DIELECTRIC PROPERTIES OF SUNFLOWER OIL

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ABSTRACT

In the present communication, dielectric properties of Sunflower Oil have been carried out. Dielectric studies, i.e., determination of dielectric constant with frequency variation and related properties were useful for explaining the deterioration with the temperature variation in determining the quality of the frying oils. Sunflower oil is one of the most demanding oils for house hold purpose and it is very important to produce the qualitative one. These dielectric studies were carried out at different temperatures with variable frequencies. The results show that the Dielectric constant of Sunflower oil is independent of frequency at room temperature from 500Hz to 4MHz. When the oil is heated, the dielectric constants decreased with increase of temperature from 308K to 333K. The dielectric losses are minimum in frequency range from 10 kHz to 8MHz at room temperature. When oil is heated the Dielectric losses are showing peaks at two frequencies in frequency range 1 kHz to 100 kHz. These peaks attribute to relaxation times the relaxation time is increasing with temperature. Finally, the dielectric losses are increasing at temperatures 313KC and 318K in the frequency range 1 kHz to 100 kHz. These results will help to enhance the efficiency these types oils.

KEYWORDS: Sunflower Oil, Dielectric Constant, Fatty Acids, Polarizability Parameter

I. INTRODUCTION

Dielectric spectroscopy is simple, rapid and non-destructive method which provides information about the dielectric response of materials to electromagnetic fields. It is convenient method for evaluating food quality. The dielectric properties of most materials depend on the frequency of the applied alternating electric field, the temperature, moisture content, density, composition and structure of the material [1].

Dielectric method has also been studied and applied to determine frying oil deterioration. Dielectric properties of edible oils and fatty acids as a function of frequency, temperature, moisture and composition were investigated [2]. According to [2] the study of dielectric properties of oils in low frequency range will benefit the development of a simple and cheap method of evaluating oil quality [3]. Investigated the dielectric properties and physical and chemical constants of 11 edible oils. They reported that the values of ε' lie in the range of about 3.0-3.2 at (298.15K) for most of the oils, the ε' oils increased somewhat with increasing value of unsaturation(IV) of the oil and decreased with increasing temperature. The interaction mechanisms of oil/fat molecules subjected to MW radiation at broad range of approved frequencies and temperature ranges. Dielectric measurement and its simplicity in analysis needs more research [1]. Dielectric measurements at three temperatures and three frequencies are carried in microwave range [4].

The vegetable oils are used as transformers coolants. So their dielectric behavior is extensively studied in engineering fields. So the importance of Dielectric spectroscopy of oils is increasing in Food industry and in Transformer fields.

The objective of our present study is to study the changes in the dielectric properties of oils under controlled heating of oil from 303K to 333K in the frequency range 100Hz to 10MHz. Since edible oils are now used as dielectric fluids in transformers, it is possible that the temperature of the environment gradually increases from 303K to 325K in tropical region. Then it may be useful to study the dielectric properties of oils under gradual heating of oil in different frequency ranges. In our present study, we investigated the changes in Dielectric constant and loss factors of Sunflower oil while heating oil under controlled conditions from 303K to 333K instead of frying.

II. MATERIALS AND METHODS

The Sunflower oil used was manufactured and packed by Aggrotech foods, Secunderabad by Priyanka Refineries. The dielectric measurements in the present investigation were taken on The HP impedance analyzer 4192A in the frequency range 100Hz to 10MHz in the temperature range 303K to 333K. The HP impedance analyzer with specially designed coaxial, cylindrical sample holder is used for measuring capacitance and dissipation factor of oils. The sample holder is placed in a specially designed glass bottle. The glass container is double walled so that through the two outlets present in the bottle, water from thermostatically controlled water bath can be circulated around glass container. So by circulating water around the glass container the temperature of the sample is maintained at required temperature.

The temperature of the circulating water through layers of sample holder has been maintained to accuracy of +/-0.05C by an electrically controlled thermostat. The oil sample is heated from 303K to 333K and readings are taken in intervals of 5-degree Kelvin. The dielectric values are taken in the frequency range 100Hz to 10MHz.

The real part of the permittivity of the sample in the sample holder is obtained from the change in capacitance value of the sample holder due to the presence of sample material, using the following equation:

$$\varepsilon' = \frac{\Delta C \times \ln\frac{b}{a}}{0.556 \times 10^{-12} h} + 1$$

Where a and b are the outside diameter of the inner conductor and inside diameter of the outer conductor respectively, h is the height of sample in the sample holder and ΔC is the change in the capacitance of the sample holder which is given by: $\Delta C = C_P - C_o$

where C_P and C_o are the capacitances of the sample holder with and without sample respectively.

The loss tangent or dissipation factor D, for the sample material was derived from the capacitance and the dissipation factor measured for the sample holder with and without sample.

$$\tan\delta = D = \frac{C_P D_P - C_O D_O}{C_P - C_O}$$

Loss factor ε” was evaluated by using the equation

$$\varepsilon'' = \varepsilon' \tan\delta$$

III. RESULTS AND DISCUSSION

The percentages of different fatty acid contents present in triglycerides of Sunflower oil are given in Table 1.

Table 1: The percentages of different fatty acid contents

Acid	Number	Sunflower oil % of acid in
Palmitic	16:0	6.6
Stearic	18:0	3.4
Oleic	18:1	25
Linoleic	18:2	65

Major contents in Sunflower oil are Oleic and Linoleic. The Saponification value of Sunflower oil used in investigation is 193.56, Iodine value is 137.91 and Molecular Weight of the oil is 869.6.

Fig-1 gives the variation of dielectric constant of Sunflower oil with frequency at room temperature. Fig-2, 3, 4 give the variation of Dielectric constants of Sunflower oil with frequency in temperature range 308K-333K.

From Fig-1 we may say the dielectric constant of Sunflower oil is independent of frequency from 500Hz to 4MHz and has maximum value. This can be taken as static dielectric constant at 303 K. Above 4MHz the dielectric constant decreases in accordance with Debye equation due to dielectric dispersion. This result is similar to the result given by [2]. It could be assumed that at lower frequencies there is equilibrium between orientation of oil molecules and electric field, therefore the ε' values virtually showed no dependence on frequency. The static dielectric constant values for Sunflower oil at different temperatures are listed out in Table 1a.

Table 1a: Static dielectric constants of SF oil at different temperatures

Temperature	Sunflower oil
30C	3.1024
35C	3.483
40C	3.414
45C	3.414
50C	3.386
55C	3.35
60C	3.327

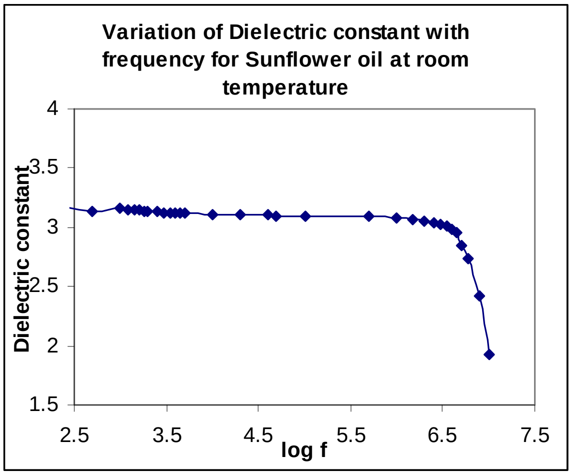

Fig-1: Dielectric constant Vs Log f of SF oil at Room Temperature

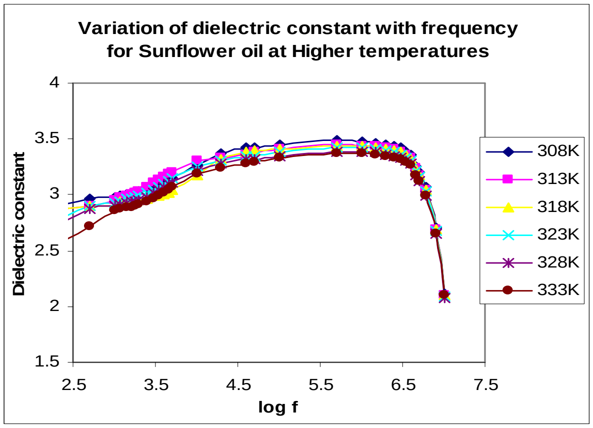

Fig-2: Dielectric constant Vs Log f of SF oil at Higher temperature

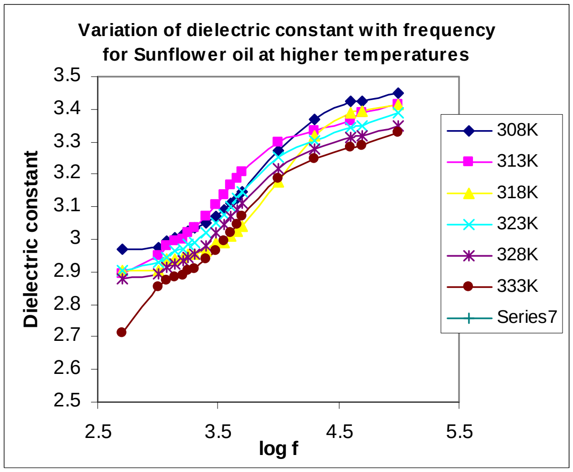

Fig-3:log f Vs dielectric constant at high temp

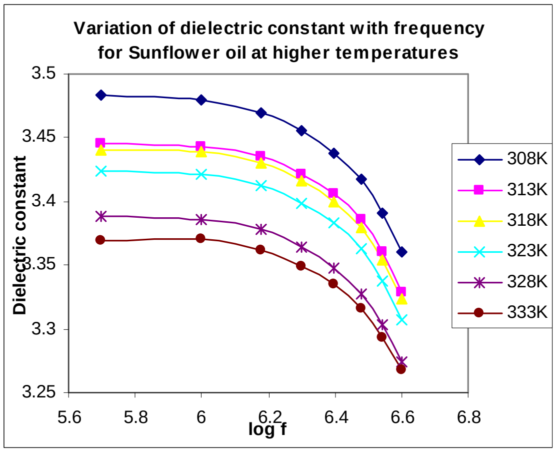

Fig-4: Log f Vs Dielectric constant

When oil is heated in controlled conditions from 303K to 308K and further, the dielectric behavior slightly changed in frequency range 500Hz to 100 kHz. In this range the dielectric constant is increasing with frequency at higher temperatures. May be increase of temperature is creating expansion of oil, which is allowing space for molecules with cis-bonds in triglyceride to rotate in the direction of field and increasing dielectric constant. But due to heating initially the dielectric constant is decreasing from 3.2 at 303K to 2.8at 308K. Then it is increasing with frequency. Then with increase of temperature the dielectric constant is decreasing from 308K to 333K similar to result of [5] who conducted experiment from 25C to 40C. Decrease in ε' value with increase of temperature is due to decrease of density of dipoles in unit volume of sample. Also increase in kinetic energy of moving segments leads to greater randomness and lesser orientation of dipoles. So dielectric constant decreases with increase of temperature.

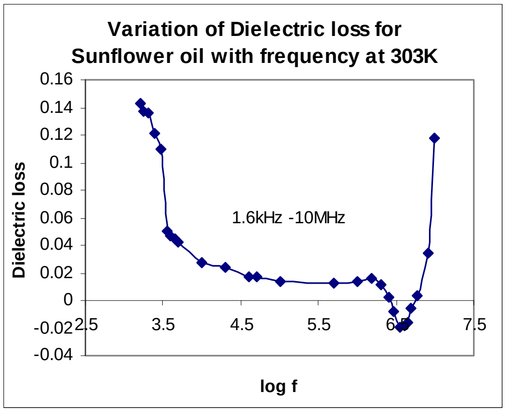

Fig-5: Variation of Dielectric loss for SF oil with frequency at 303k

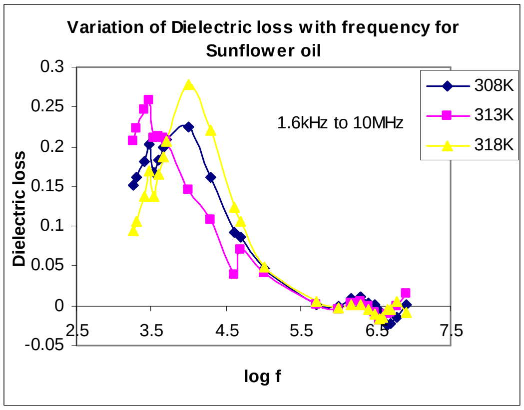

Fig-6: Variation of Dielectric loss with frequency for SF oil

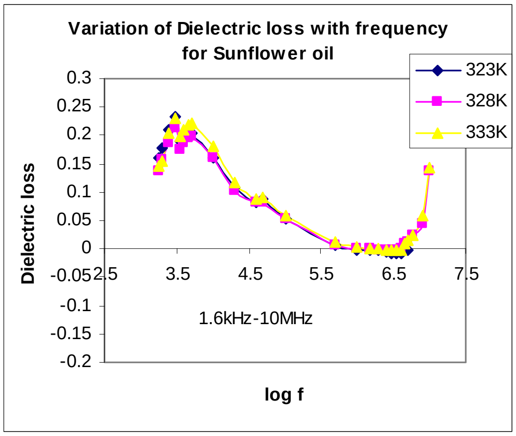

Fig-7: Variation of Dielectric loss with frequency for SF oil

Fig-5, 6, 7 indicate changes in dielectric losses with frequency at room temperature 303K, at higher temperatures 308K to 333K. At room temperature the dielectric losses are decreasing with increase of frequency in frequency range 500Hz to 5 kHz due to increase in polarization effect and then almost minimum dielectric loss value in frequency range 10khz to 8MHz. After 8MHz the dielectric losses increase steeply due to increase in conductance. Sunflower oil has minimum losses in frequency range 10 kHz to 8 MHz. When the oil is heated the frequency dependence of dielectric losses are behaving in different manner in frequency range 1.6 kHz 500 kHz. The dielectric losses are showing increase and decrease with change in frequency with two dielectric loss peaks. These peaks at higher temperatures can be attributed to accumulation of impurities or free fatty acids at electrode surface.

The relaxation time corresponding to first peak at all temperatures is $\tau = 5307.86 * 10^{-8}$ seconds. The second relaxation time corresponding to second peak is $1592*10^{-8}$ for temperature range 308KC to 318K and $3184*10^{-8}$ seconds for temperature range 323K-333K.So second relaxation time is increasing with temperature. The dielectric losses are increasing with increase of temperature for Sunflower oil at 313KC and 318K[6].

The polarizability parameters are calculated from the formulas given by [3]. r is the specific refraction of the oil. P is the specific polarization calculated using Debye equation. P_0 is the measure of Orientation polarization and μ is the effective dipole moment. [3] has given the formula for refractive index as

$$n_D = 1.4484 + 0.0002247 * IV$$

Where IV is iodine value of oil. By substituting the Iodine value of Sunflower oil, the refractive index of Sunflower oil is N_D.

$$\varepsilon_{\infty} = n_D^2$$

Similarly, Specific refractivity is given by

$$r = \frac{n_D^2 - 1}{n_D^2 + 2} * \frac{1}{\rho}$$

Where ρ is the density of oil. So r value is 0.3057 at room temperature.

The specific polarization of the oils is given by Debye equation.

$$p = \frac{\varepsilon - 1}{\varepsilon - 2} * \frac{1}{\rho}$$

The orientation polarization is given by

$$p_o = p - r$$

From this value we can calculate dipole moment from following equation.

$$\mu^2 = \frac{9kTM}{4\pi N} * p_o$$

Where k is Boltzman's constant and N is the Avogadro number. Using above equations, the changes in specific refractivity r, specific polarization p, orientation polarization p_o and molecular dipole moment of oils with varying temperature at different frequencies are listed in the following tables 2 to 7.

Table 2: Polarizability parameters for Sunflower oil from dielectric constants at 1kHz

Temp.K	ε'	ρ gm/cm^3	r/cm^{3}g^{-1}	p	p(o)	μ*10^{-13}
303	3.16	0.9128	0.3059	2.0400	1.7341	15.814
308	2.976	0.9093	0.3071	2.2265	1.9195	16.639
313	2.952	0.9058	0.3082	2.2637	1.9554	16.794
318	2.904	0.9023	0.3094	2.3343	2.0248	17.089
323	2.928	0.8996	0.3104	2.3095	1.9991	16.980
328	2.896	0.8953	0.3119	2.3635	2.0517	17.202
333	2.856	0.8918	0.3131	2.4313	2.1182	17.479

Table 3: Polarizability parameters for Sunflower oil from dielectric constants at 10kHz

Temp.K	Temp.	ε'	ρ gm/cm^3	r/cm^{3}g^{-1}	p	p(o)	μ*10^{-13}
303	30	3.110	0.9128	0.3059	2.0829	1.7770	16.009
308	35	3.272	0.9093	0.3071	1.9643	1.6573	15.460
313	40	3.300	0.9058	0.3082	1.9532	1.6450	15.403
318	45	3.179	0.9023	0.3094	2.0481	1.7387	15.836
323	50	3.253	0.8996	0.3104	1.9989	1.6885	15.606
328	55	3.218	0.8953	0.3119	2.0337	1.7218	15.759
333	60	3.187	0.8918	0.3131	2.0658	1.7528	15.900

Table 4: Polarizability parameters for SF oil from dielectric constants at 100 kHz

Temp.K	Temp.	ε'	ρ gm/cm^3	r/cm^{3}g^{-1}	p	p(o)	μ*10^{-13}
303	30	3.095	0.9128	0.3059	2.0958	1.7899	16.067
308	35	3.450	0.9093	0.3071	1.8580	1.5509	14.956
313	40	3.414	0.9058	0.3082	1.8845	1.5763	15.078
318	45	3.414	0.9023	0.3094	1.8918	1.5824	15.107
323	50	3.386	0.8996	0.3104	1.9134	1.6030	15.205
328	55	3.350	0.8953	0.3119	1.9441	1.6322	15.343
333	60	3.327	0.8918	0.3131	1.9662	1.6531	15.441

Table 5: Polarizability parameters for Sunflower oil from dielectric constants at 1MHz

Temp.K	Temp.	ε'	ρ gm/cm^3	r/cm^{3}g^{-1}	p	p(o)	μ*10^{-13}
303	30	3.0784	0.9128	0.3059	2.1114	1.8055	16.137
308	35	3.48	0.9093	0.3071	1.8428	1.5358	14.883
313	40	3.4432	0.9058	0.3082	1.8690	1.5607	15.003
318	45	3.4392	0.9023	0.3094	1.8783	1.5689	15.043
323	50	3.4216	0.8996	0.3104	1.8935	1.5832	15.111
328	55	3.3864	0.8953	0.3119	1.9226	1.6107	15.242
333	60	3.3704	0.8918	0.3131	1.9396	1.6265	15.316

Table 6: **Polarizability parameters for Sunflower oil from dielectric constants at 10MHz**

Temp.K	Temp.	ε'	ρ gm/cm^3	r/cm^{3}g^{-1}	p	p(o)	μ*10^{-13}
303	30	1.924	0.9128	0.3059	-13.2891	-13.5950	
308	35	2.117	0.9093	0.3071	10.5283	10.2212	38.395
313	40	2.105	0.9058	0.3082	11.5744	11.2661	40.310
318	45	2.104	0.9023	0.3094	11.7812	11.4718	40.676
323	50	2.093	0.8996	0.3104	13.0081	12.6977	42.794
328	55	2.074	0.8953	0.3119	16.1620	15.8501	47.812
333	60	2.099	0.8918	0.3131	12.4433	12.1302	41.827

IV. CONCLUSIONS

The Dielectric constant of Sunflower oil is independent of frequency at room temperature from 500Hz to 4MHz and then there is dielectric dispersion at higher frequencies according to Debye equation. When the oil is heated, the dielectric constants decreased with increase of temperature from 308K to 333K as given by [7]. The dielectric losses are minimum in frequency range from 10kHz to 8MHz at room temperature. When oil is heated the Dielectric losses are showing peaks at two frequencies in frequency range 1 kHz to 100 kHz. These peaks attribute to relaxation times to Sunflower oil. Sunflower oil has two different relaxation times at higher temperatures. The relaxation time is increasing with temperature.

The dielectric losses are increasing at temperatures 313KC and 318K in the frequency range 1 kHz to 100 kHz.

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