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Frequency dependent dielectric properties of coconut oil at various temperatures

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ABSTRACT

A microwave bench operating within X-band frequency range 8.2-12.4 GHz is tuned to a desired constant frequency. Dielectric constant (ε') and dielectric loss (ε'') of coconut oil are measured at four different constant frequencies, with varying temperature. The dielectric constant (ε') of coconut oil decreases with increase in frequency, while dielectric loss (ε") increases with increase in frequency. The dielectric constant (ε') of coconut oil decreases with increase in temperature while the dielectric loss (ε") increases with increase in temperature. The dielectric constant and dielectric loss of coconut oil samples are in good agreement with results reported by other researchers.

Keywords: Dielectric constant, dielectric loss, coconut oil

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INTRODUCTION

Microwaves have an ability to penetrate the food materials and dissipate heat in these materials. They are used for many food processing operations. Interaction of microwaves with 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 these waves. Dielectric properties can be defined in terms of complex permittivity (ε*). The complex permittivity (ε*) is given by the equation $\varepsilon^* = \varepsilon' - j\varepsilon''$. 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.

Researchers studying the dielectric properties of food material have determined the dielectric properties of different food products using different methods. Harish Chaudhari[1] reported dielectric constant and loss of safflower oil, musturd oil, coconut oil and seaseme seed oil at five temperatures using wave guide cell method at J-band microwave frequency. The wave guide cell method is used to find the dielectric properties of different edible oils by Agrawal et al[2]. 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. Stauffer E[3] has made a review of the analysis of vegetable oils. Kumar et al[4] measured dielectric properties of some food products for temperature range of 20 ^{0}C to 130 ^{0}C. Microwave dielectric properties of fresh fruits and vegetables from 0.2 to 20 GHz are reported by Nelson et al[5]. 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 al[8] used open ended coaxial probe method is used for the determination of dielectric properties of vegetables and fruits as a function of ash, temperature and moisture content. Dielectric properties of selected vegetables and fruits are studied in the frequency range 0.1 GHz – 10 GHz[9]. Dielectric properties of vegetable oils are studied by Shah et al[10]. Test objects, several types of vegetable oils, were measured in temperature range of 27^{0}C - 45^{0}C, and frequency range of 10 Hz to 13 MHz[11]. Rudan-Tasic D et al[12] reported the change in electric permittivity of edible oils with temperature. Chaudhari et al[13] reported temperature dependant dielectric study of some unsaturated edible oil at fixed microwave frequency. Chaudhari Harish[14] reported dependent dielectric study of linseed oil at different constant frequency with varying temperature. The frequency and temperature dependence of permittivity are measured at lower frequencies[15].

The purpose of this paper is to report dielectric properties of oil, as a function of different constant frequencies, at various temperatures ranging from 30^{0}C to 70^{0}C using the method described elsewhere[2].

MATERIALS AND METHOD

For the experimental purpose, two samples of coconut oil are purchased from the retail market and are used without further purification. The physical and chemical parameters of oil samples are measured. These are up to the mark and as per PFA slandered. These properties are given in Table 1.

Table 1: Physical and Chemical properties of coconut oil.

Properties	**Coconut oil**	
	Measured	**PFA standard**
Refractive index at 40 ^{0}C	1.4487	1.4481 – 1.4491
Specific gravity at 30 ^{0}C	0.918	0.915 to 0.920
Saponification value	268	Not less than 250
Unsaponifiable matter %	0.47	Not more than 1.0 %
Iodine value	8.7	7.5 to 10.00
Acid value	1.10	Not more than 6

The waveguide cell method is used for measurement of dielectric properties. 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 used for these measurement 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. A broadband isolator is connected, to avoid the interference between source and reflected signals. A variable attenuator is connected, to control the level of microwave power. 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 with accuracy of ± 1^{0}C. Liquid cell is surrounded by a heat-insulating container, through which water of constant temperature can be circulated. The temperature of oil at the cell is monitored and recorded using a thermometer. The experimental arrangement for measuring ε' and ε'' of oil is 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:

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

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

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:

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

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

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 coconut oil at four different constant frequencies are measured with varying temperatures from 30 ^{0}C to 70 ^{0}C. The variation in dielectric constant and dielectric loss with temperature for coconut oil for four different frequencies are shown in Figure (2) and (3) respectively. It is observed that the dielectric constant (ε') of coconut oil decreases with the increase in frequency. The dielectric loss (ε") of coconut oil also decreases with increase in frequency.

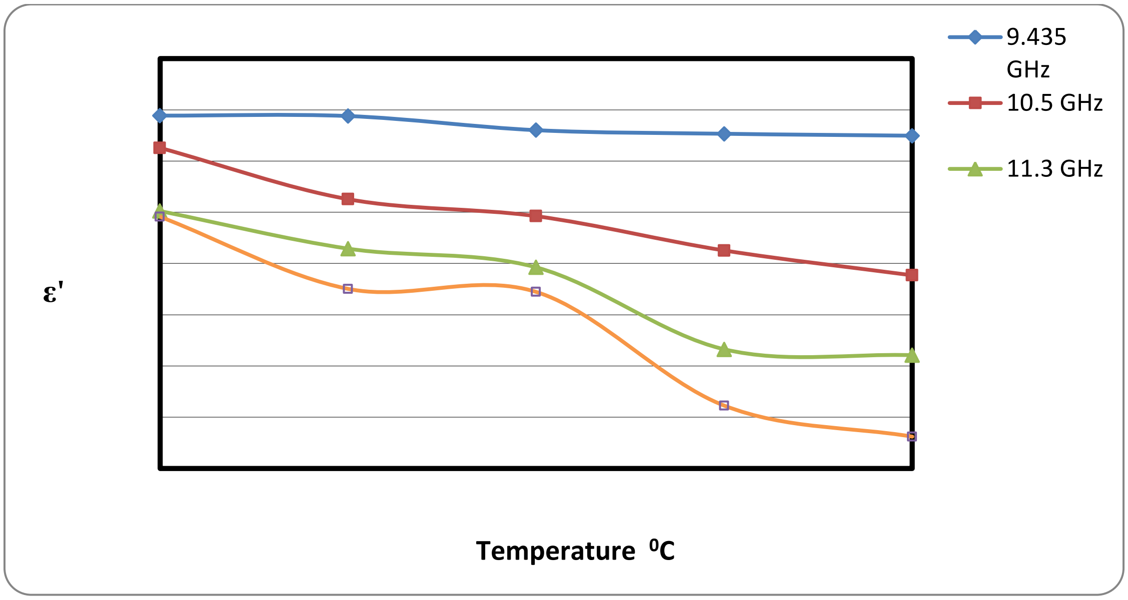

Figure 2: Variation in dielectric constant (ε') with temperature for coconut oil for different constant frequencies.

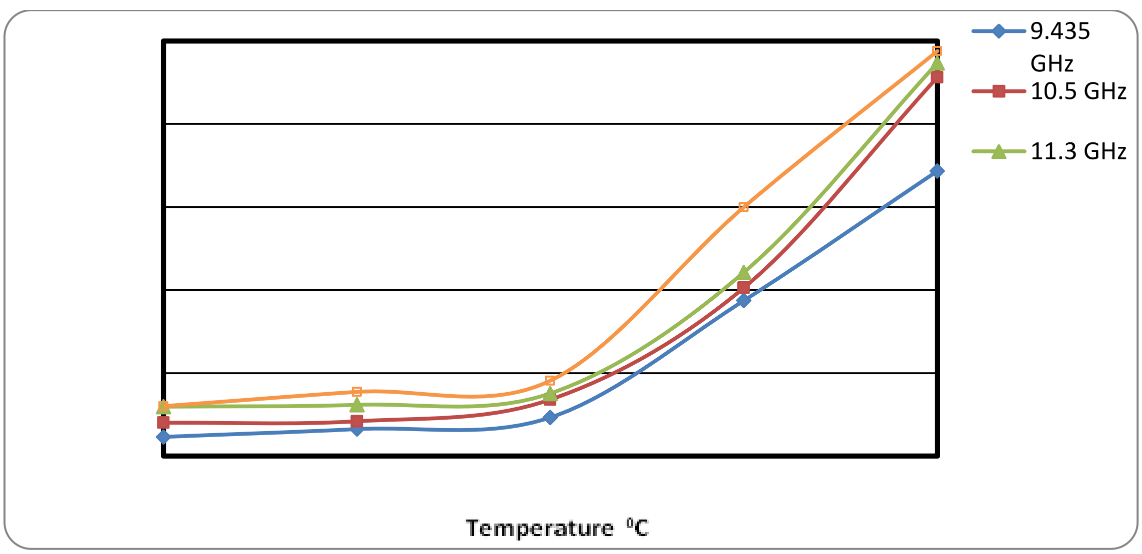

Figure 3: Variation in dielectric loss (ε") with temperature for coconut oil for different constant frequencies.

For coconut 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. This exhibits polar nature of oil molecules.

The decrease in ε’ for coconut 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 polarizibility term contributes to dielectric constant[11].

The increase in ε’’ with increase in frequency at a constant temperature is due volume conductivity. The trend of these experimental results are in good agreement with the earlier reported work [1,14].

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