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Short Communication

Dielectric study of Clove oil

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ABSTRACT

Dielectric properties of clove oil were determined using an impedance gain phase analyzer (HP 4194 A) at discrete frequencies between 10 kHz and 3 MHz and a range of temperature between 25 °C and 45 °C. A micro processor controller based temperature controller (Julabo F-25) was used for keeping the temperature of clove oil constant. Dielectric constant of the sample is found to decrease with increase in frequency and temperature, while dielectric loss decreases with increase in frequency but increases with increase in temperature. Penetration depth has been calculated with the help of dielectric data and is found to decrease with increase in frequency.

1. Introduction

Edible oils are among the important food materials as they are constituents of our dietary system and some of them are also used for enhancing flavor of food. They are useful in cosmetic, pharmaceutical, lubricant and other industries. During the extraction and purification, they undergo various processes like heating, distillation, chemical modifications etc. These processes modify the various physical properties of oils. Therefore, it is important to characterize them through various physical parameters in order to establish their purity and safety for consumption by human beings.

Clove oil is an essential oil from the clove plant. It is a natural analgesic used primarily in dentistry for its active ingredient eugenol. The main chemical components of clove oil are eugenol, eugenol acetate, iso-eugenol and caryophyllene. Eugenol, a phenylpropanoid compound, is the primary component (85.3%) of clove oil [1] with antioxidant properties [2,3]. The major component of clove oil is usually considered to be eugenol, with β-caryophyllene and lesser amounts of other components such as benzyl alcohol, but the proportions vary widely. The phenolic component, eugenol, is known to possess fungicidal characteristics [4], including activity against fungi isolated from onychomycosis. Eugenol has shown antifungal activity against *Candida albicans* and *Trichophyton mentagrophytes* and studies on clove oil also revealed that the mixture of clove oleoresin with concentrated sugar solution produces a strong fungicidal effect by reducing fungi inoculum size [5,6]. Therefore clove oil has uses in antimicrobial and antifungal activities [7–10].

Literature survey reveals that many researchers have explored and are still exploring various physiochemical properties of oils and fats. The study is mainly focused on optical properties of oils and fats such as refractive index, optical rotation, density, acid value, saponification value, iodine value and peroxide value. Viscosity and density of vegetable oils (Rapeseed and Lio) depending on the temperature before and after heating has been reported by Filali et al. [11]. Dixit et al. reported the physico–chemical properties of mint oil of mentha citrate {refractive index (RI) and relative density} [12]. Yunus et al. studied spectroscopic properties of virgin coconut oil and virgin olive oil in the wavelength range from 491.0 to 667.8 nm [13]. Various physio-chemical properties like viscosity, density, specific gravity, refractive index, conductivity, optical rotation, acid value, saponification value, iodine value and peroxide value of groundnut oil blended with other edible oils such as palm oil and rice bran oil have been studied by Pandurangan et al. [14]. Majidi and Bader reported the physico-chemical properties of twenty imported edible vegetable oils in Iraq [15]. Kumar et al. reported electrical properties of edible oil dependent on polar component, temperature and the frequency of the applied voltage [16] while Subramanian et al. estimated the density and volume,

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the thermo acoustic parameters of four Indian edible vegetable oils viz., sunflower, rice bran, groundnut and coconut, and one Indian non-edible oil, castor oil [17]. Effect of deep-fat frying on the viscosity, density and dynamic interfacial tension of palm oil and olive oil has been reported by Kalogianni et al. [18]. Yang et al. studied a method for determination of peroxide value of edible oils using electrical conductivity [19]. Cho et al. presented a correlation between refractive index and acid value of vegetable oils measured with surface plasmon resonance [20]. Kameswari et al. reported the density and ultrasonic studies on sunflower oil [21]. Near infrared spectrometry of some edible oil has been reported by Armenta et al. [22]. Sankarappa and Kumar reported dielectric properties of some refined and unrefined edible oils [23]. Mathew et al. studied dielectric properties of some edible and medicinal oils in microwave region [24]. Shah and Tahir studied dielectric properties of vegetable oils [25].

Though the composition of clove oil has been investigated [26] and optical studies of various oils have been done but the dielectric properties of clove oil have not been studied. Therefore, this paper reports the effects of frequency and temperature on the dielectric properties of clove oil.

2. Materials and methods

The material (oil) used for the present investigation was procured from Oil Research Institute Anantpur, A.P., India and was used without further purification. The experimentally determined values of dielectric constant (ε′), dielectric loss (ε″) and loss tangent (tan δ) for clove oil between the temperature range from 25 °C to 50 °C, and over the frequency range of 10 kHz to 3 MHz have been reported. For the dielectric measurements, computer interfaced impedance gain/phase analyzer (HP 4194A) has been used with microprocessor controlled temperature controller Julabo F-25. The formula used for calculating ε′ and ε″ have been discussed in our earlier papers [27–37].

3. Results and discussion

The dielectric properties of most materials vary due to varying factors. But, in general the dielectric factor is mainly dependent on the frequency of the applied electric field, the temperature, the density and the structure of the material.

Fig. 1 shows that the variation of dielectric constant with log of frequency at indicated temperatures. The dielectric spectra of clove oil indicate a general plateau which is much like the values measured at static electric field. It could be assumed that at low frequencies there is an equilibrium between the orientation of the oil molecule and the electric field, therefore, dielectric constant shows virtually no frequency dependence. It is clear from Fig. 1, that the dielectric constant value is constant in lower frequency region and the value decreases with increase in frequency. The dielectric constant decreases with increase in frequency, which is due to the dielectric dispersion of the applied electric field [38] and reveals a typical dielectric relaxation phenomenon [39]. The dielectric constant decreases with increase in temperature. It is due to the decrease of oil density, viscosity and also to the increase in the mobility of the molecules, which facilitate the effect of the strong internal electric field [40]. This decrease in dielectric constant with the increase in temperature is directly related to the density of dipoles in clove oil sample. This type of behavior has also been reported in other works [23–25,41].

In Fig. 2, the variations of dielectric loss with log of frequency at indicated temperatures are presented. The dielectric loss value for sample increases very slowly with frequency. It is observed that the dielectric loss values for the sample increases with increase in

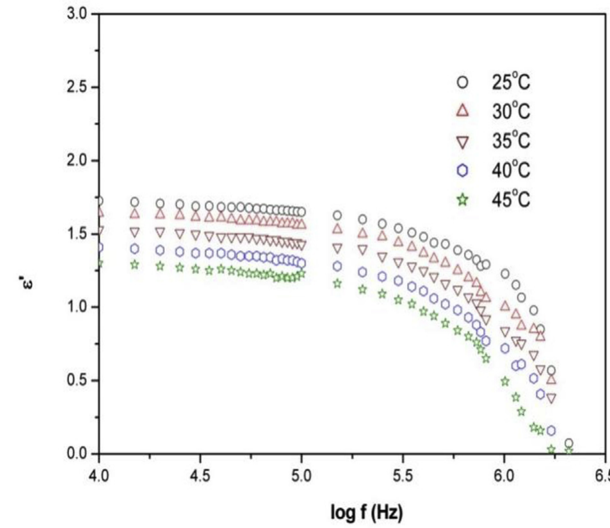

Fig. 1. Variation of dielectric constant *versus* log of frequency at indicated temperatures.

temperature suggesting that the contributing factor is ionic conductivity. The increase in loss value is slow because both ionic and dipole rotation play an opposing combination role between microwave and radio frequencies [42]. This nature of variation of dielectric loss with temperature is obvious as, oils consist of mixtures of esters, of the trihydric alcohol i.e. glycerol and fatty acids. Similar behavior has also been presented by many researchers [23–25].

Penetration depth is usually defined as the depth into a sample where the power has dropped to 1/e or 36.8% of its transmitted value. The penetration depth d_P in meters for radio-frequency and microwave energy in a lossy food material can be calculated as [43],

$$d_p = \frac{c}{2\pi f\sqrt{2\varepsilon'\left[\sqrt{1+\left(\frac{\varepsilon''}{\varepsilon'}\right)^{1/2}}-1\right]}} \tag{1}$$

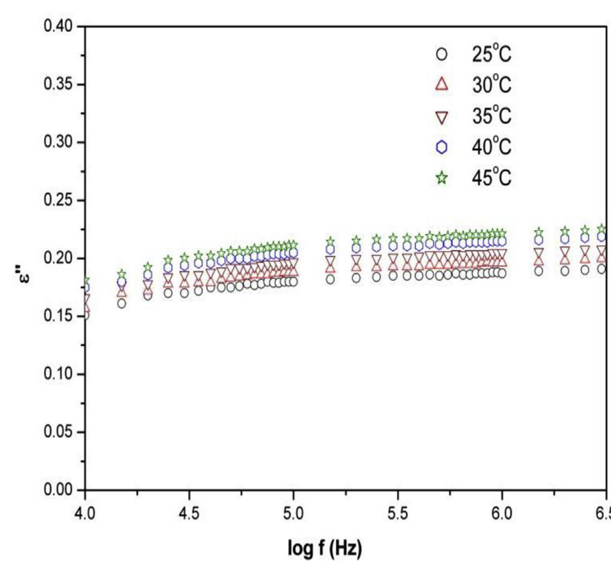

Fig. 2. Variation of dielectric loss *versus* log of frequency at indicated temperatures.

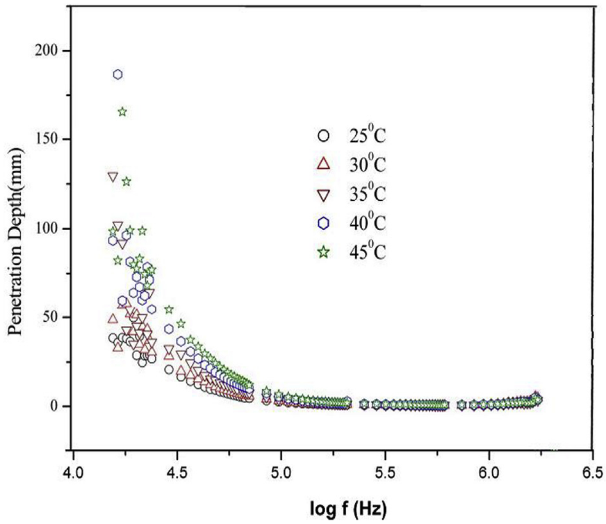

Fig. 3. Variation of penetration depth *versus* log of frequency at indicated temperatures.

where ε' and ε'' are the values of dielectric constant and dielectric loss factor of clove oil, c is the speed of light in free space and f is the frequency of electromagnetic wave in Hz. The penetration depth of electromagnetic waves into a material is inversely proportional to the frequency. Higher dielectric constant and loss factors tend to reduce the penetration depth.

The variation of penetration depth with log of frequency is shown in Fig. 3. It can be seen from Fig. 3 that penetration depth decreases with increase in frequency. That is, the shorter the wavelength, the shallower the penetration depth. This type of behavior has already been reported by Tanaka et al. [44].

4. Conclusion

Clove oil exhibits a decrease in dielectric constant with increase in frequency and temperature revealing the usual dielectric dispersion with $\varepsilon'_{max} = 1.7$ at 10 kHz and 25 °C. The dielectric loss increases slowly due to opposing ionic and dipolar interactions in clove oil having the lowest loss of $\varepsilon''_{min} = 0.15$ at 10 kHz and 25 °C. The penetration depth decreases with frequency with $d_{P(max)} = 180$ mm at 18 kHz and 25 °C. Penetration depth decreases rapidly at low frequencies and slowly at higher frequency range. The proposed technique may be applied to study the purity of any liquid sample.

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Conflict of interest

None.

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