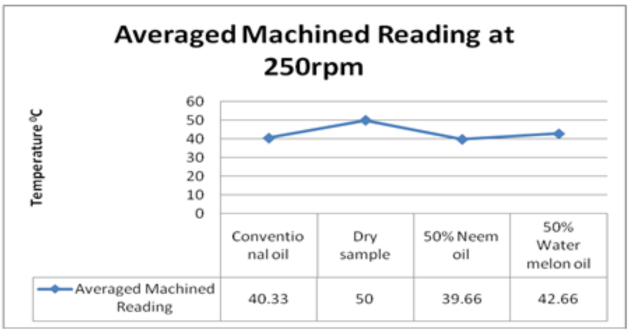

Figure 10. Plot of Average Temperatures at 250rpm 1mm depth of cut

Table 3 presented temperatures obtained with 50% oils - water emulsions machined at a speed of 250 rpm, 1 mm depth of cut. It showed that Neem seed oil was the most effective coolant with average temperature dropping to 39.66°C. Conventional cutting oil produced a temperature of 40.33°C. Water melon seed oil produced the least cooling effect with temperature drop of 42.66°C average. However went compared with dry machined work piece (50°C), all three oils are effective as coolants. Table 7 presented 50 % oil – water emulsions at 710 rpm, 0.5 mm depth of cut. At this speed, Conventional cutting oil had the best cooling effect with 44.33°C average temperature rise and this was closely followed by Neem seed oil at 45.66°C. The least cooling effect was obtained from the dry machined sample with 57.33°C average temperature, followed by Water melon seed oil at 47.66°C. This result shows that there is a slight difference between the conventional cutting oil and Neem seed oil. At 180 rpm, 0.75 mm depth of cut, the best cooling effect was given by conventional cutting oil at average temperature of 44.33°C and Neem seed oil followed at 45°C. The least cooling effect was obtained from dry machined sample with average of 54.66°C, followed water melon with 47.66°C (Table 9). Figure 10 – Figure 12 show plots of temperature (°C) on Y axis against 50% oil-water emulsions on X axis.

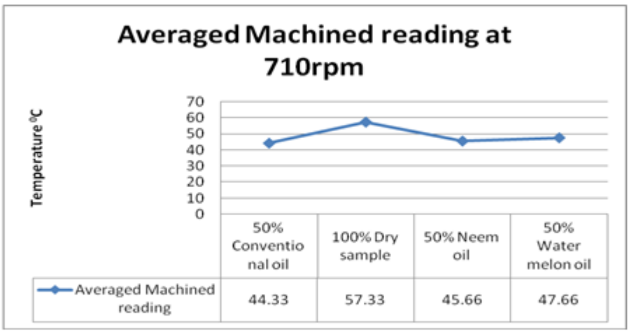

Figure 11. Plot of Average Temperatures at 710rpm 0.5mm depth of cut

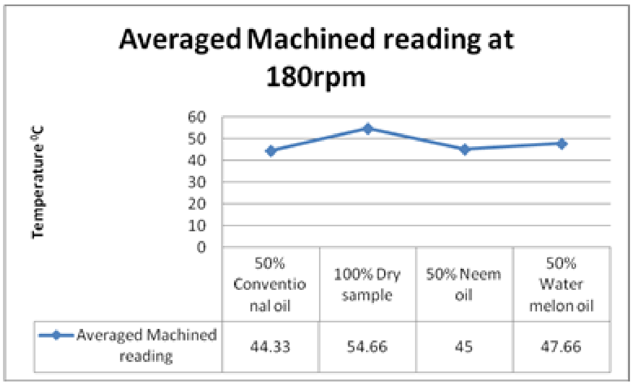

Figure 12. Plot of Average Temperatures at 180rpm 0.75mm depth of cut

Table 4 shows temperatures obtained with 25% oils and 75 % water emulsions at 250 rpm, 1mm depth of cut. Results shows that all the oils performed better than machining without lubricants since temperatures were far lower than machining without lubricant. Neem seed oil emulsion produced the most effective cooling at average temperature of 37.33°C. This was closely followed by conventional cutting oil with 38.33°C and Water melon seed oil emulsion 41.33°C. Figure 13 represents the plot of temperatures in °C on the Y axis and 25 % oil – 75 % water emulsion on the X axis.

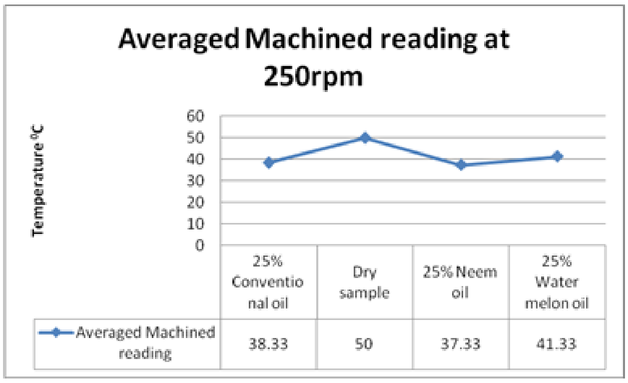

Figure 13. Plot of Average Temperatures atdepth of cut

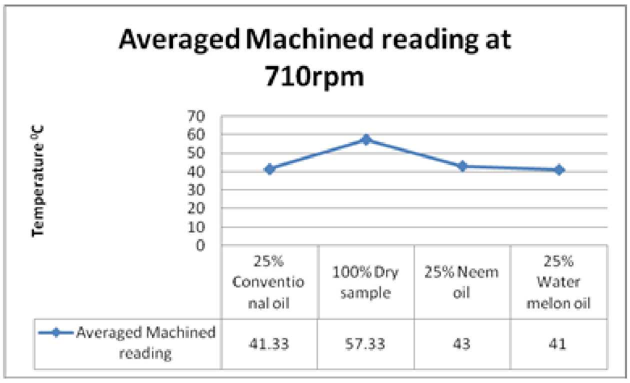

Figure 14. Plot of Average Temperatures 250 rpm, 1mm at710rpm 0.5mm depth of cut

Machining at 710 rpm, 0.5 mm depth of cut, they most effective oil was Water melon at 41°C and this was closely followed by conventional cutting oil at 41.33°C and Neem oil at 43°C respectively. The highest average temperature of 57.33°C was obtained from the dry machined sample. From this result the two oils – water emulsions tested at this speed were effective as cutting coolants since their temperatures were below that of dry machined sample and comparable to conventional cutting oils. At 180 rpm and depth of cut 0.75 mm, the most effective oil as coolant was neem oil with average temperature of 42.66°C recorded. This again was followed by the Conventional cutting oil and Water Melon oil with the same average temperature of 43.66°C recorded for each. The highest temperature was again recorded by the dry machined sample with 54.66°C. Figure 15 presented shows all the temperatures obtained machining at 25 % oils – water emulsions. Result shows that all the two oils – water emulsion tested against the Conventional cutting oil were effective as coolant.

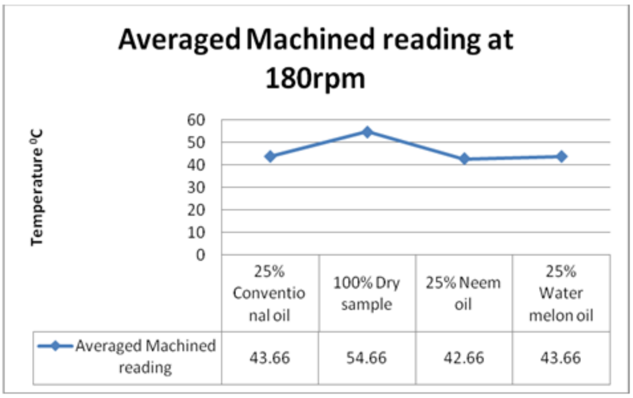

Figure 15. Plot of Average Temperatures at 180rpm 0.75mm depth of cut

4.4. Surface Roughness at Hundred Percent Pure Oils

At a speed of 250 rpm, 1 mm depth of cut and a constant feed rate of 0.25 mm, conventional cutting oil produced the best average surface finish having a roughness value of 0.002 µm. This was closely followed by water melon oil with 0.173 µm and neem oil with 0.323 µm. The least quality surfaces were produced by the dry machined sample which produced a surface roughness value of 1.311 µm. The results are presented in Table 11 and the bar chart plots in Figure 16.

Table 11. Surface roughness results

S/No	Oil	Average surface roughness
1	Neem	0.323
2	Water melon	0.173
3	Soluble	0.002
4	Dry cutting	1.311

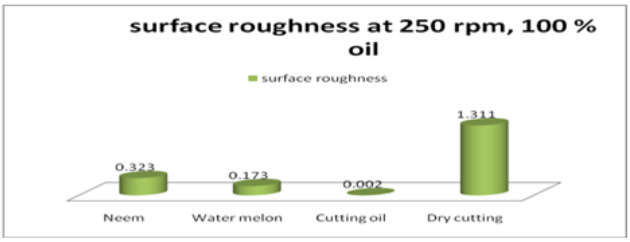

Figure 16. Surface rouighness results in bar chart

Table 12. Surface roughness results

S/No	Oil	Average surface roughness
1	Neem	0.002
2	Water melon	0.003
3	Soluble	0.002
4	Dry cutting	0.003

At 710 rpm, 0.5 mm depth of cut and 180 rpm, 0.75 mm depth of cut and the same constant feed rate of 0.25 mm, results of average surface roughness for samples tested were comparable and good; no significant difference with the best as 0.002µm and least 0.003µm and also conventional oil sample and dry sample. Table 12 presents result of the test and Figure 17 presents the plotted bar chart.

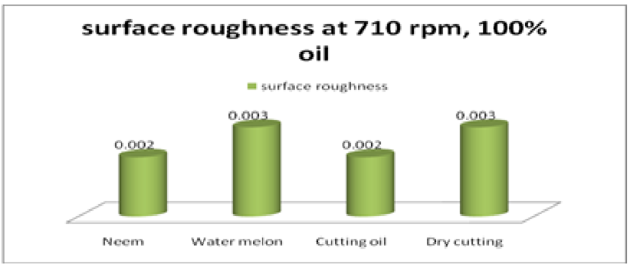

Figure 17. Surface rouighness results in bar chart

Table 13. Surface roughness results

S/No	Oil	Average surface roughness
	Neem	0.002
	Water melon	0.003
	Soluble	0.002
	Dry cutting	0.002

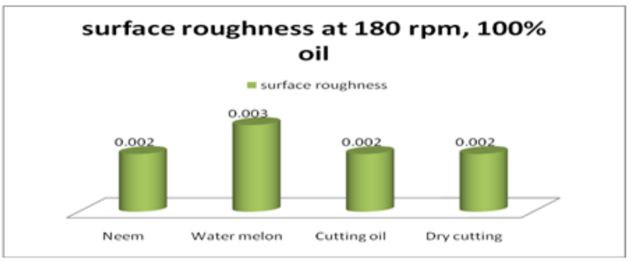

Figure 18. Surface rouighness result in bar chart

Table 13 and Figure 18 present the table of result and the graphical plot of result for surface roughness of samples machined with 100% oil at 180rpm. At the three speeds tested, average surface roughness value ranges were comparable to recommended standard roughness for surfaces produced during turning operations which has a maximum of 25 µm, Narayana *et al* (2008). However, the least quality surfaces were produced at a speed of 250 rpm, 1 mm depth of cut. Thus speed and depth of cut has direct bearing on quality of surface produced but the dominant factor was depth of cut since the feed rate was kept constant in all test samples. This result agrees with Thamizhmanii *et al* [13].

4.5. Fifty Percent Oils – Fifth Percent Water Emulsion Ratios

Table 14 - Table 15 present the surface roughness obtained at 250rpm, 1 mm depth of cut and the same feed rate of 0.25mm, jatropha produced the best average surface finish with roughness value of 0.455 µm. This was followed by water melon oil with average surface roughness of 0.662 µm and conventional cutting oil with 0.725 µm. The least surface finish was produced by neem oil, followed by castor oil with average roughness value of 1.329µm and dry sample with 1.311µm. It can be seen from the bar chart in Figure 19 that with this emulsion ratio, some of the oils produced better surface finish than conventional cutting oil tested.

Table 14. Result of surface roughness

S/No	Oil	Average surface roughness
1	Neem	1.427
2	Water melon	0.662
3	Soluble	0725
4	Dry cutting	1.311

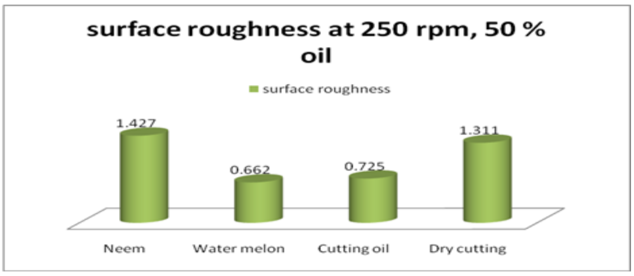

Figure 19. Surface rouighness result in bar chart

At 710 rpm, 0.5 mm depth of cut and same feed rate, results shown in Table 15 proves the average surface roughness values to be between 0.002 µm and 0.305 µm. Moringa oil and neem oil produced the best at 0.002 µm and 0.003 µm. Castor oil, water melon and jatropha oil average surface roughness were comparable as they fell between 0.295 µm and 0.305 µm. Figure 20 present the bar chart of the surface roughness.

Table 15. Result of surface roughness

S/No	Oil	Average surface roughness
1	Neem	0.003
2	Water melon	0.305
3	Soluble	0.003
4	Dry cutting	0.003

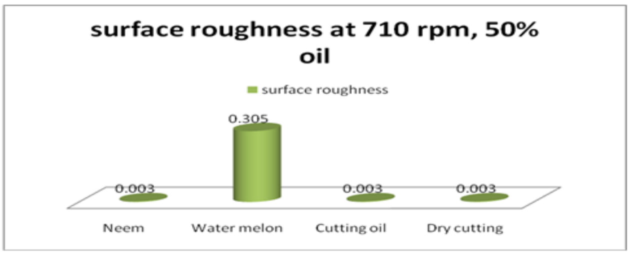

Figure 20. Surface rouighness result in bar chart

Table 16 shows average surface roughness at 180rpm, 0.75mm depth of cut. Conventional cutting oil and the dry machined sample roughness values were comparable (between 0.002µm and 0.003µm), while that for neem which was the least in surface quality was 0.416 µm, followed by water melon oil with 0.265µm. Figure 20 shows the plots of bar chart at 180rpm.

Table 16. Result of surface roughness

S/No	Oil	Average surface roughness
1	Neem	0.416
2	Water melon	0.265
3	Soluble	0.003
4	Dry cutting	0.002

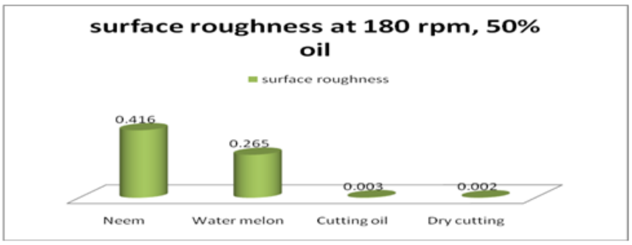

Figure 21. Surface rouighness result in bar chart

4.6. 25% Oils – 75 % Water Emulsions

Table 17 shows values of the average surface roughness obtained machining at 250rpm, 1mm depth of cut. Water Melon oil produced 0.002µm while Neem oil produced 0.488µm. These surfaces were better in quality than the Conventional cutting oil which produced 0.682 µm and the Dry machined sample 1.311µm. However, these oils emulsions still fell within the range of surface roughness recommended for turning operations. Figure 22 shows the bar chart of the roughness values.

Table 17. Result of surface roughness

S/No	Oil	Average surface roughness
1	Neem	0.488
2	Water melon	0.002
3	Soluble	0.682
4	Dry cutting	1.311

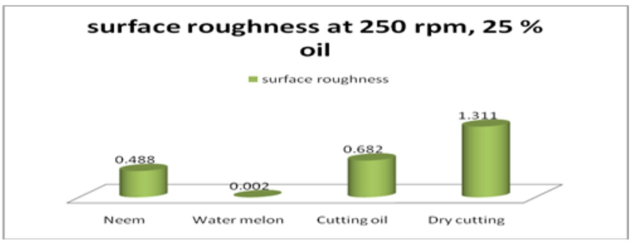

Figure 22. Bar chart of surface roughness of work pieces machined at 25% oil, 250rpm, 1mm depth of cut

At 710rpm, 0.5mm depth of cut, average surface roughness is presented in Table 18. It shows the values for all the oils and Dry sample to be of similar quality, falling between 0.002µm and 0.003µm. Figure 23 shows the bar chart of the roughness values for the different oils and Dry sample. These surfaces again, fall within the recommended range for turning operations.

Table 18. Result of surface roughness

S/No	Oil	Average surface roughness
1	Neem	0.003
2	Water melon	0.002
3	Soluble	0.003
4	Dry cutting	0.003

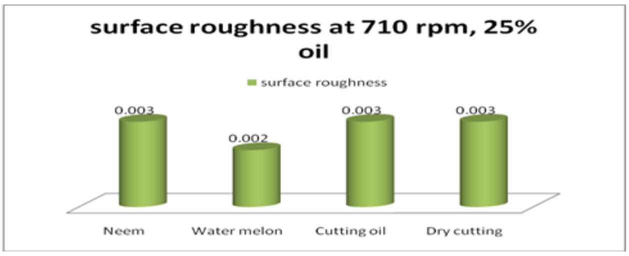

Figure 23. Surface roughness of work pieces machined at 25% oil, 710rpm, 0.5mm depth of cut

Table 19 shows the results of average surface roughness obtained for all the oils and dry machined sample at 180rpm, 0.75mm depth of cut. Surface roughness for the oil emulsions were the same at 0.002µm. These depict the surfaces to be of good quality that fall within limits acceptable in turning operations as can be seen in Figure 24 that present the bar chart of the roughness values.

Table 19. Result of surface roughness

S/No	Oil	Average surface roughness
1	Neem	0.002
2	Water melon	0.002
3	Soluble	0.002
4	Dry cutting	0.002

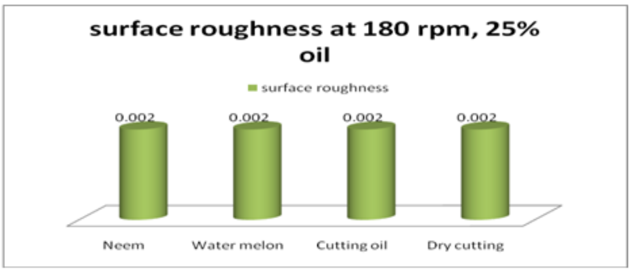

Figure 24. Surface roughness of work pieces machined at 25% oil, 180rpm, 0.75mm depth of cut

These results also indicated clearly that the speed and depth of cut play key roles in the quality of surfaces obtained when turning [2]. As the speed is increase, and the depth reduced, the surface roughness value also reduces indicating better surface finish.

4.7. Chip Formation

Chips generated during the machining processes with oil and its emulsions are described below

At 250 rpm, 1mm depth of cut, dry machined work piece produced chips that are continuous, long open spring-like shapes with blue-black color. Chips were between 130mm and 170mm long; about 2mm wide. Sample machined at 710rpm, 0.5mm and 0.75mm depths of cut at 180 rpm, chips were discontinues with blue/black and slivery color respectively; 2.5mm wide and about 10mm long. Plate 1 and Plate 2 show the pictures of chips formed machining dry without cutting fluid.

Plate 1. Micrograph of steel chips at 250 rpm, 1 mm depth of cut

Plate 2. Micrograph of steel chips Mixture at 710 rpm, 0.5 mm depth of cut and 180 rpm, 0.75 mm depth of cut dry sample

For chips produced with 100 % straight oils, soluble oil produced blue-black chips that are very short and discontinuous with maximum lengths of about 8mm and width of about 3 mm. Neem seed oil produced small open spring-like continuous chips of light silver to brown color, length averaging about 54mm and width of about 1 mm. Water melon oil produced coil chips of about 33 mm average length, 2.5mm width having silver-white color and appeared as if scraped from surface of the metal work piece. Plate 3 - Plate 5 show the photmicrographs of steel chips produced with 100 % oils

Plate 3. Micrograph of steel chips at 100 % Neem oil

Plate 4. Micrograph of steel chips at 100 % Water Melon oil

Plate 5. Micrograph of steel chips at 100 % Conventional oil

At 50% oils and 50% water emulsions, soluble oil produced chips that are very closely coil ranging between 10mm to 24mm length and having width of about 1mm. Neem seed oil produced a mixture of small open coil and discontinuous chips that are silvery white in color having average length of 34 mm and width of about 2mm. Water melon produced chips that were a mixture of short and medium length coils averaging 20mm and 62mm with a silver color but with the oil sticking to it given it a brownish color appearance. Plates 6-8 shows the Micrographs of steel chips produced with 50% oils.

Plate 6. Micrograph of steel chips at 50 % Neem oil

Plate 7. Micrograph of steel chips at 50 % Water Melon oil

Plate 8. Micrograph of steel chips at 50 % soluble oil

With 25% oils and 75% water emulsions, soluble oil produced long, open semi spring-like chips that are dark blue-black color and have lengths varying between 64mm to 86mm and 120mm to 185mm, with widths of between 1mm and 1.5mm. Neem seed oil produced short length coil chips that are silvery in color with length averaging 12mm and width of 1.5mm while Water melon produced chips of closed coil with silvery color and an average length of 83mm and width 2mm. Plate 9-Plate 11 present the photomicrographs of steel chips produced with 25% oils mixture in the emulsions.

Plate 9. Micrograph of steel chips 25% neem oil

Plate 10. Micrograph of chips 25% water melon oil

Plate 11. Micrograph of steel chips 25% soluble oil

5. Conclusion

It has been established that environmental-friendly vegetable-based oils can successfully replace petroleum-based mineral oils as cutting fluids. With slight modifications and deliberate manipulation of some of components of the oils, even better performing cutting fluids can be obtained. From the results it can be comfortably concluded that the cooling property of neem and water melon vegetable cutting fluids gave a performance in comparison with that of conventional soluble oil, as indicated by slight temperature differences on the values obtained. Dry machining generated higher temperatures than neem, water melon or soluble oils. This is probably due to reduced tool performance in the absence of cutting fluids. Surface roughness of the neem and water melon oil machined work pieces was comparable to that of the soluble oil machined samples. This was an indication of good lubricity. Better surface finish indicates that there is less friction and tool wear between tool and workpiece.

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