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The Influence of Food Solutes on Dielectric Properties of Locally Prepared 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 ^oC before and after heating up to 120 ^oC, and it was found that the physical properties remains the same. The food solutes include: Irish potato, Sweet potato, Egg, Plantain, Red-Beans and Yam. These solutes were made in paste forms and equal amount each100 gm were measured and fried in 200 mL of groundnut oil. The physical properties of the remaining groundnut oil after frying, each sample was 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 observed result, egg (highly protein) shows the highest increase in the values of dielectric constant, K(3.4653), and yam (carbohydrates) has the least increase in the value of K (2.361). The increase in K is due to additional polarization of solute molecules from the egg during frying.***

Keywords: Groundnut oil, solutes, dielectric constant, physical property, independent and frying

1. Introduction

Generally, edible oils, for example, groundnut oil (organic compound) belongs to a homogenous series of fats and oil with similar chemical characteristics. Dielectric constant is one of the microscopic physical property of liquid which result from the molecular charge separation in the presence of an applied electric field. In linear and isotropic dielectrics, the molecular charge is directly proportional and in the same direction as the applied field. 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 and Ngoddy,1985).

The dependence of the capacitance of the dielectric between the plates of a capacitor shows the phenomenon of dielectric constant. Dielectric constant is known to depend on the physical properties of the dielectric; e.g. temperature, solute/impurities, electric and magnetic fields applied to the dielectric. The investigation of dielectric constant at various frequency ranges has been carried out in different ways. At high voltage and frequency (10^9 Hz), Schering bridge was used and at frequencies (10^8 -10^{11} Hz), electromagnetic wave interact with the medium inserted into the wave guide or conical lines, and the standing wave patterns measured. At frequencies above 10^{11} Hz, optical techniques involving reflection and transmission were employed. Analytical techniques in chemistry also have application in determining dielectric constant (Arthur, 1984)

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 dielectric constant, was carried out in Yola, North of Nigeria.

Dielectric

Dielectrics are materials that have relatively low electrical conductivity called insulators. In more general sense, dielectrics include all materials except the condensed state of metals.

There are basically, two types of dielectrics called polar and non-polar dielectrics. As a result of these types, it is easy to study the electrical and the general properties of matter. A non-polar molecule is one, which the center of gravity of the positive nuclei and the electrons normally coincide, while a polar molecule is one in which their center of gravity does not coincide.

A dielectric is characterized by its dielectric constant and dielectric loss. That is heat is generated as a results of molecular collision which separated the heat that supposed to be taken away by thermal conduction. When a dielectric is introduced between the plates of a capacitor in the presence of electric field, the nuclei of molecules of dielectric move in the direction of the field while the electrons move in the opposite direction. The movement of positive charges to one end and negative to the other opposite end shows the phenomenon of polarization. As a result opposite charged ions pair themselves thereby given rise to diploe which produce field in the opposite direction of the applied field and this reduces the electrical field strength between the plates. The presence of permanent polarized molecules exhibits increase in the capacitance of a capacitor or dielectric constant as far greater than those dielectrics which are merely polarized by action of the field (Ike, 2006)

The dielectric constant is the numerical factor by which the capacitance of a capacitor increases when a dielectric material is introduced between the parallel plates of a capacitor (Faraday, 1837). The presence of a dielectric material between the plates of a capacitor reduces the potential difference (p.d) between the plates. When an applied electric field exceeds a certain value, called the dielectric field strength, break down will occur and heavy electric current flow through the dielectrics. This then shows that, every dielectric material has a characteristic dielectric strength (Nelkon, 1981).

Dielectric Constant, K

The capacitance of capacitor depends on the permittivity of the dielectric between the plates of a capacitor. Dielectric constant of a dielectric can be defined in terms of capacitance or permittivity of the dielectric. Dielectric constant is the ratio of the capacitance when dielectric is between the plates to the capacitance when vacuum (or air) is the dielectric. Thus

$$K = \frac{C}{C_o}, \text{ or } K = \frac{\varepsilon}{\varepsilon_o} \equiv \varepsilon_r \qquad (1)$$

Where C is the capacitance of the dielectric, C_o is the capacitance of the vacuum, ε is the permittivity of the dielectric, ε_o is the permittivity of vacuum and ε_r is the relative permittivity.

Dielectric constant varies with temperature as a result of changes in molecular orientation due to chemical or phase transitions (Brown, 1988). When there are two dielectrics between plates, the one with higher dielectric constant dominate the one with low dielectric constant. This means that, an impurity which enhances high increase in dielectric constant suppress the one with low increase.

The main aim of this research is to investigate the dependence of dielectric constant, of groundnut oil with different food samples dissolved in the oil during frying process. This oil contaminated by these food solutes cab be of used as an insulator in a capacitor, oil and wax impregnated paper are used as insulator in transformers.

2. Methodology

Construction of parallel plate capacitor

Two plane transparent glass was cut to a dimensions measured 10.0 cm by 12.5 cm aided with a diamond cutter. On one side of each glass, glue was smeared on their surfaces and the gummed surfaces were coated with aluminum foil. Connected to aluminum foil were a fabric connecting wire Projected from either side of the plates. The two surfaces coated with aluminum foil were coupled to form a parallel plates capacitor separated at a distance of 0.19 mm. The coupled capacitor was used in determining the dielectric constant of groundnut oil.

Source of groundnut oil and preparation of solutes

The dielectric material was 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 this temperature, it may likely decompose or ignite. Before measurements were made, the bulk oil was first sieved, and their dielectric constants K of this fresh oil were determined. On heating the oil to 120^0C, it was allowed to cool to room temperature (36^0C), and its dielectric constant was determined. It was observed that the physical properties before and after heating remain the same.

Measurement of dielectric constant of groundnut oil

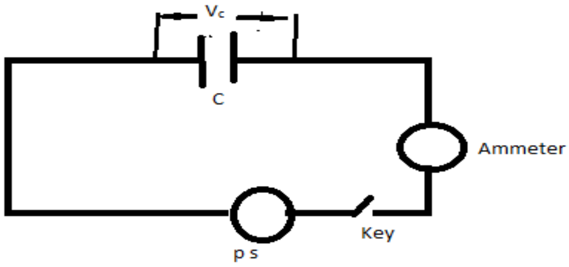

Figure 1: Current – voltage relation in ideal capacitor.

The parallel plates capacitor constructed was connected in series with an ammeter, key and 2volts signal generator as shown above in fig.1.A voltmeter was connected across the capacitor.

With air as dielectric between the plates of the capacitor and the frequency of the signal generator fixed at 50 KHz, the voltage V_c across the capacitor was varied and the corresponding current I_c were recorded. The least square methods was employed in determining the scope of the graph of V_c against I_c. The slope of the graph of V_c against I_c is the resistance of the capacitor from which the capacitance of the capacitor was calculated since the frequency f is known. Slope, S is given as

$$S = \frac{1}{2\pi f C_o} = X_c \qquad (1)$$

Where X_c is the reactance of the capacitor and C_o is the capacitance of empty space, and it is given as

(2)

This procedure was repeated with fresh groundnut oil and contaminated groundnut oil was filtered and used as dielectrics at room temperature. However, the capacitor was washed and dried before the next procedure. The dielectric constants of fresh groundnut oil and contaminated groundnut oil were calculated using the following relationships:

Dielectric constant, K of fresh groundnut oil

$$= \frac{\text{Capacitance of capacitor with fresh groundnut oil as dielectric}}{\text{Capacitance of capacitor with air as dielectric}}$$

$$K = \frac{C}{C_o} \qquad (3)$$

Dielectric constant, K^1 of contaminated groundnut oil as dielectric

$$= \frac{\text{capacitance of a capacitor with contaminated groundnut oil as dielectric}}{\text{Capacitance of capacitor with air as dielectric}}$$

$$K^1 = \frac{C^1}{C_o} \qquad (4)$$

3. Results

Table 1: Voltage and current variation at a frequency of 50 KHz

Voltage V_c (v)	Current I_c (mA)						
	A Fresh oil	B Oil + Egg	C Oil + plantain	D Oil + yam	E Oil + S.P	F Oil + I.P	G Oil + R.B
0.2	0.09	0.18	0.10	0.08	0.16	0.10	0.10
0.4	0.18	0.27	0.20	0.15	0.24	0.23	0.20
0.6	0.25	0.33	0.26	0.19	0.31	0.28	0.27
0.8	0.30	0.41	0.38	0.28	0.40	0.40	0.36
1.0	0.35	0.52	0.42	0.34	0.44	0.43	0.42
1.2	0.43	0.57	0.49	0.40	0.51	0.52	0.49
1.4	0.49	0.71	0.60	0.47	0.62	0.61	0.59

Table 2: Effect of solutes from different food samples on a capacitor

Parameter	Samples as dielectric (oil diluted with solute from)						
	A Fresh oil	B Oil + Egg	C Oil + plantain	D Oil + yam	E Oil + S.P	F Oil + I.P	G Oil + R.B
X_c (Ω)	2341.927	1578.556	1726.555	2316.891	1960.499	1692.775	1786.813
$C \times 10^{-9}$ F	1.359179	2.016463	1.843617	1.373882	1.62617	1.880403	1.781439
$\varepsilon \times 10^{11}$ Fm^{-1}	2.065952	3.065023	2.802290	2.088301	2.467898	2.858212	2.707787
K	2.335729	3.465261	3.168221	2.360996	2.790161	3.231444	3.061376

4. Discussion

Dielectric Constant

Yam, potatoes and plantain are mainly contains carbohydrates, while beans and egg mainly contain high content of protein. Experimentally, dielectric constant of pure groundnut oil was found to be 2.336 at 36 ^oC. The availability of solutes introduced to the g/nut oil during frying of food items resulted in altering the dielectric constant of groundnut oil as observed from the table 2. Solute from egg shows the highest increase in dielectric constant as compare with that of fresh oil without contaminant. According to Brain in (1984), the percentage combinations of fatty acids in groundnut oil are: static acid, 5 %, palmitric acid is 12 %, linoleic acid, 23 % and oleic acid is 57 %. As seen from the extractof Handbook of physics and chemistry – America Institute of science, it shows that, the dielectric constant, Kof g/nut oil was given as 2.408.The experimentally result was in fairly agreement with this theoretical result.

According to Douglas and Glenn (1982), the content of egg per 100 gram is about 74 % water, 0.9 gram carbohydrate and 12.9 gram protein. Protein contain about 30 – 40 % polar compound and water contains polar molecules which may be responsible for the increase in dielectric constant as 3.4562 (the highest of the experimental result). Beans on the other hand contain 22.4 gram protein and 10.4 % water. Although, water was added to the powdered beans and the mixture was well stirred before it was fried, the low increase in dielectric constant may be to the fact that, water added was not up to 74 % like that of the egg, even though it contained highest content of protein.

Similarly, yam, potatoes and plantain have carbohydrate content between 17 – 319 by mass per 100 gram, water between 66 – 75 %, and protein, 1.1 to 3.2 gram per 100 gram. Despite the high water content of these foods, the contaminant from these food show low dielectric constant. These low values may be due to low level of protein content and high content of non-polar molecules of carbohydrates.

Another factor that may led to these increase in dielectric constant is the presence of nutrients. The element may loss or gain electrons during frying thereby producing ions. This dipoles add up result in polarization of molecules of the oil thereby increasing the dielectric constant of g/nut oil. Egg and beans have larger contents of calcium, iron, phosphorus, sodium and potassium than yam, potato and plantain, as such the low level of these elements may attribute to low dielectric constant of beans while for egg their high level may led to its high value of K.

Presence of gel, PH value and iso-electric point that were not determined mighty have attributed to variation of dielectric constant of g/nut oil.

The effect of impurities due to some food items on the dielectric constant of g/ nut oil is presented inn table 2 above. This shows that the dielectric constant of g/ nut oil increases with solute / impurities. Generally, it was shown that the increase in dielectric constant is independent of whether the impurity is mainly carbohydrate or protein. The independence of increase in dielectric constant on the class of food item could be due to linear polarization of the oil samples, since the field was relatively not high as too create large molecular charge separation which is usually responsible for dielectric constant. In another perspective, this could be due to the fact that the food items belonging to the same class may not contain equal amount of factors responsible for increase in dielectric constant e.g. water, nutrient elements, isoelectric point and PH concentration to mention but a few.

However these factors were not determined, but were extracted from the standard table for the purpose of discussion. Likewise also the table for dielectric constant and method of processing in order to determine the physical properties of groundnut oil differ from the one employed in this study.

5. Conclusion

Effect of solutes on dielectric constant, of groundnut oil was found to vary independent of the class of food items. However, it was found that, presence of food samples, generally increase the dielectric constant, K of groundnut oil. The general increase in K may be attributed to effect of additional polarization added to oil from food molecules.

These variations may have advance application in the study of quality control of groundnut oil in food industries and insulation industries. Thus, if such solutes were properly incorporated with groundnut oil, they can be employed as an insulator in a capacitor and transformer. For example, if one need to increase the capacitance of a capacitor, the solute if properly incorporated with this oil, can be used as dielectric for the capacitor. Similarly, oil impregnated paper are used as an insulator in a transformer in order to insulate the primary coil from the secondary coil.

6. 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.

The above suggestion can be determined using current – voltage relation to determine K.

References

[1] Alfred, I. I and Ngoddy, P.O. (1985). Integrated Food Science and Technology for the Tropics. Department of food science and technology, Uni. Of Nigeria NSUKKA
[2] Arthur, K. F. (1984). Fundamental of Electricity and Magnetism. Uni. Of Calfonia Beckeley
[3] Brain, F. A. (1984). Food Science a Chemical Approach Principal Newport College of Further Education
[4] Condon, EE.U. & Odishaw, H. (2nd Edition). Hand Book of Physics New York
[5] Douglas, M. & Glenn, D. C. (1982). Food and Production Encyclopedia. USA
[6] Ike, E. E. (2006). Fundamental Principles of University Physics
[7] Nelkon, M. (1981). Principle of Physics
[8] Nelkon and Parker (Six edition). Advance Level Physics

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

Table 2: Dielectric list of some organic liquids
Courtesy: Handbook of Physics & Chemistry, America Institute of Science

Substance	Permittivity (ε_r)	Temperature (T °C)
$C_{22}H_{44}O_2$ Butyl Stearat	3.11	30
$C_{22}H_{42}O_3$ Butyloleate	4.0	25
$C_{21}H_{21}O_4P$ Tricresyi phosphate	6.9	40
$C_{14}H_{36}O_2$ Stearic Acid	2.29	70
$C_{14}H_{36}O_2$ Ethyl palmitate	2.26	100
$C_{14}H_{36}O_2$ Ethyl palmitate	3.2	20
$C_{14}H_{36}O_2$ Ethyl palmitate	2.71	104
$C_{18}H_{34}O_2$ Oleic Acid	2.46	182
$C_{18}H_{34}O_2$ Oleic Acid	2.46	20
$C_{18}H_{34}O_2$ Oleic Acid	2.45	60
$C_{18}H_{34}O_2$ Oleic Acid	2.41	100
$C_{18}H_{34}O_2$ Oleic Acid	2.61	0
$C_{18}H_{32}O_2$ Linolic Acid	2.71	20
$C_{18}H_{32}O_2$ Linolic Acid	2.7	70
$C_{18}H_{32}O_2$ Linolic Acid	2.6	120
$C_{16}H_{34}O_2$ Palmic Acid	2.3	71
$C_{10}H_8$ Naphthalene	2.54	85
C_6H_{10}Ethyl benzene	2.412	20
C_6H_6 Benzene	2.284	20

C_9H_{20} n-Nonane	1.972	20
n- Decane	1.991	20
n-Decane	2.050	-30
n-Decane	1.84	130
n-decane	1.783	170
$CHBr_2$ Bromoform	4.39	20
$CHCl_3$ Chloroform	4.806	20
CCl_4 Carbon tetrachlorine	2.238	20
CO_2 Carbon dioxide	1.60	0
Transformer oil	2.2	20
Mineral oil	2.2	30