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Microwave dielectric properties of unsaturated edible oils at different temperatures

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ABSTRACT

The real (ϵ') and imaginary (ϵ'') parts of the complex dielectric constant (ϵ^*) of different unsaturated edible oils were measured at different temperatures ranging from 30 °C to 70 °C at 9.435 GHz microwave frequency. The X-band setup in the TE₁₀ mode with slotted section and crystal detector were used for this measurement. The values of dielectric constant and dielectric loss show remarkable variation with temperature. It observed that the dielectric constant and dielectric loss are different for different oils, due to their different physical and chemical properties.

Keywords: Microwave X-band, Dielectric constant, Dielectric loss.

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INTRODUCTION

Microwaves are a part of the electromagnetic spectrum and have a frequency range 300 MHz to 300 GHz. They lie between the radio (3 kHz to 300 MHz) and infrared (300 GHz to 400 THz) frequencies of the electromagnetic spectrum. Microwave radiation has the ability to heat materials by penetrating and dissipating heat in materials. Due to this ability, microwaves have been used in the polymer and ceramic industries, medicine (warming blood, thawing frozen tissues and tumor therapies) and textiles. Microwaves are used for several food processing operations, including thawing, blanching, pasteurization, and sterilization, dehydration, baking, and roasting. Interaction of microwaves with materials depends on their dielectric properties, which determine the extent of heating of a material when subjected to electromagnetic fields. Dielectric properties consist of dielectric constant and dielectric loss factor. Dielectric constant is a measure of the ability of a material to store electromagnetic energy, where as dielectric loss factor is a measure of the ability of a material to convert electromagnetic energy to heat. Dielectric properties can be defined in terms of complex permittivity (ϵ^*). The complex permittivity (ϵ^*) is composed of a real part dielectric constant (ϵ') and an imaginary part dielectric loss (ϵ'') and is given by the equation $\epsilon^* = \epsilon' - j\epsilon''$. Food works as a fuel for human body. It keeps us physically and mentally fit. Edible oil extracted from fresh plant sources is important and essential part of food. They are key components of the diet and provide characteristics flavors and textures of foods. Albert J. Dijkstra *et al*¹. explained production of vegetable oils from oilseeds and beans. In India, different oils used by the peoples of different regions as per the production and availability in the respective area, some of them are mustard oil, sunflower oil, groundnut oil, soya bean oil, almond oil, safflower oil, coconut oil etc. Supriya Dubhashi *et al*². reported quantitative analysis of neem extract complex using phosphatidyl choline obtained from soya lecithin oil. Topical anti acne formulation of coriander oil with penetration enhancer were reported by Vats A *et al*³. Safflower oil is a light, non-greasy and easily absorbed vegetable oil⁴⁻⁵. It has high in oleic acid and high levels of monounsaturated fat and vitamin E, makes it a healthy choice for losing weight, maintaining healthy skin and hair, improving heart health and cardiovascular system. Safflower oil is a good source of omega-6 fatty acids as building blocks for prostaglandins in the body i.e. help to balance blood pressure, control muscle contractions. The presence of vitamin E in it makes an antioxidant-rich food that cleanses the body of free radicals and reduces risk of heart disease and cancer. It reduces the appearance of wrinkles by softening; smoothing and hydrating the skin therefore used as massage oil and as an ingredient in soaps and cosmetics. Mustard oil used for cooking in North

India, Eastern India, Nepal, Bangladesh and Pakistan. It reduces skin dryness and improve blood circulation hence used as body oil for massage. It is also beneficial for hair growth. The characteristic pungent flavor of mustard oil is due to presence of Allyl isothiocyanate. Mustard oil has about 60% monounsaturated fatty acids (42% erucic acid and 12% oleic acid); it has about 21% polyunsaturated fats (6% the omega-3 alpha-linolenic acid and 15% the omega-6 linoleic acid), and it has about 12% saturated fats. It has high levels (6–11%) plant-based omega-3 fatty acids along with Calcium, Phosphorus, Iron, beta-carotene equivalent, riboflavin and niacin⁶⁻⁷. The major components of coconut oil is triacylglycerols i.e. ester of glycerol with three fatty acid namely trilaurin 19 % (C36), dilaurylacaprylglycerol (C34) & dilaurylamyristyl-glycerol (C38) both 16%, lauryldicaprylglycerol (C32) & lauryldimyristylglycerol (C40) both about 10%. Coconut oil has about 94% saturated fatty acids above 62% of medium chain fatty acids like capric acid, caprylic acid, caproic acid & lauric acid. They have anti oxidizing properties and increase the rate of metabolism in our body, thereby aiding weight loss, increase level of good cholesterol (high density lipoproteins) and lower the level of bad cholesterol (low density lipoproteins), lower risk of heart attack. Coconut oil it used for silky hair and a smooth and young skin due to presence of vitamin-E⁸⁻⁹. These acids convert themselves to great anti microbial and anti fungal agents like monocaprin and monolaurin when acted upon by certain enzymes. This oil taken regularly in proper quantity can help to cure chronic digestive problems. The saturated fatty acids help to protect against many types of cancer. Coconut oil is found to help absorption of fat soluble vitamins, glucose etc. The proper secretion of insulin, improves circulation and fight tumours, colitis, ulcers in stomach and food pipe and renal infections. Jha S *et al*¹⁰. described the development and characterization of olive oil based pharmaceutical microemulsion system by using sophisticated physical techniques like differential scanning calorimetry studies. Lipids are fatty acids and their derivatives, which are naturally occurring organic molecules that dissolve in non-polar organic solvent. Vegetable oil is mostly containing about 98% of lipids, mostly found in form of triglycerides i.e. ester of glycerol (Figure-1).

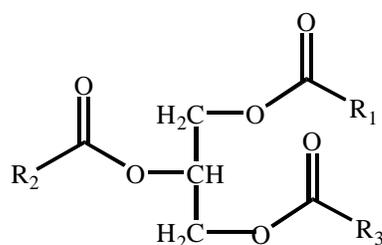


Figure-1 Triglycerides

Fatty acids are occurs naturally in oil as aliphatic saturated, unsaturated and polysaturated fatty acid containing ten or more carbon chain (Figure-2).

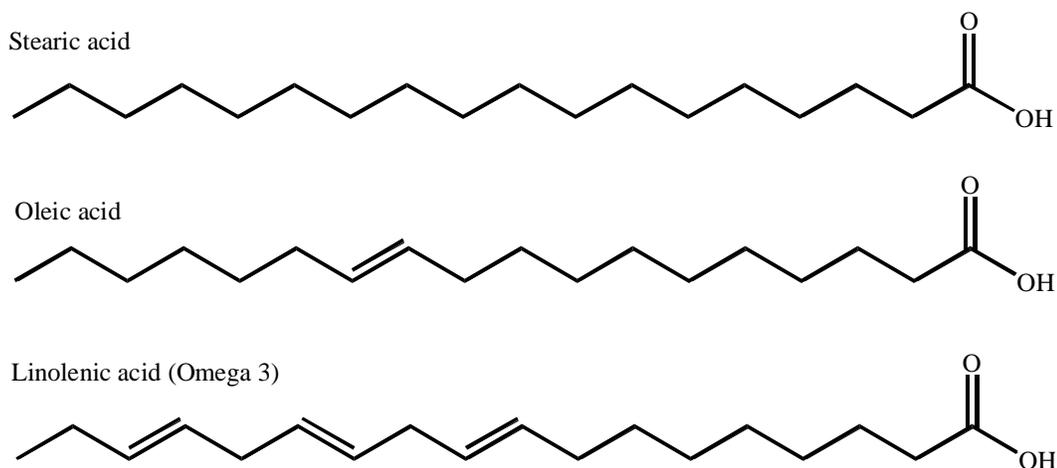


Figure-2 Fatty acids

In edible oils the proportion of various fatty acids, vitamin, moisture and other nutrient may vary with quality of seed, method of extraction, role of heat, pre and post processing including heating, distillation and chemical modification, which may alter their properties. In this work, we special focus on dielectric properties of different oils. Many researcher¹¹⁻¹⁵ studying the dielectric properties of food material have used open-ended co-axial probe method. Luque de Castro et al¹⁶. describe roll of the role of microwaves in the extraction of fats and oils. Hiromi Yoshida et al¹⁷. studied microwave roasting not only for phospholipid composition but also for positional distribution of the fatty acids and suggest that unsaturated fatty acids located in the 2-position are significantly protected from microwave roasting. Number of studies determines the dielectric properties of food products using the open-ended coaxial probe method. Kumar et al¹⁸ measured dielectric properties of pumpable food products under continuous flow conditions at a temperature range of 20 °C to 130 °C. Agrawal et al¹⁹ have used the wave guide cell method to find the dielectric properties of different edible oils. They have reported the microwave dielectric properties of pure oils and mixture of mustard oil with coconut oil, groundnut oil, linseed oil in different volume percentage at a constant temperature. Sipahioglu et al²⁰ used the open ended coaxial probe method for the determination of dielectric properties of vegetables and fruits as a function of temperature, ash and moisture content. There is a need to study the impact of impurities due to addition of different oils, effect of temperature with microwave techniques. In the present paper, the microwave dielectric properties of different edible oils at single frequency with various temperatures is reported

MATERIALS AND METHODS

Different edible oils are collected from the market. The physical and chemical properties of oils are measured at AGMARK approved Shri. Venkatesh Food Laboratories, Shivaji Nagar, Nanded - 431602 and are given in (Table-1). Iodine value represents degree of unsaturation, it is expressed in number of centigrams of iodine per gram of sample. Saponification value give idea of average size of fatty acid in the sample, it is measure of amount of alkali necessary to saponify all triglyceride in the sample. Acid value measure amount of free fatty acid in the sample (Figure-3).

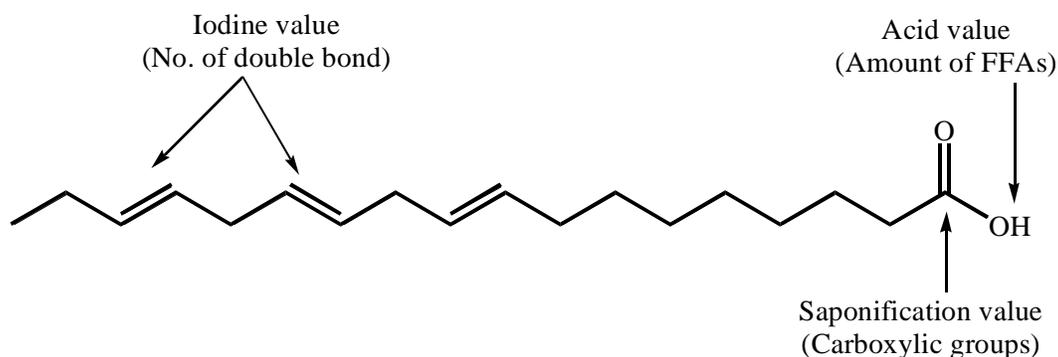


Figure-3 Chemical properties of oil

Table-1: Physical and Chemical properties of edible oils.

Name of the oil	Refractive index (40°C)	Specific gravity (30°C)	Saponification value	Iodine value	Acid value	Unsoinable matter (%)
Safflower oil	1.4682	0.916	189.40	141.32	0.18	0.40
Musterd oil	1.4652	0.909	171.24	106.36	1.52	0.48
Coconut oil	1.4487	0.918	268.00	8.70	1.10	0.47
Seasemeseed oil	1.4657	0.917	190.52	110.40	1.43	0.53

For measurement and estimation of dielectric properties of oils, the wave-guide cell method is used. The experimental set-up 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 with minimum isolation of 20 dB and minimum insertion loss of 0.4 dB used to avoid the interference between source and reflected signals. To control the power at desired level, a variable attenuator connected after the isolator. Resonance type frequency-meter with high Q-factor and with 5 MHz resolution used to measure the signal frequency. The diode detector with square law characteristics with VSWR better than 2:1 used to detect the output power. A micro ammeter used for measurement of power. The liquid cell connected to slotted section. The liquid cell is equipped with movable short plunger with scale division 0.001cm. The bench is tuned to frequency 9.435 GHz and kept undisturbed throughout the experiment. For accurate measurement of wavelength,

the probe carriage mounted with a dial gauge having least count of one micron. Accuracy of measurement of real (ϵ') and imaginary (ϵ'') parts of the complex dielectric constant (ϵ^*) is ± 0.001 and ± 0.004 respectively. The water bath and a thermostat used to maintain the constant temperature within the accuracy limit of $\pm 1^\circ\text{C}$. The sample cell is surrounded by a heat-insulating container, through which the water of constant temperature is circulated. The constant temperature of the cell recorded using a thermometer. The dielectric constant and dielectric loss of pure oils at various constant temperatures at microwave frequency 9.435 GHz are determined by applying following relations:

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

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

Here, λ_0 , λ_c and λ_d are the free space wavelength, cut-off wavelength and wavelength in the dielectric sample, respectively. α_d and β_d are attenuation constant of the material measured in nepers per meter and phase shift per unit length of the sample measured in radians per meter, respectively, and 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 the wave-guide.

RESULTS AND DISCUSSION:

The values of dielectric constant ϵ' and dielectric loss ϵ'' for different oils under study are measured at different temperatures. The variation of dielectric constant and dielectric loss with temperature for oil samples under study are shown in figure 4 and 5 respectively. The dielectric constant of edible oils decreases with increase in temperature. The dielectric loss increases with increase in temperature. The dielectric constant and dielectric loss for these edible oils have different values at the same temperature; this is due to their physical and chemical properties. These results are in good agreement with the earlier reported work. The dielectric constant is maximum for safflower oil and minimum for mustured oil at 30°C . As the safflower has least

acidic value among oil samples whereas mustered oil has maximum acidic value, therefore, the safflower has the maximum value of dielectric constant and mustered oil has the minimum dielectric constant (Figure.-4 and Figure -5).

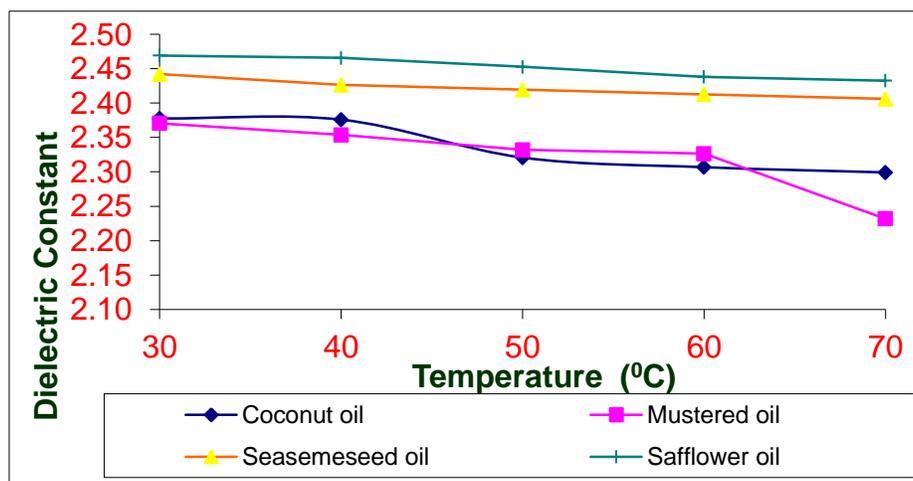


Figure. 4: Variation of dielectric constant with temperature for oils.

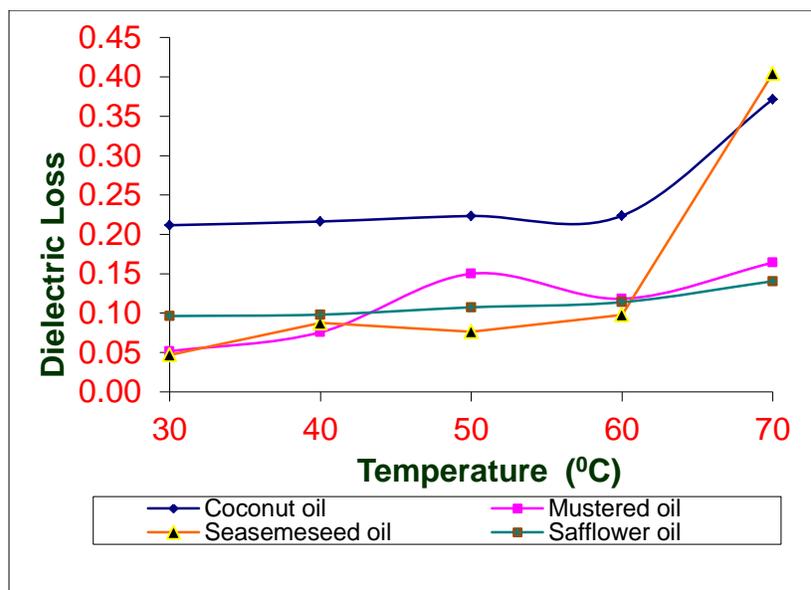


Figure. 5: Variation of dielectric loss with temperature for oils.

CONCLUSION

The data obtained from this study used to estimate the parameters like relaxation time, conductivity, dipole moment and thermodynamic parameters of liquid. With help of dielectric properties, different scales can be prepared; it will be use to find the amount of impurities in unsaturated oils. The dielectric data that can be correlated with physico-chemical properties of oils, which provide the information weather available product in market, is suitable for consumption or not.

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