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Effects of Food Impurities (Solutes) on Surface Tension of Groundnut Oil

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Abstract
The variation of some physical properties of groundnut oil with food solutes were investigated at room temperature, using standard laboratory experiments. These physical properties of groundnut oil were determined at room temperature 36 ^{o}C before and after heating up to 120 ^{o}C, and it was found that the physical properties remains the same. The following food samples Irish potato, Sweet potato, Egg, Plantain, Beans and Yam were used to introduce solute into the groundnut oil. These food samples were made in paste form and equal amount of each(100 gram) were measured and fried in 200 mL of groundnut oil. The physical properties of the remaining groundnut oil after frying, each sample were determined. The result shows that the physical properties of groundnut oil increase or decrease as compared to their values measured in the absence of solutes. However, the variation of physical property is independent of the class of food solutes. From the observation, egg (highly protein) shows the highest increase in the values of surface tension γ (3.420 x 10^{-2} Nm^{-1}) then followed by most highly carbohydrates food (yam, sweet potato, and Irish potato) with surface tension, γ (3.296 x $10^{-2}Nm^{-1}$, 3.172 x 10^{-2} Nm^{-1} and 3.109 x 10^{-2} Nm^{-1} respectively). Beans (protein) has the least increase in surface tension γ, 2.488 x $10^{-2}Nm^{-1}$. An increase or decrease in γ depends on the intermolecular strength of force of adhesion present.

Key words: Solutes, physical properties, surface tension, groundnut oil, paste forms and adhesion

INTRODUCTION

Generally, edible oils, for example, groundnut oil (organic compound) belongs to a homogenous series of fats and oil with similar chemical characteristics. The surface tension is a macroscopic physical property of a liquid, result from the interaction between the molecules making the bulk liquid. The knowledge of the effect of impurity and other physical quantities of edible oils have both industrial and domestic applications and are useful as a prime index for quality control processes (Alfred,& Ngoddy1985). The interplay of cohesive and adhesive forces in liquid exhibits the phenomenon of surface tension has been known to depend on several variables and importance among the variables are temperature, impurities, magnetic field and electric field. It was explained in second edition of Handbook of physics written by Condon and Odishaw that the greater the concentration of solute in the surface region than in the bulk region, surface tension of liquid or solution tend to decrease with increase in concentration of the solute (capillarity active). But if the concentration of the solute in the bulk is greater than in the surface, surface tension will increase with an increase in concentration (capillarity inactive). As observed by Tareev in (1979), films of organic solutes in a dilute solutions are predominant in nature.

A molecule in the center of a liquid is known to attract equally in all directions by the surrounding molecules. Molecules on the surfaces of liquids however, are only attracted towards the interior of the liquid. The surface molecules are therefore are pulled inwards to be minimized or to balance the pull. The resultant force on the molecules inside the liquid is zero. Since the molecules at the surface are attracted downwards by the inner molecules, the surface of liquid is under tension. Work is done in removing the molecules at the surface to infinity. The energy required to sustain the removal of these surface molecules is called surface energy (Ike, 2010). Surface tension is the measure of the inward force on the surface of the liquid. This force must be overcome in order to expand the surface area. It can also be defined as force acting in the surface of a liquid tending to minimize the area of the liquid. This behavior account for a spherical shape of liquid drops on capillary action. The surface tension of liquids decreases with increase in temperature, since the increase molecular motion tends to decrease the effect of intermolecular attractive forces. Also, the presence of impurities affect the surface tension of liquids. For example, detergents lower the surface tension of water. In this research, solute from egg, plantain, potato show an increase in surface tension of diluted groundnut oil while solute from yam and beans lower surface tension of same oil.

The main aim of this research, is to investigate the dependence of surface tension of groundnut oil with different food samples dissolved in the oil during frying process. This will no doubt, if properly incorporated will help in quality control in food industries.

The research on investigation of effect of concentration of solute introduced into a locally prepared groundnut oil from the following food samples; egg, red beans, yam, plantain, Irish potato and sweet potato on surface tension was carried out in Yola, North of Nigeria.

Theoretical view of Surface Tension

The surface tension γ of liquid is defined quantitatively as the perpendicular forces exerted by the surface molecules on a unit length of an imaginary straight line drawn in the liquid surface.

The basis for the variation of surface tension with impurity is the relationship between the dielectric constant, K and surface tension, γ of oil samples. Various theories Ikata in (1990) observed that surface tension effect is associated with the intermolecular forces acting in the liquid. In such class of liquid, it is believed that the ions dispersion and the hydrogen type of forces do predominate despite the fact that the oil molecules are polar.

Surface tension decrease with increase in temperature since the molecules of the liquid are counteracting the mutual molecular attraction with increased energy. EOtVOS (84) derived a relationship between the surface tension γ and temperature T and Ransay and Shields modified EOtVOS equation as

$$\gamma \frac{M_v}{3} = K_c\left(T - T_c - 6\right) \quad (1)$$

Where M_v is the molar volume of liquid, T_c is the critical temperature, K_c is the EOtVOS constant to normal liquids.

The theory of motion of molecule of liquid was developed by Born and courant (38), suggested that K_c is influenced by number of degree of freedom for molecular motion and the orientation molecules in the surface molecular shape and packing mutual interaction between part of molecules and the thickness of surface layer. K_c is not universal constant.

Gradually, several empirical relations were further established.

$$\gamma = \gamma_o(1 - bT) \quad (2)$$

$$\gamma = \gamma_o\left(1 - \frac{b^1 T}{T_c}\right) \quad (3)$$

where b and b^1 are constants

The above equation does not fit experimental data. Kafayama (149), further modified the equation which fit experimental data that is well close to critical temperature.

$$\gamma\left(\frac{M}{\rho_l - \rho_v}\right)^{2/3} = K_c T_c\left(1 - \frac{T}{T_c}\right) \quad (4)$$

where M is the molecular weight, ρ_l and ρ_v are the densities of liquid and vapor respectively.

Vander Waals (231) still proposed the equation in which he introduced the universal constant K_u for liquids

$$\gamma = K_u T_c^{1/3} P_c^{2/3}\left(1 - \frac{T}{T_c}\right)^n \quad (5)$$

where n is the average for many liquids established by Furgusen (100). Numerical value of n is 1. 21.

Macheod (176), eliminated the factor $\left(1 - \frac{T}{T_c}\right)$ from the Vander Waals equation and obtained

$$C_k = \frac{\gamma}{(\rho_l - \rho_v)^4} \quad (6)$$

Equation (6) is called Katayama's equation.

The frame method by Torsion Balance Type E2 established a formula for determining the surface tension of a liquid using microscope slide given as

$$\gamma = \frac{W}{2(L + t)} \quad (7)$$

Where W is the weight in newton, L is the length of slide given in meter and t is the thickness of microscopic slide in meter.

This method was used to investigate the effect of impurity due to some food items, such as egg, yam, plantain, potatoes and beans on the surface tension of groundnut oil at room temperature. These impurities were introduced into groundnut oil during frying process.

Effects of Solute on Surface Tension

When insoluble surface-active material is placed upon a clear liquid surface, the substance spread to form a mono-layer and always accompanied by a decrease in the free surface energy of the system. The film pressure or surface pressure, P_s is given as

$$P_s = \gamma_L - \gamma_{Lf} \qquad (8)$$

Where γ_L is surface tension of pure liquid, γ_{Lf} is the surface tension of the liquid with the absolute film on it. The property of absorbed monolayer is justified by the three states of matter, in 2-D.

Since surface tension depends on temperature at the region of contact, with the frame, vapour, solid and liquids are subject to expand. Liquid and solid expanded film contribute to small area per molecule whereas vapor expanded film contribute to gaseous state or phase. These changes was observed by Ehrentest (76), and he further modified the equation as the equation of state for perfect gas in 2-D, and it is given as

$$P_c = K_c T \qquad (9)$$

And for liquid expanded film is

$$(P_s + P_o)(\rho - \rho_o) = K_c T \qquad (10)$$

Where ρ_o and P_o are constant in some systems. Intermediate film is formed between liquid expanded film and the condensed film, it can be homogeneous films.

For soluble substance, it was observed that, the greater the concentration of solute in the surface region than in the bulk region. Surface tension of the liquid or solution tends to decrease with increase in concentration of the solute in the bulk is greater than in the surface. Surface tension increases with an increase in concentration (capillary inactive). Traube (228) proposed that films of organic solutes absorbed from dilute solutions are predominantly in nature.

It was observed that food samples dissolved in groundnut oil during frying are thereby changes the concentration of groundnut oil. The knowledge of capillarity, inactive was used to investigate the effect of concentration of some food items on the surface tension of groundnut oil.

METHODOLOGY

Source of groundnut oil and preparation of solutes

The material was a locally produced groundnut oil bought from Jimeta market, in Adamawa state -Nigeria. Groundnut oil is commonly used in cooking and frying. Its melting point ranges, from 0 -3^0C, and becomes very hot at temperature 175^0C - 200^0C. Above these temperature, it may likely decompose or ignite. Before measurement were made, the bulk oil was first sieved, and its surface tension γ this fresh oil was determined. On heating the oil to 120^0C, it was allowed to cool to room temperature (36^0C), and its surface tension γ was determined. It was observed that the physical properties before and after heating remain the same.

Measurement of Surface Tension of G / Nut Oil by the Torsion Balance Type E2.

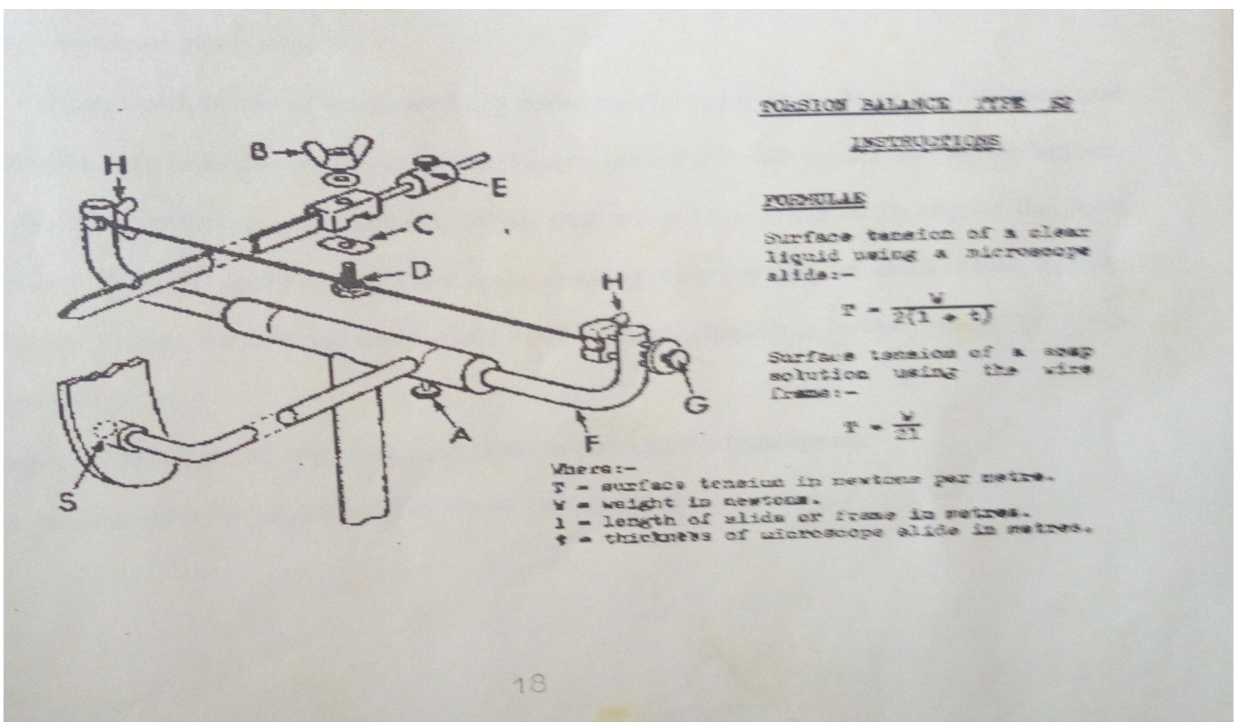
The apparatus were assembled as shown above in Fig 1. The wire frame was thoroughly cleaned to remove all traced of dirt and grease, and hanged below the scale pan of the torsion balance which was suspended at the 'V' notched in the beam (pointer). The pointer was set to zero by adjusting the position of counter weight (counter), E. To tension the wire, the thumbscrew, A was slacked to adjust the position of the scale support until the pointer was just cleared off the direction or position; a shallow wide dish (beaker) contained oil was set below the wire frame and the orientation of the frame was adjusted in such a way that the edge of the wire frame at the balance pointer levered up to the oil.

By depressing the scale pan, the lower edge of the wire frame was immersed in oil. Slowly, the balance scale was titled back by means of levelling screw (base knurled screw) for fine adjustment. The reading on the scale when the wire / slide breaks contact with the surface of the oil was noted. Procedure was repeated two times to ensured consistency.

Dish contained oil was carefully removed without disturbing the balance. The weight, Mg was placed on the scale pan to give the mean scale reading as before. This was repeated on each sample of oil that have been used in frying of the food samples, and the scale and mean scale reading were noted in each case. All the readings were noted in each case. All readings were taken at room temperature 36 ^{o}C.

The length of the wire frame was measured using a pair of calipers. Result observed were tabulated.

Figure 1: Torsion Balance Type E2



Calculation of Surface Tension

The surface tension γ of a groundnut oil was determined using Torsion Balance Type E2 and the value of it were calculated using the expression

$$\gamma = \frac{W}{2(L+t)} \qquad (11)$$

Where L is the length of the slide or frame in meter, t is the thickness of microscopic slide in meter and W is the weight in newton.

Results

	Sample food fried with groundnut oil						
	A Fresh oil	B Oil + Egg	C Oil + plantain	D Oil + yam	E Oil + S.P	F Oil + I.P	G Oil + R.B
Mean scale reading	0.400	0.500	0.425	0.550	0.525	0.45	0.42
Mass added to scale pan (kg) x 10^{-3}	4.50	5.50	4.170	5.30	5.10	5.00	4.00
Surface tension γ (nm^{-1}) x 10^{-2}	2.799	3.420	2.593	3.296	3.172	3.109	2.488

Table 1: Variation of surface tension with different solute

Discussion

The surface tension of groundnut oil without contaminant was found to be 2.8 x 10^{-2} Nm^{-1}. When groundnut oil was adulterated with solutes from the following food samples (egg, yam and potatoes) in the course of frying them resulted in increasing the surface tension of groundnut oil. Solutes from plantain and beans lower the surface tension of groundnut oil. From the related literature, plantain and beans have lower water content compare to the other four food items fried. These low water content may attribute in decreasing the surface tension of g/nut oil used in frying them. Other reasons, may be due to the fact that, solutes from these food may contained high concentration of insoluble solutes or soluble solute with high concentration on the surface than in the bulk region of the oil. Formation of intermediate film as a result of liquid and vapour expanded film, may also be the reason. The protein-starch relation tends to reduce the formation of gel and formation of monolayer by insoluble solute and this can weaken the intermolecular force existing in the liquid. Liquids with high concentration of soluble solutes in the bulk region than that on the surface tends to have higher surface tension.

As indicated in appendix 1, Irish potato and beans are highly proteinases food, and according to Adamson in (1982), the higher the concentration of the protein in a liquid the lesser becomes the surface tension of the contaminated groundnut oil. In general, when protein molecules are absorbed onto the interface, they may change the tertiary structures to suit the new environment, such as specific orientation and film formation to obey the law of thermodynamics and thus reduce the surface energy. Though it is a slow diffusing molecules (Douglas and Genn, 1982). As observed by Ghost et al (), the physical chemistry of surface, that contained about 0.06% of egg albumin solution at (pH 4.9, 30°C), reduces surface tension from 6.2 x 10^{-2} Nm^{-1} to a low value within 55 min. It may also be that the contaminated groundnut oil might have contained emulsion (colloidal dispersion or intimate mixture of liquids) and basically, such mixtures do causes unstable arrangement in the liquid. Therefore contaminant from Irish potato and red beans might have acted as an emulsifying agent, which according to Mc William Margaret in (1989), say that emulsifiers promote stability between the interfaces of two media. Proteins are capable of acting as an emulsifier and such emulsifiers according to her can reduce surface tension. According to Douglas et al in (1982), emulsion depends on complex interaction of emulsion type, concentration, degree of dispersion and nature of the emulsifying agents.

Also observed by Brain in (1984), different protein has different abilities of reducing surface tension.

Observation from the table 1, shows that impurities from egg, yam and potatoes increases the surface tension of groundnut oil while solutes from plantain and red beans decreases the surface tension of the same oil. It was observed that these changes in surface tension is independent of class of food sample. Similarly, it also be argued that surface tension of groundnut oil increases because of concentration of solutes from the yam, egg, sweet potato and plantain in the bulk region are higher than that on the surface and it decreases because the concentration of solute from Irish potato and red beans are higher on the surface than those at the bulk region.

Other fact is that solutes from the egg, sweet potato and plantain may contained more of emulsifying agent, which may cause unstable arrangement within the medium, hence this may result in increasing the surface tension.

Conclusion

Effect of solutes on surface tension of groundnut oil was found to vary independent of the class of food items. The changes in γ, is basically governing by behavior of intermolecular forces; the adhesive and cohesive.

These variations may advance application in the study of quality control of groundnut oil in food industries. For example, emulsion needs to be stable when they are part of food product, if top quality is to be achieved. It is known that when emulsion in a cake bath is broken, the texture of it becomes coarse. Therefore the inclusion of emulsifying agents in a commercial shortening helps to increase the stability of the emulsion, thereby promoting fine texture in cakes. Emulsifier in margarine enables warming without excessive splattering.

Recommendation

Any researcher that has interest in this work should try the following method:

1. Vary the masses of the food sample (in paste form) and fry each in the same volume of groundnut oil
2. Vary the volume of oil and keep mass constant for each sample
3. Try finding out the chemical composition of groundnut oil before and after frying to check whether variation in physical properties is due to contamination rather than the solutes.

Torsion balance Type E2 can be used to determine γ of groundnut oil.

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Appendix

Table 1: Food composition of some local food (100 g).

Courtesy: Brain Fox A. (1984). Nigeria Institute of Food Science and Technology

Sample	Egg			Irish potato	Yam	Sweet potato	Plantain	Red Beans	
	whole	white	yolk					Red	cooked
Water (%)	73.7	87.6	51.1	75	75.5	70.6	66.4	10.4	69.0
Protein (g)	12.6	10.9	16.0	3.2	2.1	1.7	1.1	10.4	69.0
Carbohydrate (g)	0.9	0.8	0.6	17-43	23.2	26.3	31.2	22.4	7.7
Calcium (mg)	54	9	141	7	20	32	7	60.6	21.4
Phosphorus (mg)	205	15	596	53	69	47	30	110	37.8
Iron (mg)	2.3	0.1	5.5	0.6	0.6	0.7	0.7	406	140
Sodium (mg)	122	146	52	3	--	1.4	5.0	6.9	2.4
Potassium (mg)	129	407	98	407	600	280	385	10	3

