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Temperature and Frequency dependent dielectric properties of groundnut oil

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ABSTRACT

The complex permittivity (ϵ^*) is composed of a real part relative dielectric constant (ϵ') and an imaginary part dielectric loss (ϵ''). Dielectric constant (ϵ') and dielectric loss (ϵ'') of pure groundnut oil are measured at different temperatures and frequencies. X-band microwave bench operating in the frequency range 8.2-12.4 GHz is tuned to desired constant frequency. It is observed that the dielectric constant (ϵ') of groundnut oil decreases with increase in temperature while the dielectric loss (ϵ'') increases with increase in temperature. The dielectric constant (ϵ') of groundnut oil decreases with increase in frequency, while dielectric loss (ϵ'') increases with increase in frequency. The dielectric constant and dielectric loss of groundnut oil samples are in good agreement with the earlier reported work.

Keywords: Microwave bench , Dielectric constant, Dielectric loss, groundnut oil.

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INTRODUCTION

Food works as fuel for human body. Healthy food plays vital role for keeping us physically and mentally fit. Edible oils extracted from plant resources or different seeds are part of our food. They are key components of the diet and provide characteristics textures and flavors of foods. In India, different edible oils are used by the peoples of different regions as per the production of related seeds in the particular area; some of them are groundnut oil, safflower oil, mustard oil, sunflower oil, soya bean oil, coconut oil etc. These edible oils have specific medicinal uses. Depending upon the requirement, availability different oils are used in different parts of world. Some oils can be used as ayurvedic medicines. In some cases, it becomes essential to use warm oils, by applying suitable heating process.

Microwaves are used for several food processing operations. They have an ability to penetrate the food materials and dissipate heat in these materials. Interaction of microwaves with these materials depends on the dielectric properties of food materials. With this, it is possible to measure the extent of heating of a material when subjected to electromagnetic fields. Dielectric properties can be defined in terms of complex permittivity (ϵ^*). The complex permittivity (ϵ^*) is given by the equation $\epsilon^* = \epsilon' - j\epsilon''$. Dielectric constant of a material is measure of its ability to store electromagnetic energy, whereas dielectric loss factor is a measure of its ability to convert electromagnetic energy to heat.

Many researchers studying the dielectric properties of food material have determined the dielectric properties of different food products using different methods. Dielectric properties of binary mixture of sunflower oil and groundnut oil in different volume percentage at five temperatures are reported by Chaudhari H C.¹ The wave guide cell method is used to find the dielectric properties of different edible oils Agrawal Shilpi et al². They have reported the dielectric properties of pure oils and mixture of mustard oil with coconut oil, groundnut oil, linseed oil in different volume percentage at room temperature. Kumar et al⁴ measured dielectric properties of pumpable food products for temperature range of 20 °C to 130 °C. Nelson S O et. al.⁵ reported microwave permittivities of fresh Fruits and vegetables from 0.2 to 20 GHz. The frequency and temperature dependence of the dielectric properties of food materials are reported by Nelson et. al.⁶. The frequency dependence of the dielectric properties of milk are reported by Nunes et. al.⁷. Sipahioglu et al⁸ used open ended coaxial probe method for the determination of dielectric properties of vegetables and fruits as a function of temperature, ash and moisture content. Dielectric properties of selected vegetables and fruits are studied in the frequency range 0.1 GHz –

10 GHz⁹. Dielectric properties of vegetable oils are studied by Shah et al¹⁰. Test objects, several types of vegetable oils, were measured in temperature range of 27⁰C - 45⁰C, and frequency range of 10 Hz to 13 MHz¹¹. Rudan-Tasic D et al¹² reported the change in electric permittivity of edible oils with temperature. Chaudhari et al¹³ reported temperature dependant dielectric study of some unsaturated edible oils at fixed microwave frequency. Chaudhari Harish¹⁴ reported frequency and temperature dependent dielectric properties of unsaturated linseed oil. Stauffer E¹⁵ has made a review of the analysis of vegetable oils, also forensic approach to this study is used. Javed, M. Akram et.al¹⁶ studied the dielectric properties of cholesterol derivates. The frequencies and temperature dependence of permittivity are measured at lower frequencies¹⁷.

The purpose of this paper is to report dielectric properties of groundnut oil, as a function of frequency, at various temperatures ranging from 30⁰C to 70⁰C.

MATERIALS AND METHOD

Peanut oil, also known as groundnut oil is a mild-tasting vegetable oil derived from peanuts. The oil is available with a strong peanut flavor and aroma. It is often used in many countries, all over the world, both for general cooking, and in the case of roasted oil, for added flavor. Peanut oil has a high smoke point relative to many other cooking oils, so is commonly used for frying foods. Its major component fatty acids are oleic acid, linoleic acid and palmitic acid¹⁸.

Groundnut oil is purchased from the retail market and is used without further purification. The physical and chemical parameters of oil are measured and are given in Table 1. These properties are compared with the literature values. It is observed that these values are in very good agreement with literature values. This oil sample is best suitable as per PFA standard¹⁹.

Table 1: Physical and Chemical properties of groundnut oil.

Properties	Groundnut oil		
	Measured	PFA standard ¹⁹	Literature ²
Refractive index at 40 ⁰ C	1.4632	1.4620 – 1.4640	1.462
Specific gravity	0.911	0.909 to 0.913	0.913
Saponification value	191.8	188 to 196	190.13
Iodine value	94.4	85 to 99	87.21
Acid value	1.3	Not more than 6	---
Unsaponifiable matter %	0.45	Not more than 1%	---
Bellier turbidity test	40 ⁰ C	39 ⁰ C to 41 ⁰ C	---

Experimental Details

Waveguide cell method is used for measurement of dielectric properties of groundnut oil. These measurements are carried out using a microwave bench operating in X-band frequencies tunable at a desired constant frequency. The X-band experimental setup for measurement of dielectric

properties consist of a reflex klystron 2K25 as the microwave source, with maximum output power of 25 mW and frequency range 8.2-12.4 GHz. To avoid the interference between source and reflected signals, a broadband isolator is connected. The isolator is followed by a variable attenuator, to control the microwave power at desired level. To measure the frequency of the signal, a frequency meter with high Q-factor and with 5 MHz resolution is used. To detect the output power diode detector, with square law characteristics having VSWR better than 2:1 is used. A micro ammeter is used for measurement of output power. The liquid cell is connected to slotted section. The liquid cell is equipped with movable short plunger with scale division 0.001cm. The bench is tuned to a desired constant frequency and is kept undisturbed throughout the experiment. For accurate measurement of wavelength, the probe carriage is mounted with a dial gauge having least count of one micron. The water bath and a thermostat have been used to maintain the constant temperature within $\pm 1^{\circ}\text{C}$, accuracy limit. Liquid sample cell is surrounded by a heat-insulating container, through which water of constant temperature is circulated. The temperature of oil at the cell is monitored and recorded using a thermometer. The experimental arrangement for measuring the dielectric properties of a oil is as shown in Figure (1).



Figure 1: Experimental set-up for measuring dielectric constant and loss of a liquid, when sample length is in multiple of λ_d .

The dielectric constant and dielectric loss of oil are determined by following relations:

$$\epsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \left[1 - \left(\frac{\alpha_d}{\beta_d}\right)\right]^2$$

$$\epsilon'' = 2 \cdot \left(\frac{\lambda_0}{\lambda_c}\right)^2 \left(\frac{\alpha_d}{\beta_d}\right)$$

Here, λ_0 , λ_c and λ_d are the free space wavelength, cut-off wavelength and wavelength in the dielectric sample (oil), respectively. α_d is attenuation constant of the material measured in nepers per meter and β_d is phase shift per unit length of the material measured in radians per meter. These are calculated by following relations :

$$\alpha_d = \frac{2.302}{2L} \cdot \log \left[\frac{\sqrt{x_1}}{2\sqrt{x_2} - \sqrt{x_1}} \right]$$

$$\beta_d = \frac{2\pi}{\lambda_d}$$

x_1 and x_2 are output power readings without and with sample length L in waveguide.

RESULTS AND DISCUSSION

The values of dielectric constant (ϵ') and dielectric loss (ϵ'') for groundnut oil with four different frequencies are measured at different constant temperatures from 30 °C to 70 °C. The variation in dielectric constant and dielectric loss with temperature for groundnut oil for four different frequencies are shown in Fig. (2) and (3) respectively. It is observed that the dielectric constant ϵ' of groundnut oil decreases with the increase in frequency. The dielectric loss ϵ'' of groundnut oil also decreases with increase in frequency.

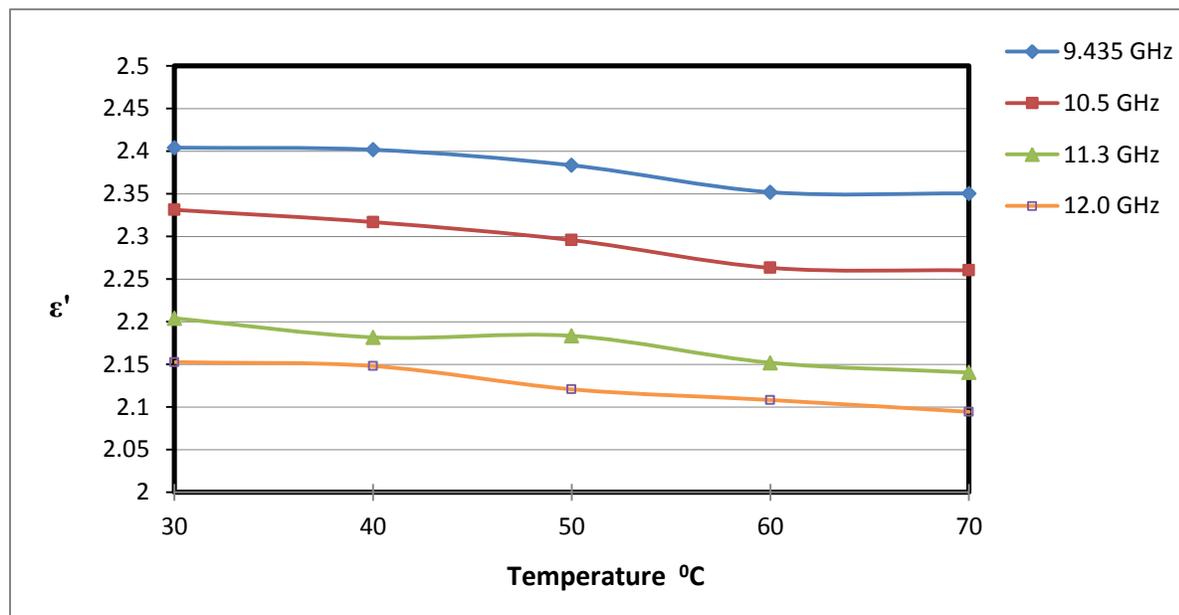


Figure 2: Variation in dielectric constant (ϵ') with temperature for Groundnut oil for different frequencies.

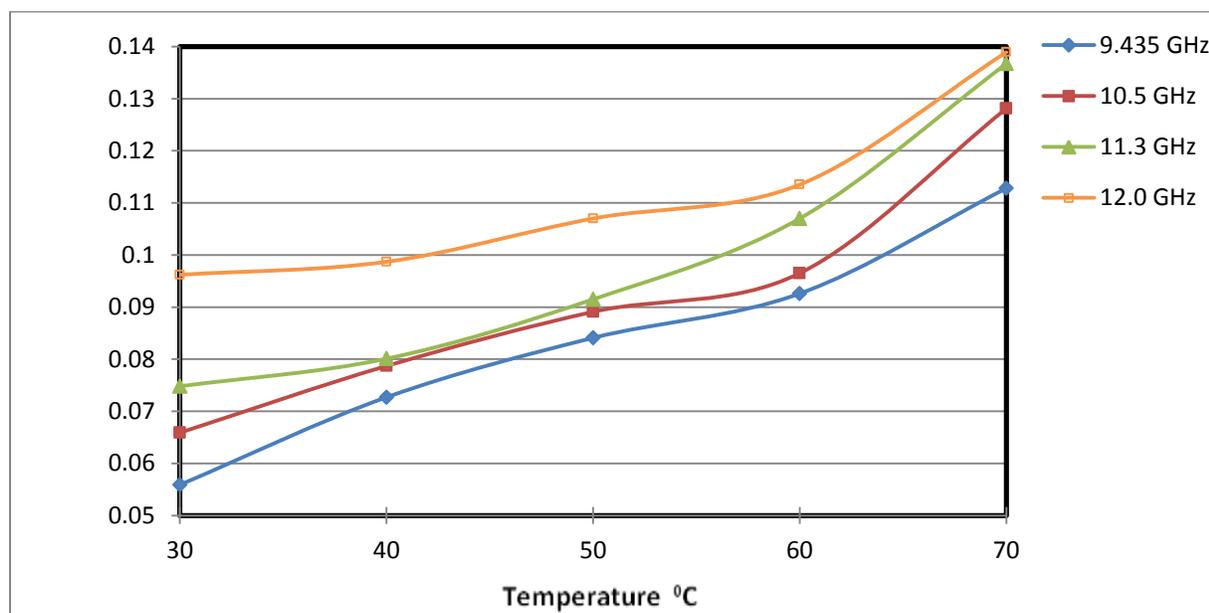


Figure 3: Variation in dielectric loss (ϵ'') with temperature for Groundnut oil for different frequencies.

For groundnut oil, dielectric constant decreases with increase in temperature while dielectric loss increases with increase in temperature. The temperature dependence of the dielectric constants shows that the value of ϵ' decreases with increasing temperature, indicating the presence of a definite dipole moment, which exhibits polar nature of oil molecule.

The decrease in the dielectric constant for groundnut oil as a function of temperature for different frequencies of the applied electric field is observed. This behavior is normal because at higher

frequencies there is insufficient time for the molecule to rotate, i.e. the orientation polarization decreases with a tendency to disappear; therefore, at these frequencies, only the polarizability term contributes to dielectric constant¹¹.

The increase in dielectric loss with increase in frequency at a constant temperature may be due volume conductivity. These results are in good agreement with the earlier reported work^{1,10,11,13,14}.

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