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The effect of temperature change on the surface tension of some locally produced vegetable oils in Yola, Nigeria

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Abstract
Surface tension of some locally produced vegetable oils; shear butter, con oil, groundnut oil, cotton seed oil, soya beans oil were determined using a temperature control capillary rise setup. The surface tension of the vegetable oils decreased with increasing temperature. Palm oil and cotton seed oil had higher surface tension, while shear butter had the least surface tension among the vegetable oils studied. The values of the surface tension of the vegetable oils considered were comparable to the surface tension values obtained in the literature.

Keywords: Vegetable Oils, Surface tension, Density, Temperature, thermometer, capillary tube, water bath

1. Introduction
Surface tension is a physical property of a liquid caused by the cohesive forces between liquid molecules. Liquid molecules placed within the bulk of a liquid are completely surrounded by like molecules so that the forces of attraction between adjacent molecules are equal in all directions. Conversely, the molecules on the surface of the liquid at the liquid/gas interface present unbalanced forces, resulting in an inward attraction (Bernat *et al,* 2012).

Surface tension is a property of liquids such that their surfaces behave like a thin, elastic film. Surface tension is created by the inward pulling force exerted on the surface of a fluid. The surface tension can also be defined as the force F per unit length L tending to pull the surface back. Due to surface tension, the molecules in a liquid/gas interface are in tension and tend to contract in a minimum surface area (Dikko and Edwin, 2014).

Surface tension has a deep influence on the final quality in many products such as fuels, detergents, ink jet products, pharmaceuticals and lubricants among others. Additionally, surface tension plays an important role in processes as wetting, penetrating, and foaming or droplet formation of a liquid, thus governing the chemical and physical behaviour of liquids. Surface tension depends on variables such as temperature, pressure and, in case of mixtures, composition. In case of fuels destined to internal combustion engines, surface tension greatly influences the droplet formation in the injection system as well as the atomization properties related to the quality of ignition (Bernat *et al,* 2012).

A vegetable oil is a triglyceride extracted from a plant. Such oils have been part of human culture for millennia. The term "vegetable oil" can be narrowly defined as referring only to plant oils that are liquid at room temperature, or broadly defined without regard to a substance's state of matter at a given temperature. For this reason, vegetable oils that are solid at room temperature are sometimes called vegetable fats. Vegetable oils are composed of triglycerides, as contrasted with waxes which lack glycerin in their structure. Although many plant parts may yield oil, in commercial practice, oil is extracted primarily from seeds. These oils make up a significant fraction of worldwide edible oil production (Wikipedia, 2014).

The following are some popular major oils:-

1. Coconut oil, a cooking oil, with medical and industrial applications as well. Extracted from the kernel or meat of the fruit of the coconut palm.

2. Corn oil, one of the principal oils sold as salad and cooking oil.
3. Cotton seed oil, used as a salad and cooking oil, both domestically and industrially.
4. Olive oil, used in cooking, cosmetics, soaps, and as a fuel for traditional oil lamps.
5. Palm oil, which the most widely produced tropical oil and also used to make biofuel, is popular in West African and Brazilian cuisine.
6. Peanut oil (Ground nut oil), a clear oil with some applications as a salad dressing, and, due to its high smoke point, especially used for frying.
7. Rapeseed oil, including Canola oil, one of the most widely used cooking oils.
8. Safflower oil, until the 1960s used in the paint industry, now mostly as a cooking oil.
9. Sesame oil, cold pressed as light cooking oil, hot pressed for a darker and stronger flavor.
10. Soya bean oil, produced as a byproduct of processing soya meal.
11. Sunflower oil, common cooking oil, also used to make biodiesel.
12. Almond oil, used as edible oil, but primarily in the manufacture of cosmetics.
13. Beech nut oil, from *Fagus sylvatica* nuts, is well-regarded edible oil in Europe, used for salads and cooking.
14. Cashew oil, somewhat comparable to olive oil, and may have value for fighting dental cavities.
15. Hazelnut oil, mainly used for its flavor and also used in skin care, because of its slight astringent nature.
16. Macadamia oil, with a mild nutty flavor and a high smoke point.
17. Mongongo nut oil (or *manketti oil*), from the seeds of the *Schinziophyton rautanenii*, a tree which grows in South Africa. High in vitamin and also used in skin care.
18. Pecan oil, valued as food oil, but requiring fresh pecans for good quality oil.
19. Pine nut oil, sold as gourmet cooking oil, and of potential medicinal interest as an appetite suppressant.
20. Pistachio oil, strongly flavored oil with a distinctive green color.
21. Walnut oil, used for its flavor, also used by Renaissance painters in oil paints.

2. Materials and Method

Some locally produced vegetable oils in Yola, Nigeria, like shear butter, groundnut oil, palm oil, con oil, cotton seed oil, soya beans oil were used in the study. These oils were bought directly from the people that produced them with traditional and local equipments. Density is an important physical characteristic of any substance, and is a measure of the mass per unit of volume of that substance. It is an accepted fact that vegetable oil density decreases linearly with increasing temperature. This relationship can be expressed mathematically as, equation (1)

$$\rho = a + b \cdot T \qquad (1)$$

Where ρ is the density expressed in g cm^{-3}, T is the temperature expressed in °C, a is the intercept and b is a negative slope. The density values of the vegetable oils used in this study were obtained from literature (Fogiel, 1994) (Abolle et al, 2009), (Dikko, 2014), (Rodenbush *et al*, 1999), (Fasina et al, 2006)

Figure 1, shows the end of a capillary tube of radius, *r*, is immersed in a liquid. For sufficiently small capillaries, one observes a substantial rise of liquid to height, *h*, in the capillary, because of the force exerted on the liquid due to surface tension. Equilibrium occurs when the force of gravity on the volume of liquid balances the force due to surface tension. The balance point can be used to measure the surface tension (Bernat *et al,* 2012).

$$\gamma\,(2\pi r) = \rho h(\pi r)g \qquad (2)$$

where r is the radius of the capillary, h is the capillary rise, ρ is the liquid density, g is the acceleration due to gravity, and γ is the surface tension of the liquid. Rearrangement gives a simple expression for the surface tension as

$$\gamma = \tfrac{1}{2}\rho g r h \qquad (3)$$

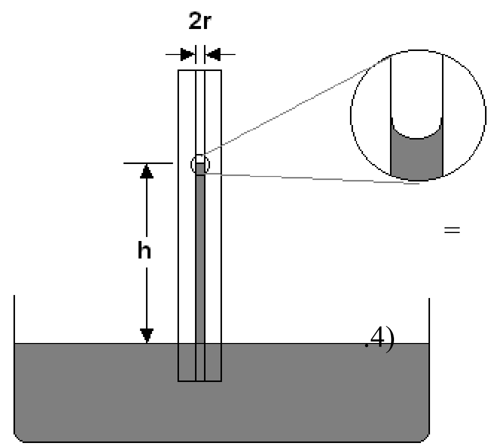

Fig 1: Capillary rise due to surface tension.

The boundary shows that the surface is not perfectly flat. It curves up or sometimes down for certain materials at the wall to form a meniscus, as shown in the inset in Figure 1.The material in this region also contributes to the force of gravity, so one often finds a correction to equation (3) of the form

$$\gamma = \tfrac{1}{2}\,\rho g r(h + r/3) \qquad (4)$$

The contact angle which is the angle between the surface of the liquid and surface of the glass, has been assumed to be 0°.

The diagram for the setup used in this study is shown in Fig.2, with a test tube fitted with a two-hole stopper.

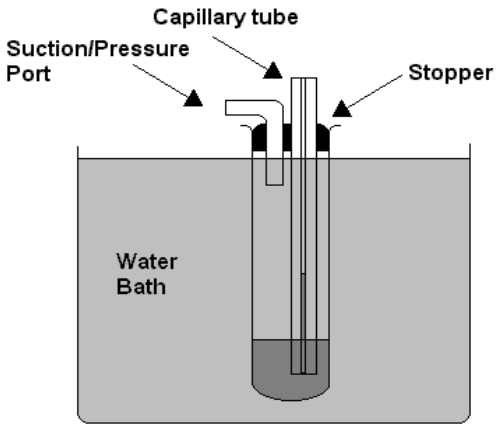

Fig 2: Diagram for the apparatus for measuring capillary rise at a temperature

The capillary tube is fitted through one hole and a length of a thermometer cut to expose the capillary at both ends. This is fitted through a glass sleeve and held in place by a piece of rubber tubing. In the second hole is a tube through which pressure or suction can be applied. This test tube apparatus is immersed in a water bath to allow control of temperature at 313 K (Bernat *et al,* 2012).

A cathetometer was used to determine the rise above the level of the material in the test tube. The height of the liquid in the test tube and then the height of the liquid in the capillary were recorded. Then the difference in these heights is the capillary rise. The measurement, like all measurements, was done relative to the surface tension of water. The temperature was controlled by opening the stopcocks to allow circulation of water from the thermal bath into the cylindrical container that holds the experiment. Then everything was allowed for 10 minutes to come to a constant temperature and the temperature of the bath was recorded from the thermometer on the bath.

3. Results and Discussion

The surface tension values of the vegetable oils studied are presented in Table (1). The surface tension of all of the oils decreased with the temperature increase. This could be due to the energy obtained to overcome the resistance to to pull back the molecules from each other. This may be due to the attractive forces among the oil molecules. From Figure (3), one can see that the reduction of the surface tension is of linear trend of the temperature increment.

Table 1: Variation of surface tension (mN/m) of vegetable oils with temperature

T(K)	Shear butter	Groundnut	Cotton seed	Soyabean	Palm	Corn
313	31.32	33.33	33.54	32.42	33.55	33.34
323	30.22	32.54	32.62	31.61	31.62	32.23
333	29.22	31.43	30.71	31.44	31.14	31.44
343	28.12	30.81	30.05	31.24	30.05	30.91
353	27.44	30.32	29.24	30.33	29.33	30.24
363	26.73	29.12	28.62	29.52	28.44	29.43
373	25.63	28.42	27.71	28.61	28.25	28.71

Palm oil and shear butter has the highest and least surface tension, respectively, from all six vegetable oils studied. The other oils, soya bean oil, groundnut and cotton seed, are ranged between these two surface tension limits. Corn oil had second highest surface tension among the oils studied. The high oil surface tension could be attributed to the stronger attraction force between oil molecules. Therefore, shear butter is the liquid with the weakest in terms of its resistance to pull back in relative comparison to the other five oils.

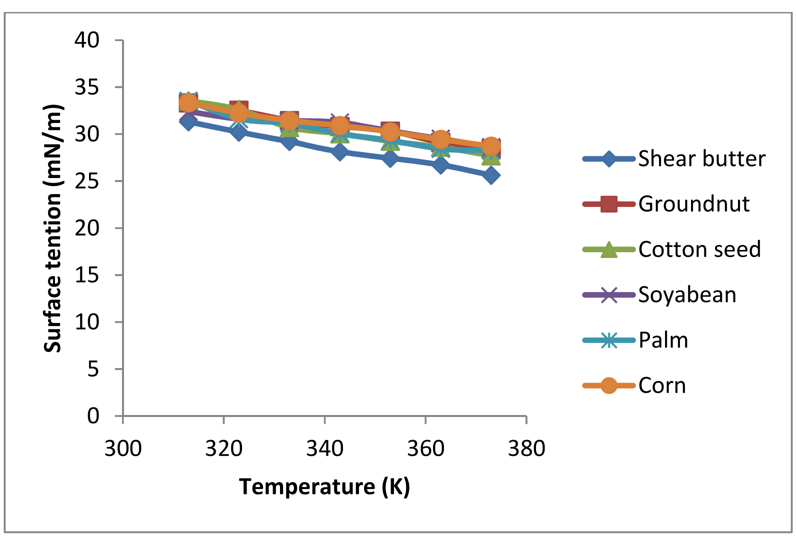

Fig 3: Variation of some locally produced vegetable oils with temperature

The surface tension of the vegetable oils studied fall between 25.63 mN/m and 33.55 mN/m, within temperature range of 313 K to 373 K, which are comparable to the ones in literature (Nazima and Adeel, 2013), (Bernatt et al,2012). (Fogiel, (1994).

4. Conclusion

The surface tension of the vegetable oils decreased linearly with increasing temperature Palm oil has the most surface tension followed closely by corm oil, while shear butter oil has the least surface tension followed by cotton seed oil among the oils studied. The values of the surface tension of the vegetable oils determined in this study, locally produced, are comparable to those produced by modern machines.

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