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Determination Of Some Physical Properties Of Castor *(Ricirus Communis)* Oil

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Abstract :*The energy crisis and shortage of fuel emanating from total dependence on mineral oil with resultant socio-economic problems demand the need to explore the use of renewable energy as alternative. This study evaluates the physical properties of the castor (Ricirus communis) oil. A quantity of 35 kg dried base decorticated seeds of castor was locally obtained, volume of 5 litres of castor oil was extracted from the seeds using existing hydraulic press machine, while its physical properties was determined through laboratory analytical procedure of American Society for Testing and Materials analytical standard 960-52 (ASTM,D960-52). The properties determined were: viscosity, density, flash point, pour point, melting point, refractive index, specific heat and thermal conductivity. Comparisons of the properties were also made with the standard lubricant (SAE 40 engine oil). The principles of flow theories were employed to develop heat generated equation in terms of temperature, density and viscosity of the oil and a computer program in C^{++} language was thus written. The physical properties of Castor oil are viscosity (889.3 cst), density (0.959) g/ml, flash point (145)^{o}C, pour point (2.7)^{o}C, melting point (-2 to -5)^{o}C, refractive index (1.480), specific heat (0.089) KJ/Kg/K and thermal conductivity (4.727)W/m^{o}C, respectively. Comparative analysis showed that the values of viscosity, density, thermal conductivity and pour point for Castor oil were higher than the values of SAE 40 engine oil while specific heat, flash point and refractive index values of Castor oil were less than the values of SAE 40 engine oil. The result showed that the average values for density and viscosity of Castor oil were 936Kgm^{-3} and 0.7938N.S/m^{2}. Sensitivity analysis showed that Castor oil has highest density and viscosity value at 30^{o}C and lowest value at 100^{o}C. In conclusion, Castor oil is suitable as alternative to conventional lubricating oils in auto engines. This study provides baseline information for production of lubricating oil from Castor seeds.*

Keywords: **The physical properties, viscosity, density, flash point, pour point, melting point, refractive index, specific heat capacity and thermal conductivity.**

INTRODUCTION

There has been renewed interest in the use of vegetable oils for the manufacture of biodiesel due to their less polluting and renewable nature when compared to conventional diesel. The focus has been mainly on oils from seeds such as soybean, rapeseed, sunflower and safflower (Lang *et al.*, 2001), which are essentially edible in nature. In India, with its abundance of forest resources, there are a number of other non-edible tree borne oil seeds with an estimated annual production of more than 20 million tones, which have great potential for making biodiesel to supplement other conventional sources (Kaul *et al.,* 2003). Among these, Karanja (Pongamia glabra) and Jatropha (Jatropha curcas) have been successfully proved as the potential source for biodiesel (Pramanik, 2003).

With the increasing population today, over 90% of the world entire population depends on petroleum or fossil fuel as the only source of energy. With recent findings, it has been made known that there is gradual depletion of oil and gas reserve that it will get to a time when there will not be enough energy from fossil fuel to serve the world at large. Since the petroleum crisis in 1970s, the rapidly increasing prices and uncertainties concerning petroleum availability, a growing concern of the environment and the effect of greenhouse gases during the last decades, has revived more and more interests in the use of renewable energy as a substitute for fossil fuel (Wang *et al.,* 2006).

The use of vegetable oils and animal fats for lubricant oil purpose has been practised for many years (Lou, 2005). In the field of oil production, agricultural produce are natural endowment which can be used in the production of oil as bio- oil from renewable agricultural waste such as castor and Jatropha seeds which will serve as revenue generation for the country and also create employment for the youth in the country as well as enhance technological developments of the nation.

The common name "castor oil" probably comes from its use as a replacement for castoreum, a perfume base made from the dried perennial glands of the beaver. It has another common name, palm of Christ, or Plama Christi, that derives from castor oils ability to heal wounds and cure ailments. Another plant species, *Fatsia Japonica*, is similar in appearance and is known as the false castor oil plant.

The toxicity of raw castor beans due to the presence of ricin is well-known. Although the lethal dose in adults is considered to be four (4) to eight (8) seeds, reports of actual poisoning are relatively rare (Wedin *et al.,* 1986). According to the 2007 edition of the Guinness Book of World Records, this plant is the most poisonous in the world.

Castor oil is one of the vegetable oils that have higher viscosity and density in comparison with fossil fuel. To lower the viscosity and density of the renewable oil, preheating is necessary prior to using (Alamu and Durowoju, 2003).

MATERIALS AND METHODS

The materials used for this study were Castor and Jatropha seeds. Four (4) bags of fresh/green Castor seeds weighing 27 kg each were sourced from Saka's farm at Afon Town in Asa Local Government and Baba Olunlade's farm near Metropolitan Square, Asa-Dam Road, Ilorin. It was allowed to dry and was reweighed to be 16 kg each. This showed a significant weigh loss of 11 kg.

Hence 27 kg of fresh castor seeds is equivalent to 16 kg of dry seeds with husk, which means that 108 kg of fresh castor seed with husk is equivalent to 64 kg of dry castor seeds with husk. When seeds were dehusked the weight of seeds reduced to 35 kg of clean Castor kernels compare to the original weight of 64 kg. This was used to produce approximately 5 litres of extracted oil. This shows that seven (7) kg of the seeds produced approximately one (1) litre of extracted oil.

Four (4) bags of fresh jatropha seeds weighing 25 kg each were sourced from COGA's farm, Bode Saadu, Moro Local Government Area of Kwara State. It was allowed to dry and reweighed to be 15 kg each. This showed a significant weigh loss of 10 kg. This means that 25 kg of fresh Jatropha seeds was equivalent to 15 kg of dry seeds with husk. Therefore, 100 kg of fresh jatropha seeds with husk was equivalent to 60 kg of dry jatropha seeds with husk. The seeds were dehusked andthe weight reduced to 32 kg of clean jatropha kernels. This was used to produce approximately four (4) litres of extracted oil. This shows that eight (8) kg of the seeds gave approximately one (1) litre of extracted oil.

Some of the physical properties of oil extracted from the castor and jatropha seeds were determined using different kind of machines such as Temperature Assembly to determine flash point, and pour point, Refractometer to determine Refractive index. Viscosity and density of both castor and jatropha oils were determined at various temperatures of 30 ^oC, 40 ^oC, 50 ^oC, 60 ^oC, 70 ^oC, 80 ^oC, 90 ^oC and 100 ^oC with different apparatus such as density bottle to determine density, Ostwald viscometer to determine viscosity and thermometer to determine temperature.

The viscosity of the oil was determined by pouring 200 ml of the extracted oil into the Ostwald's viscometer until the two non-reading arms were full. The pressure from the reading arms timed at interval of 3 minutes (180 seconds) for the castor oil while 35 seconds for the Jatropha Oil. The time was multiplied by the instrument's constant which is 4.697. This gave the viscosity in centistokes. The kinematic viscosity was determined by ASTM D-445.

The density of the oil was determined by using a clean density bottle of 10 g which was dried in the oven with temperature 5 ^oC and kept in desiccators to cool. The density bottle was weighed when empty as 10 g, and was also weighed when it was filled with water (63 g), as well as when it was filled with castor oil (60.8 g), and when it was filled with Jatropha oil (58.7 g), which means water's volume was 53ml, castor oil weight was 50.8 g and Jatropha oil weight was 48.7 g. The calculation of the density goes thus: Weight of density Bottle empty = a grams, Weight of density Bottle + water = b grams, Weight of density bottle + sample = c grams, the density was determined by ASTM D-1293 method. Density, $\rho = \frac{c-a}{b-a}$

(1)

Flash point: 150 ml of extracted oils was poured into a metal container and heated at a controlled rate temperature of 36 ^oC after, which, the flame being passed over the surface of the extracted oils was observed at a regular intervals of 5 secs for 1 min. The flash point was determined by ASTM D-93 method.

Pour point: 150 ml of extracted oil was cooled inside an ice pack cooling bath of temperature 70^oC to allow the formation of paraffin wax crystals. At 9^oC above the expected pour point of 12^oC, and subsequently for every 3^oC, the test jar was removed and tilted to angle 45^o to check for surface movement. The oils extracted do not flow after tilted; the jar is held horizontally for 5 sec. 3^oC is added to the corresponding temperature of 0^oC. The pour point was determined by ASTM D-97 method.

Melting point: 150 ml of oils extracted was placed in capillary tube of 92 mm in length and 24 mm in diameter, which was heated at the controlled rate temperature of 36^oC. The temperature at which castor oil melted was between -2 to -5^oC, while Jatropha oil melts at 4 to 5^oC.

Refractive index: Two drops of the extracted oil was put into the lens of an Abbe refractometer. Water at 30^oC was circulated round the lens to keep its temperature uniform. Through the eyepiece of the refractometer, the dark portion viewed was adjusted to be in line with the intersection of the cross. At no parallax error, the pointer on the scale pointed to the refractive index which was read against the internal monochromatic source of light in the equipment. This was repeated 3 times and the mean value noted and recorded as the refractive index.

Specific heat capacity: A copper calorimeter was weighed and recorded. 150 ml quantity of oil was also weighed and its temperature which is 15^oC was noted and transferred to the calorimeter. A known volume of water (53 ml) was heated to a temperature of 20^oC above that oil, the heat hot water was transferred to the oil in the calorimeter, which was closed and stir until it reaches the equilibrium temperature and it was recorded. Specific heat capacity was calculated using equation 2.

$$c = t/m, \qquad (2)$$

where C = SHC of calorimeter, (kJ/kg/K*)*, t = heat loss, (^oC), m = mass of oil, (ml)

Ambient temperature, T_a = 20.1 ^oC (degree to minimize error due to heat transfer to or from the surroundings).

Thermal conductivity: Sato-Riedel method is the most popular method used for liquid thermal conductivity. This method is one of the corresponding state theories and it was estimated with the following scheme below:

$$\lambda_l = \frac{2.64\times10^{-3}}{\sqrt{M}} \times \frac{3+20(1-Tr)^{2/3}}{3+20(1-Tbr)^{2/3}} \quad (3)$$

Where: λ = Thermal Conductivity (W/m^{o}C)

Tr = Reduced Temperature, (^{o}C)

Tbr = Boiling Point/Critical Temperature, (^{o}C)

M = Molecular Weight, (g)

4.0 RESULTS AND DISCUSSION

The results of real values, average values and variation values for the physical properties of oils extracted from castor seeds using Hydraulic press machine and mechanical oil extraction method is shown in Table 4.1.

4.1 Comparison of Some Oil Properties

Some properties of standard base oil 500 Solvent Neutral were compared with the extracted oils (castor oils) with emphasis on their possible use as lubricants. Properties considered were viscosity, density, thermal conductivity, specific heat capacity, flash point, pour point and refractive index (Table 4.2). Comparative analysis showed that the values of viscosity, density, thermal conductivity and pour point for Castor oils were higher than the values of standard base oil of 500 Solvent Neutral while specific heat, flash point and refractive index values of Castor oils were less than the values of standard base oil of 500 Solvent Neutral.

However castor seeds 442-have high viscosity hence, there is a need to reduce the viscosity because it is an important and vital property when considering the lubricating characteristics of the engine for high performance. Hence the viscosity reported herein was higher than ASTM D-445 standard this could be as a result of variation in temperature. The lower the temperature value, the higher the viscosity value. This can be achieved through temperature varying method before usage. The analysis showed that the viscosity values for castor and jatropha oil was 889.3 and 162.8 centrostokes while standard base oil of 500 Solvent Neutral was 95.0 centrostoke.

Density of a material is defined as the measure of its mass per unit volume (e.g in g/ml). The density of vegetable oil is lower than that of water and the difference in density of vegetable oils are quite small, particularly amongst the common vegetable oils. Generally, the density of oil decreases with molecular weight, yet increase with unsaturation level. From the experiment conducted, the density of castor and jatropha seed oils are 0.9590 g/ml and 0.9200 g/ml, while the value of base oil of 500 Solvent Neutral was 0.9000 g/ml.

The flash point is related to the safety requirement in handling and storage of fuel however, both Castor and Jatropha oils have very high flash point values. This makes them safer to handle and store. When compared with standard base oil, it was discover that base oil of 240 ^{o}C was higher than the two extracted oils of 145 ^{o}C and 113 ^{o}C respectively. But the two sampled oils are good and can be use.

The value of pour point for both Castor and Jatropha oils were 2.7 ^{o}C and 7.7 ^{o}C which was higher than base oil 500 Solvent Neutral value of -6.0 ^{o}C. To meet with the ASTM D-97 standard the vegetable oil sampled (i.e Castor and Jatropha oil) need some adjustment to ensure that their pour point reduced to the bearest minimum, in order to suit for the purpose of its utilization.

Refractive index analysis showed that there was little difference between the value obtained for Castor oil, 1.480 and that of the Jatropha oil 1.435. Comparing this result with the ASTM values that ranges from 1.476 – 1.479, a little difference is noticed. However, this little difference can be considered being within an acceptable experimental error range that can be attributed to the presence of some impurities and other component of the extracted oil mixture. Thus, the refractive index of both Castor and Jatropha oils was in agreement with ASTM specification.

The specific heat capacity for the two sampled oils are similar to each one another but far lower than that of base oil of 500 Solvent Neutral which was 1.270 kJ/kg/K, compared with castor and jatropha oils that were 0.089 kJ/Kg/K and 0.082 kJ/kg/K., respectively. Thermal conductivity value obtained in this study was 4.727 W/m^{o}C for Castor oil and 4.250 W/m^{o}C for jatropha oil while for base oil of 500 Solvent Neutral the value was 0.875W/m^{o}C, which was very lower compare with the value obtained from the vegetable sampled oils.

Table 1: Physical Properties of Castor and Jatropha Oil Extracted

	Properties	Castor Oil							
		Real Values	Average Values	Standard Deviation	Deviation				
1	Viscosity (centistokes)	897.10							
		887.70	889.27	7.18	2.68				
		883.00							
2	Density (g/ml)	0.96							
		0.96	0.96	0.00	0.02				
		0.96							
3	Thermal Conductivity(w/m^{0}C)	0.09							
		0.09	0.09	0.00	0.06				
		0.09							
4	Specific Heat (kJ/kg/K)	4.72							
		4.66	4.73	0.07	0.27				
		4.80							
5	Flash Point (^{o}c)	145.00							

		145.00	144.67	0.58	0.76				
		144.00							
6	Pour Point (°c)	3.00							
		2.00	2.67	0.58	0.76				
		3.00							
7	Refractive index	1.48							
		1.48	1.48	0.00	0.00				
		1.48							

Table 2: Compared Properties of Castor Oil Extracted with Base Oil of 500 Solvent Neutral

S/No	**Properties**	**Name of Oil Used**		
		500 Solvent Neutral	Castor Oil	
1.	Viscosity (centistokes)	95(30°C)	889.3(30°C)	889.3(30°C)
2.	Density (g/ml)	0.9000	0.9590	
3.	Thermal conductivity (W/m°C)	0.875	4.727	
4.	Specific heat (kJ/kg/K)	1.270	0.089	
5.	Flash Point (°C)	240	145	
6.	Pour Point (°C	-6.0	2.7	
7.	Refractive index	1.483	1.480	

Table 3: Determination of Averages and Deviations from real value obtained from Varied Density at Different Temperatures.

Temp, °c	Castor Oil			Deviation
	Real Values	Average Values	Standard Deviation	
30	0.96			
	0.96	0.96	0.00	0.02
	0.96			
40	0.95			
	0.95	0.95	0.00	0.02
	0.95			
50	0.95			
	0.95	0.95	0.00	0.00
	0.95			
60	0.94			
	0.94	0.94	0.00	0.00
	0.94			
70	0.93			
	0.93	0.93	0.00	0.00
	0.93			
80	0.93			
	0.93	0.93	0.00	0.00
	0.93			
90	0.92			
	0.92	0.92	0.00	0.00
	0.92			
100	0.91			
	0.92	0.91	0.01	0.08
	0.91			

Table 4: Varied Density at Different Temperatures for Castor and Jatropha Oil

Temperature (°C)	**Castor Oil**	**Jatropha Oil**
30	0.959	0.920
40	0.951	0.907
50	0.946	0.893
60	0.940	0.891
70	0.933	0.887
80	0.926	0.881
90	0.919	0.876
100	0.914	0.871

Table 6: Varied Viscosity at Different Temperatures for Castor and Jatropha Oil

Temperature (°C)	**Castor Oil**	**Jatropha Oil**
30	889.3	162.8
40	865.8	150.3
50	826.5	147.3
60	820.7	143.6
70	795.7	133.7

80	755.3	128.9
90	717.1	123.2
100	678.6	117.9

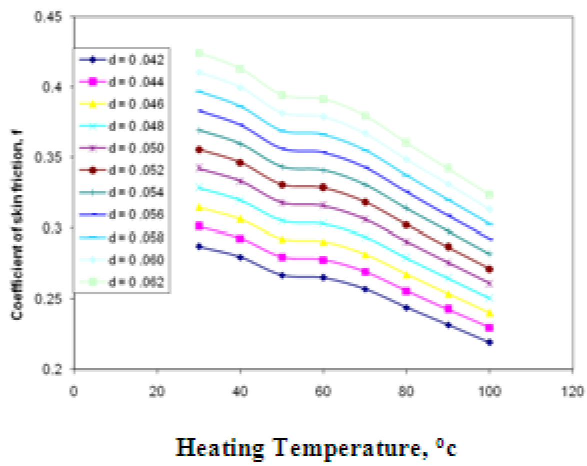
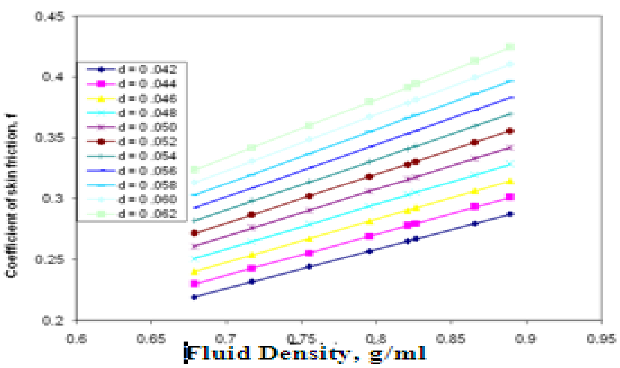


Fig. 1: Plot of Coefficient friction versus Heating Temp. for Castor Oil.

Fig. 2: Plot of Coefficient of skin friction versus Fluid Viscosity for Castor Oil



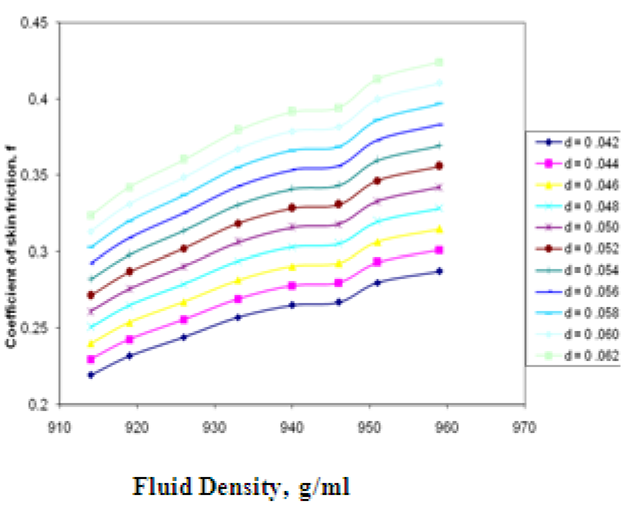
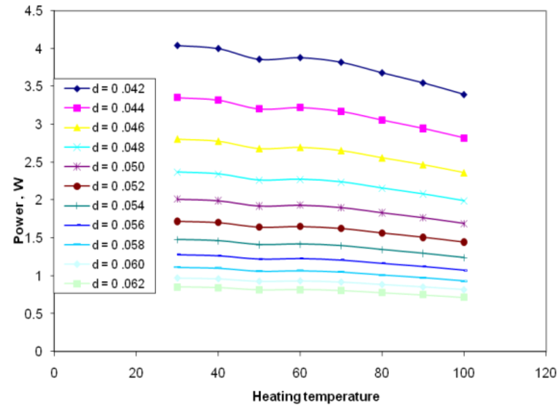


Fig. 3: Plot of Coefficient of skin friction versus Fluid density for Castor Oil



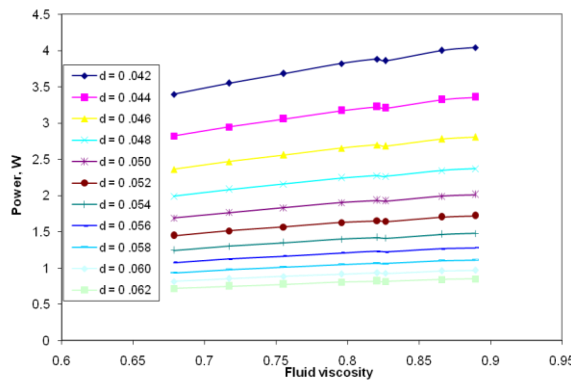


Fig. 4: Plot of Power versus Heating Temperature for Castor Oil, N.S/m

Fig. 5: Plot of Power versus Fluid Viscosity for Castor Oil

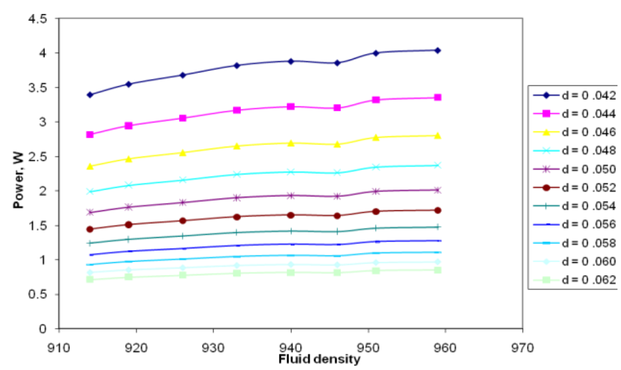


Fig. 6: Plot of Power versus Fluid Density for Castor Oil

CONCLUSIONS

Oil extracted from non-edible seeds of Castor and Jatropha were analyzed and simulated to determine the physical properties, varied density and viscosity with respect to change in temperature. The result showed that the average values for density and viscosity of Castor oil is 936 kgm^{-3} and 0.7938 N.S/m^2, while for the Jatropha oil is 890.75 kgm^{-3} and 0.1385

N.S/m^2 which compare favourably with 500 solvent neutral that is bright and clear in appearance (see Table 2)

Viscosity of a fluid is an important property to consider in the selection of oil for any engine. The viscosity of Castor and Jatropha oils reduces substantially after all the necessary treatment and the sampled oils can perform the required functions much better with increase in temperature. The temperature was found to decrease in the pipe diameter for castor oil while the temperature remains constant as the diameter of pipe increase for the jatropha oil. Most of the values complied with the standard specified by American Standards and Testing Materials (ASTM) hence, the oils are of good quality and could be recommended for suitable industrial usage or exported to generate revenue.

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Table 5: Determination of Averages and Deviations values from real values obtained from Varied Viscosity at Different Temperatures

Temperature °c	Castor Oil				Jatropha Oil			
	Real Values	Average Values	Standard Deviation	Deviation	Real Value	Average Values	Standard Deviation	Deviation
30	897.10				169.10			
	887.70	889.27	7.18	2.68	155.00	162.83	7.18	2.68
	883.00				164.40			
40	868.90				150.30			
	854.90	865.80	9.73	3.12	151.20	150.30	0.90	0.95
	873.60				149.40			
50	822.00				148.00			
	826.70	825.60	3.20	1.79	146.50	147.33	0.76	0.87
	828.10				147.50			
60	817.30				145.60			
	822.00	820.73	3.01	1.73	143.30	143.57	1.91	1.38
	822.90				141.80			
70	798.50				133.90			
	794.70	795.73	2.42	1.56	134.80	133.73	1.16	1.08
	794.00				132.50			
80	756.20				129.20			
	755.30	755.27	0.95	0.97	126.80	128.87	1.92	1.39
	754.30				130.60			
90	728.00				122.10			
	718.60	717.07	11.78	3.43	124.50	123.23	1.21	1.10
	704.60				123.10			
100	685.80				117.40			
	671.70	678.63	7.05	2.66	117.40	117.87	0.81	0.90
	678.40				118.80			