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Density and surface tension relationship of olive oil and carrot oil at different temperatures

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Abstract
Density and surface tension of Olive oil and Carrot oil obtained in Yola, Nigeria were measured at different temperatures using a digital vibrating tube density meter and Interfacial tensiometer method respectively. The results show that the density and surface tension of Olive oil and Carrot oil decreases linearly with increasing temperature. The studies reveal that the density and surface tension of Olive oil decreases with temperature faster than those of Carrot oil. Furthermore, the results show that the surface tension increases with density for all vegetable oils and at all temperatures. It must be noted that all of the plots have straight lines which strongly suggested that all vegetable oils were Newtonian fluids.

Keywords: Density, Surface tension, Temperature, Oil, Liquid

Introduction

Oils and fats are the essential materials for margarine, shortening, salad oil, and other specialty or tailored products, which have become significant ingredients in food preparation or processing in homes, restaurants, or food manufacturers. The majority of the edible oils and fats produced worldwide annually is derived from plant sources and is referred as vegetable oils. Common commercially-available vegetable oils are canola, corn, olive, peanut, soybean, sunflower, and others. There are also number of new vegetable oils such as grape seed, rice bran, macadamia nut, and many others [1].

Measurements of physico-chemical properties such as density, viscosity, surface tension, refractive index and ultrasonic velocity of pure components and their mixtures are being increasingly used as tools for investigations of the properties of pure components and the nature of intermolecular interactions between the components of liquid mixtures. Liquid mixtures due to their unusual behavior have attracted considerable attention. Data on some of the properties associated with the liquids and liquid mixtures like refractive index, ultrasonic velocities and surface tension find extensive application in chemical engineering process simulation, solution theory and molecular dynamics [2].

Surface tension is the fundamental property of a liquid, which makes the free surface of a liquid, behaves like a stretched elastic membrane. It is also an inherent property of a liquid to alter its shape in such a way that the area of its free surface is minimum possible. According to the molecular theory, this arises, because the molecules in the bulk of the liquid experience zero resultant intermolecular force due to their nearest neighboring molecules while the molecules in the surface of the liquid experience finite resultant intermolecular force acting inwardly the bulk of the liquid due to excess neighboring molecules below them. Because of the inherent tendency of a liquid to contract, it behaves as if there exists in its surface a tension which acts equally in all directions. This surface tension of a liquid is defined as the force per unit length acting on either side of an imaginary line drawn in the surface at equilibrium. The direction of the force is tangential to the surface and perpendicular to the line [3, 4].

Whenever a liquid is placed in contact with a solid, the liquid surface is in general curved. When a liquid gets in contact with a solid, there exists a boundary in which there is the surface tension in solid-liquid interface. The angle between the solid surface and the tangent to liquid surface drawn from the point where the liquid surface meets with the solid surface measured through the liquid is called the angle of contact. Those liquids whose angle of contact is acute or less than 90^0 rise in the capillary tube while those liquids having angle of contact obtuse or greater than 90^0 fall or depress in the capillary tube. Similarly, liquids with concave meniscus fall in the capillary tube. Examples of liquids with acute angle of contact and meniscus concave include water, alcohol, ether, glycerin and so on. In practice, angle of contact for such liquids that rise in capillary is small, nearly zero, when they are in contact with glass. Examples of liquids with obtuse angle of contact and convex meniscus are mercury. It is crystal clear that the angle of contact also explains the shape of the liquid meniscus near a solid surface [5].

It is popularly known that the factors affecting surface tension of a liquid include temperature, nature of the liquid itself, impurities or contaminations [6] and so on. For example, detergents and temperature decrease surface tension of water. Consequently, the knowledge of surface tension has found useful applications in everyday life which include quality control in industries, upward movement of kerosene in wicks of lamp for lighting and stoves for cooking, enhances cleansing effect of soaps and detergents, movement of pond skater on water, and design of umbrella, raincoat and tents to mention nut a few.

In this paper, the surface tension of Olive oil and Carrot oil is investigated at various temperatures. Over the years the author noticed through private communications with traders (sellers) and customers (consumers or users) of these oils patronize particularly oil based on its color, odor, taste, cost, advert slogans made by manufacturers through news media and so on. Consequently, the traders are ignorant of the effect of temperature on surface tension of the oils, displaying them under hot sun and the consumers buy out of ignorance.

Materials and Method

The Olive oil and Carrot oil used were obtained from Yola market in their sealed containers. A thermostatically controlled well-stirred water bath whose temperature was controlled to ±0.01 K accuracy was used for all the measurements. All the measurements were done by using electronic balance accurate to 0.02 g. Densities were measured in an Anton Paar DMA 60 digital vibrating tube density meter, with DMA 602 measuring cell. Air and redistilled water were used for the calibration of the density meter

Surface tension of pure liquids over the whole temperature range was determined using Interfacial tensiometer (ASTM D.971) with 1No. 4cm platinum ring as per IS 6104.. It was calibrated with distilled water. The accuracy of the surface tension measurement was estimated to be $0.03mNm^{-1.}$ [2].

Results and Discussion

The density and surface tension of Olive oil and Carrot oil at different temperatures are presented in Table 1. The results show that these quantities decrease with increasing temperature. The variations of these oil properties can be explained in terms of molecular theory that all substances are made up of small tiny building units called molecules as follows: According to the molecular theory, when a liquid is heated the molecules move apart i.e. it expands, the number of molecules or mass remains the same but the volume increases and as a result the density decreases

Table 1: Density and surface tension of olive oil and carrot oil at different temperatures

T(K)	Density ($kg/m^{3)}$)		Surface tension (mN/m)	
	Olive oil	Carrot oil	Olive oil	Carrot oil
313.15	888.89	886.77	34.46	34.18
323.15	882.47	880.92	33.46	33.23
333.15	876.12	874.19	32.54	32.25
343.15	870.34	868.08	31.53	31.17
353.15	863.71	861.08	30.65	30.43
363.15	856.6	854.18	29.83	29.56
373.15	850.15	848.12	29.1	28.77

The plot of density versus absolute temperature in Fig 1, the correlation coefficient R^2 has value 0.9993 and 0.9922 for Olive oil and Carrot oil respectively. Also the decrease in density per Kelvin for Carrot oil is – 0.6592 kg $m^{-3}k^{-1}$ which is relatively lower than that of Olive oil – 0.6444 kg $m^{-3}k^{-1}$ i.e. Olive oil expands faster on heating than Carrot oil. The linear density regression lines at absolute zero temperature give the values of densities of Carrot oil and Carrot oil as 1088.9 kgm^{-3} and 1096.6 kgm^{-3} respectively. At the absolute temperature, the molecules of the oils are expected to be at rest with zero kinetic energy and minimum intermolecular distance with maximum potential energy, which in agreement with Yerima [3]

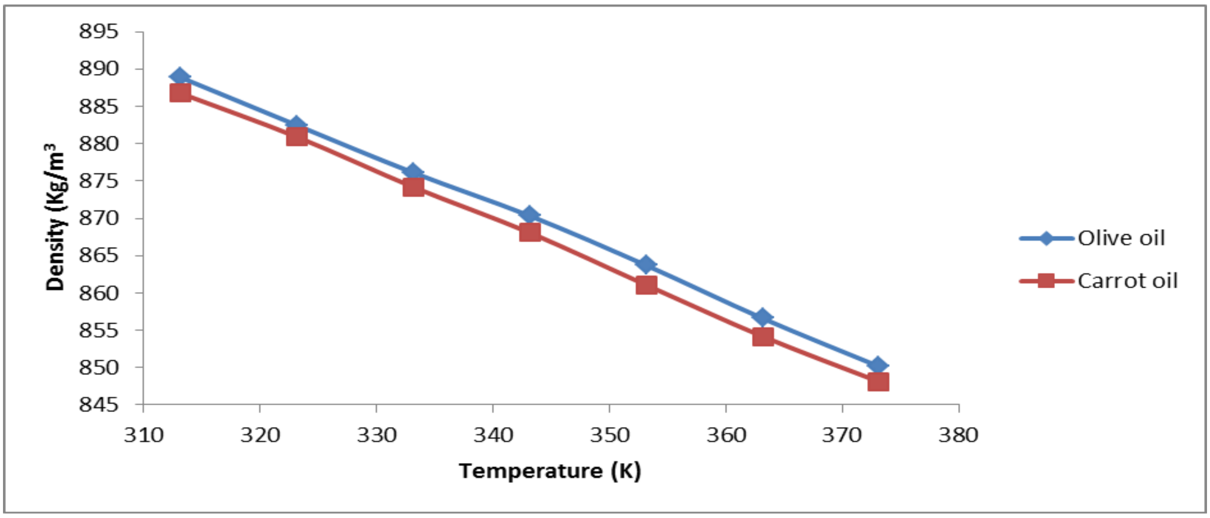

Fig 1: Densities of Olive and Carrot oils as functions of temperature

The densities of Olive oil and Carrot oil increase linearly with surface tension (Fig. 7). This is true since both quantities decrease with increasing temperature (Fig. 1 & 2). The regression lines are:-

$\rho_{olive} = 7.7187\gamma + 631.88, with \quad R^2 = 0.9947$ and

$\rho_{carrot} = 7.4425\gamma + 642.56, \ with \quad R^2 = 0.9789$

for Olivet oil and Carrot oil respectively. For $\gamma = 0$, we have critical density values of 630.69 kgm^{-3} and 641.43 kgm^{-3} for Olive oil and Carrot oil respectively

The molecular theory explains that when a liquid in a glass capillary tube is heated, the sum of the cohesive forces existing between the molecules of the liquid and the adhesive forces between the molecules of the liquid and glass decreases. This means that the surface tension decreases with increasing temperature (Table 2). Fig. 2 shows the surface tension-temperature regression lines have the decrease of surface tension per Kelvin as – $8.28x10^{-5}$ $Nm^{-1}K^{-1}$ and – $8.60x10^{-5}$ $Nm^{-1}K^{-1}$ with R^2 values of 0.9924 and 0.9584 for Olive oil and Carrot oil respectively. This reveals that the rate of decrease in surface tension of Olive oil is faster and yet smoother than that of Carrot oil which may be due to the nature of the entanglement of the molecules in the surface tension of the oils. Also, from the linear regression analysis, we deduced the critical temperatures at which surface tension vanishes or becomes zero to be 757.6 K and 699.5 K for Olive oil and Carrot oil respectively.

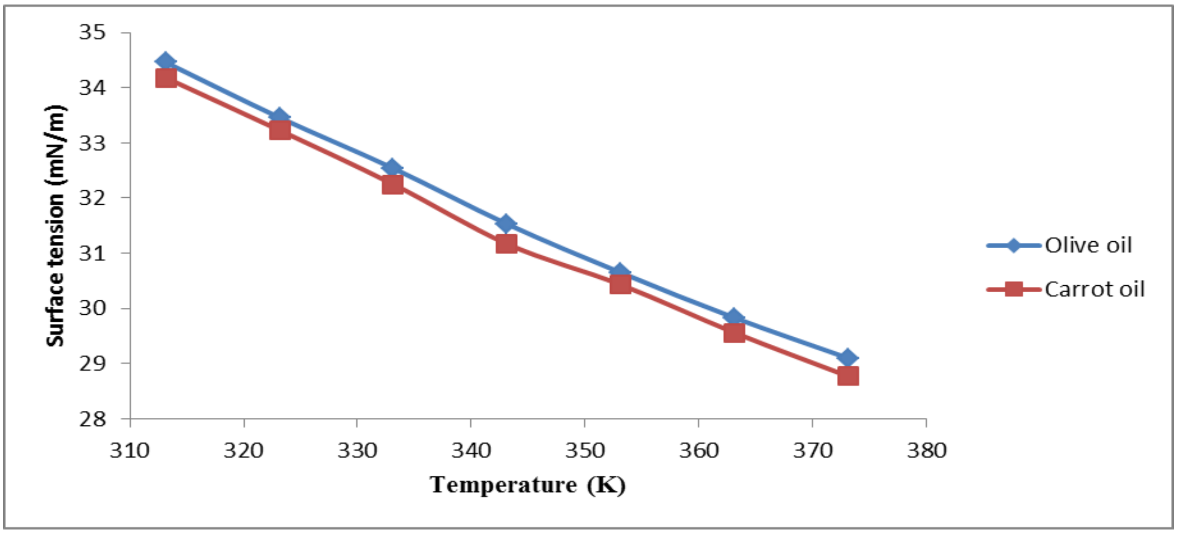

Fig 2: Variation of surface tension of olive oil and carrot oil with temperature

According to molecular theory, the decrease in the intermolecular force with temperature affects the curvature of the meniscus of the liquid in the capillary tube and hence the contact angle. When the adhesion is greater than cohesion, the liquid has concave meniscus and when cohesion dominates it has convex meniscus. The results show that the surface tension increases with density for all vegetable oils and at all temperatures. It must be noted that all of the plots have straight lines which strongly suggested that all vegetable oils were Newtonian fluids.

Conclusion

The density and surface tension of Olive oil and Carrot oil were studied at various temperatures using the densitometer and Interfacial tensiometer method respectively. The results show that density and surface tension linearly decreases with temperature. Also, the linear regression analysis reveals that the rate of decrease of these quantities of Olive oil with temperature is faster than that of Carrot oil. Therefore, Olive oil may be a better medium for digestion and transport of material through capillary blood vessels to other parts of the body.

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