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An Assessment of the Physico-chemical Properties of Melon Seed (*Citrullus lanatus*) Oil as Base Material for Oil-in-Water Emulsion Cutting Fluid

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Abstract. The study highlights melon seed oil as possible cutting fluid for machining processes. The properties of melon seed oil were investigated. Formulation of oil-in-water with addition of some additives was carried out and the results obtained suggest that melon seed oil possesses the relevant properties as a base material for oil-in-water emulsion cutting fluid.

Introduction

There is a growing public interest in environmentally friendly cutting fluids due to new awareness of environmental and health problems associated with conventional mineral cutting fluids [1]. Report has shown that about 80% of all occupational diseases of operators were due to skin contact with cutting fluids [2]. In United State of America alone, about seven hundred thousand to one million workers are exposed to cutting fluids. It is reported that the European Union alone consumes approximately 320,000 tonnes per year of cutting fluids of which, at least two-thirds need to be disposed [3]. Therefore, the growing demand for biodegradable materials has opened an avenue for using vegetable oils as an alternative to mineral or petroleum-based polymeric materials. Vegetable oils have displayed excellent lubrication properties in laboratory investigations [4]. Vegetable oil primarily consists of triglycerides structure which provides desirable qualities for boundary lubrication when it is used as cutting fluid. It provides high strength lubricant films that interact strongly with metallic surfaces, reducing both friction and wear due to their long and polar fatty acid chain [5]. The fatty acids found in natural vegetable oils differ in chain length and number of double bonds [6]. The proportions of each fatty acid depend not only on the type of plant, but also on the climate, the weather and the food available [7].

This work studies the properties and formulation of melon seed oil-in-water emulsion cutting fluid. The higher percentage of water in the formulation would bring the benefit of high thermal conductivity of the cutting fluid during machining process.

Material and Method

Material :- Melon seed (*Citrullus lanatus*) oil is the biological ancestor of water melon now found all over the world, but originated from the western Kalahari region of Namibia and Botswana, where it can still be found in the wild in a diversity of forms together with other citrullus species. Its production in Nigeria amounted to 347,000 tons from 361,000 hectares and it is cultivated across the country in Nigeria but with a higher intensity in Kogi state (211,600 hectares) [8]. Melon seed consists of 50% oil and 35% protein [9] and the melon seed (*Citrullus lanatus*) oil used for this study was sourced from a local market in Iwo, Oyo state, South –West of Nigeria.

Experimental Method.

(a) Properties of Melon Seed Oil. An assessment of physico-chemical properties of melon seed oil is necessary, as it serve as a guide in the type and quality of additives needed for the formulation of emulsion of oil-in-water cutting fluid. Experiments were carried out to determine the following properties of melon seed oil (i) fatty acid composition, (ii) free fatty acid, (iii) iodine value, (iv) flash point, (v) pour point (vi) density and (vii) viscosity

(b) Formulation of Oil-in-Water Emulsion Cutting Fluid. Oil-in-water (O/W) emulsions were formulated using design of experiment method. Four variables (additives) were examined at two levels (2^4 planning) besides the oil and water. Table 1 shows the factors or variables and levels examined in the factorial planning. The system was submitted to mechanical stirring at speed of 760 rpm for 10 minutes at room temperature of 25^{o}C. The experiments were carried out in replicate**.**

Table 1: Factors and levels examined in the factorial planning

Factor	Symbol	Level	
		Minimum - (%)	Maximum + (%)
Emulsifying agent	A	8.0	12
Anticorrosive agent	B	2.0	4.0
Antioxidant agent	C	0.5	1.0
Biocide	D	0.5	1.0

Results and Discussion

The fatty acid composition or profile of melon seed (*citrullus lanatus*) oil is shown in Table 2 below. It indicated that melon seed (*citrullus lanatus*) oil has approximately 16.98% of saturated fat and 80.66% of unsaturated fat.

Table 2: Fatty Acid Composition of melon Seed (*citrullus lanatus*) oil.

Acid type %	C12:0 (lauric acid)	C14:0 (myristic acid)	C16:0 (palmitic acid)	C18:0 (stearic acid)	C18:1 (oleic acid)	C18:2 (linoleic acid)	C18:3 (linolenic acid)	others
Melon oil	-	0.27	16.74	0.01	37.36	43.3	0.12	2.2

The properties of vegetable oils are determined by their fatty acid composition. A high content of linoleic/linolenic acid decreases thermal-oxidative stability, whereas a higher proportion of long chain saturated fatty acids leads to inferior cold flow behavior.

Table 3 shows the other properties of melon (*citrullus lanatus*) oil**.** Free fatty acid (FFA) is pro-oxidants and contributes to the decreased shelf life of oil. When significant amount of FFA are present in the oil, smoking becomes excessive and the oil must be discarded. The iodine value is a measure of unsaturation in oil. Flash point is the lowest temperature at which application of an igniter causes the vapour of a specimen to ignite under the specified test conditions. Viscosity is calculated from the time it takes the oil to flow from the starting point to the stopping point using a calibration constant supplied for each tube. The pour point of oil is defined as the lowest temperature at which movement of the test specimen is observed under the prescribed conditions of the test. Density is measured as ratio of mass to volume and is restricted to liquids with vapor pressures below 600mm Hg (80K Pa) and viscosity below about 15,000 cP at test temperature.

Table 3: Physical chemical properties of melon (citrullus lanatus) oil

Melon seed oil	Value	Method
FFA (as palmitic acid)	1.43 %	AOCS Ca 5a-40
Iodine value	17.67	AOCS Tg 1a-64 (1997)
Flash point	271.5^{o}C	ASTM D 93
Pour point	3.0^{o}C	ASTM D97
density @ 15^{o}C	0.9209 g/cm^3	ASTM D4052
viscosity @ 40^{o}C, 100^{o}C	36.58 mm^2/s (cP); 8.108 mm^2/s (cP)	ASTM D445 and ISO 3104

The application of Design Expert software indicates the ANOVA for the full model to be significant for viscosity and pH responses with additives A and B respectively having effect on the response. The values of pH for all the runs fall within acceptable level [10], but run 15 gives the optimum viscosity of 2.81cP. Table 4 shows the complete list of level combinations realized with this factorial planning.

Table 4: Experimental matrix of the 2^4 factorial planning

Run	pH	Viscosity	Run	pH	Viscosity
1	10.77	2.09	9	10.83	1.99
2	10.68	2.53	10	10.90	1.72
3	11.60	2.06	11	10.26	2.52
4	10.65	2.18	12	10.94	2.79
5	10.77	1.85	13	10.51	2.78
6	10.93	2.26	14	10.98	1.93
7	11.04	2.34	15	10.88	2.81
8	10.59	2.30	16	10.82	2.17

Conclusion

The physico-chemical properties of melon oil sourced from Nigeria have been determined. The ranges of pH values (9 and 11) were obtained for all the runs and this show that the cutting fluid is corrosion resistance. The highest viscosity value of 2.81cP for run 15 will provide a better surface roughness during machining process compared to any other value of viscosity, because the higher the viscosity (the lubricating ability) the lower the surface roughness.

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