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Microwave Dielectric Study of Turmeric (*Curcuma Longa* L.) at 9.85 GHz Frequency.

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Abstract:

Historical interest in dielectric properties of agricultural and Medicinal products and definitions of dielectric terms are presented briefly. The nature of dielectric properties variation with frequency, temperature, and product density is discussed. Techniques for measurement of dielectric properties are briefly reviewed, and graphical data on the dielectric properties of products are presented that illustrate the dependence of these properties on moisture content, frequency, temperature, and density. Models for estimating the dielectric properties of Turmeric as functions of moisture content, frequency, temperature, and bulk density are presented. Finally, applications of the dielectric properties of agricultural, Medicinal and products are described that include microwave - frequency (µf) and, improvement of nutritional and keeping qualities of some products, and controlling insects in grain. Uses of dielectric properties for product quality measurement and the rapid determination of moisture content are described. Principles of moisture determination in single kernels and seeds and in bulk grain by microwave measurements are presented.

Key words: Dielectric Constant, Dielectric Loss, Permittivity, Conductivity, Relaxation Time, Moisture content.

Introduction:

Curcuma longa L. a member of the ginger family (*Zingiberaceae*), commonly known as Turmeric has rhizomes below the ground. *Curcuma longa* has been used for thousands of years as a remedy in the traditional Indian and folk medicine for the cure of a large variety of illnesses, such as inflammation, infectious diseases, and gastric, hepatic, and blood disorders. Curcumin is a major isolated polyphenol from the rhizome of turmeric (*Curcuma longa*). It has a wide range of pharmacological effects such as antioxidant, anti-inflammatory, antimicrobial, antitumor, and hepatoprotective activities. In this review, we summarize the pharmacological activities of curcumin and its applications. The effect of packing density, moisture content and temperature on dielectric parameters such as dielectric constant (ε'), dielectric loss (ε''), loss tangent ($\tan\delta$), relaxation time (τ_p), conductivity (σ_p) for Turmeric was assessed. The results show that there was a systematic increase in dielectric constant (ε') and loss factor (ε'') with increasing values of relative packing fraction (δ_r) and decrease in dielectric constant and loss factor with increasing temperature. Experimental results of different relative packing fractions were further used to obtain transformation to 100% solid bulk using correlation equations of Landau-Lifshitz- Looyenga and Bottcher. There is a fair agreement between experimental values and theoretical values of different dielectric parameters.

Experimental details:

Dielectric constant (ε') and dielectric loss (ε") were measured by using reflectometric technique [4, 5, 10]. Measuring the reflection co-efficient from air dielectric boundary of sample in the microwave X – band at 9.85 GHz frequency at 20°, 35° and 50°C temperature. The following equations were used to determine the dielectric parameters.

$$\in' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \quad \text{.......... (1)}$$

$$\in'' = \frac{1}{\pi}\left(\frac{\lambda_0}{\lambda_d}\right)^2 \alpha_d \beta_d \quad \text{.......... (2)}$$

Where,

λ_0 = the wavelength in free space.

λ_c = 2a is cut-off wavelength of the wave guide.

a – is broader dimension of the rectangular wave guide.

αd = is the attenuation introduced by the unit length of the dielectric materials.

βd = $2\pi\lambda_d$ is phase shift introduced by the unit length of the dielectric materials.

λ_d = wavelength in the dielectric powder.

Detail regarding the procedure is given in [12]. In the present investigation, small quantity of powder was introduced in the cell and the plunger was brought over the powder column. A pressure was allowed to exert by plunger on powder in the dielectric cell. The height of the powder column and the corresponding reflection co-efficient was measured by means of a crystal pick-up in the directional coupler. This process was repeated at every addition of powder in the cell. The relationship between reflected power and height of the powder column was approximately given by a damped sinusoidal wave. The distance between two adjacent minima's of the curve gave half the dielectric wavelength (λ_d =2L).

For the determination of dielectric parameters of Turmaric, three samples of various particle sizes were prepared by using sieves of different size. For the comparison of correlation formulae between powder and bulk, the packing fraction (δ_r) were taken as the ratio of density of powder and the density of the finest crushed closely packed particle assembly of the sample. The conductivity (σ_p) and relaxation time (τ_p) were obtained by using following relations.

$$\sigma_p = \omega \epsilon_0 \epsilon'' \quad ....(3)$$

$$\tau_p = \frac{\epsilon''}{\omega \epsilon'} \quad .... (4)$$

Where,

ω - is angular frequency of measurement (9.85 GHz).

ε_o - is permittivity of free space.

For low loss materials, dielectric constant (ε') and loss factor (ε") for bulk materials can be correlated with their powder form by the relations derived independently by Landau-Lifshitz and Looyenga, [8].

$$\epsilon'_S = \frac{\left[\left(3\delta + 2\epsilon'_p - 2\right)\epsilon'_p\right]}{\left(3\delta - 1\right)\epsilon'_p + 1} \quad ..... (5)$$

$$\epsilon''_S = \left(\frac{\epsilon''_P}{\delta_r}\right)\left(\frac{\epsilon'_S}{\epsilon'_P}\right)^{2/3} \quad for \frac{\epsilon''}{\epsilon'} << 1 \quad .... (6)$$

Where,

ε'_s – is the dielectric constant for the material in bulk,

ε'_p – is the dielectric constant of powder sample at relative packing fraction (δr).

ε''_s and ε''_p – are the dielectric losses for solid and powder respectively.

The results obtained have been verified with values obtained from Bottcher's equation [3].

$$\epsilon'_S = \frac{\left(2\epsilon'_P + 3\delta - 2\right)\left\{\left(3\delta - 1\right)\left(\epsilon'^2_P + \epsilon''^2_P\right) + \epsilon'_P - 2\epsilon''^2_P\right\}}{\left(3\delta - 1\right)^2\left(\epsilon'^2_P + \epsilon''^2_P\right) + 2\epsilon'_P\left(3\delta - 1\right) + 1} \quad ......(7)$$

$$\epsilon''_S = \frac{2\left(3\delta - 1\right)\left(\epsilon''^3_P + \epsilon'^2_P\epsilon''_P\right) + \epsilon''_P\left(3\delta - 2\right) + 4\epsilon'_P\epsilon''_P}{\left(3\delta - 1\right)^2\left(\epsilon'^2_P + \epsilon''^2_P\right) + 2\epsilon'_P\left(3\delta - 1\right) + 1} \quad ......(8)$$

Results and Discussion:

Dielectric constant (ε') and dielectric loss (ε") along with the values of relative packing fraction (δr) of Turmeric powder are given in table -1. The values of (ε'_p) and (ε''_p) obtained experimentally for different grain sizes and temperature showed that, there is simultaneous increase in dielectric constant (ε') and loss factor (ε") with increasing temperature. This was expected, because with higher values of relative packing fraction (δr) the inter particle hindrance offered to the dipolar motion for a compact medium will be much higher than for less bounded particles. Such observations have been already made by other workers [2, 9, 11] for higher values of packing fraction.

Values of relaxation time (τ_p) loss tangent (tanδ) conductivity (σ_p) and values of moisture content with relative packing fraction and different temperature revealed that there was increase in (σ_p), (τ_p) and (tanδ) with the increasing values of packing fraction (δr). There was systematic decrease in (σ_p), (τ_p) and (tanδ), moisture percentage with increasing values of temperature. Such behaviour is expected because when polar molecules are very large, the rotator motion of the molecules is not sufficiently rapid for the attainment of equilibrium with the field. The increase in conductivity therefore suggests that at higher compactions, no micro cracks are developed in the sample due to high mechanical pressure. The decrease in relaxation time (τ_p) with increasing temperature may be due to increase in the effective length of dipole. In addition, due to increasing temperature, number of collisions increase causes increase in energy loss and thereby decreasing relaxation time.

Table -2 shows measured and computed values of dielectric parameters for bulk from powder measurements. The results reported at δr = 1 are those measured on the finest crushed powder sample packed very closely in a wave-guide cell pressing it under a fixed pressure, so as to obtain minimum voids between the particles. Out of the three powder samples of different packing fractions, the samples having minimum particle size is defined as finest which is about 0.70µm. In this case, we assumed it as solid bulk for getting correlation between powder and solid bulk. The correlation formulae were used to find other value for (δr >1). The bulk values obtained for (ε') and (ε") are same to the measured values and those calculated from [8], are closer to the values calculated from [3] formulae. The values of packing density increase linearly with the values of dielectric constant, dielectric loss and conductivity increases (Fig.1-5). There was a simultaneous decrease of dielectric constant, dielectric loss and conductivity with increase in the temperature.

Conclusion:

Thus, it was found that experimentally measured values of (ε') and (ε") at ($\delta r = 1$) are similar to those calculated from Landau-Lifshitz-Looyenga formulae. There was fair agreement between the values obtained experimentally and calculated theoretically by using Bottcher's formulae. The correlation formulae of Landau-Lifshitz-Looyenga and Bottcher can be used to provide accurate estimate of (ε') and (ε") of powder materials at known bulk densities. It may be thus, predicted that Turmeric powder is having cohesion in its particles and serve as a continuous medium.

TABLE: 1

Values of wavelength in dielectric (λ_d) and $\left(\frac{d\rho}{dn}\right)_{mean}$ (i. e. slope of graph between VSWR (1/ρ) and powder length $\left(n\frac{\lambda_d}{2}\right)$ along with relative packing fraction (δ_r) at temperature 20˚C to 50˚C.

The operating frequency (f) = 9.850 GHz

The free space wavelength (λ_o) = $\left(\frac{C}{f}\right)$ = 3.061 cm

The cutoff wavelength of the wave guide λ_c= 2a = 4.575 cm

The guide wavelength λ_g for empty cell = 3.331 cm

Forward current (I_f) = 73.50 μA

Relative Packing fraction	20˚C		35˚C		50˚C	
(δ_r)	λ_d cm.	$\frac{d\rho}{dn}$	λ_d cm.	$\frac{d\rho}{dn}$	λ_d cm.	$\frac{d\rho}{dn}$
0.9324	2.015	0.0837	2.018	0.075	2.021	0.0621
0.9565	2.010	0.0957	2.012	0.083	2.014	0.0711
0.9752	1.989	0.1046	1.998	0.096	2.010	0.0922
1.000 (Solid bulk)	1.928	0.137	1.935	0.103	2.080	0.0995

TABLE: 2

Values of dielectric constant ($\in'_p$), dielectric loss ($\in''_p$), loss tangent (tanδ), relaxation time (τ_p), conductivity (σ_p) and moisture percentage of Dry Ginger powder at different temperatures and packing fraction (δr).

Temp ˚C	Packing Fraction (δ_r)	$\in'_p$	$\in''_p$	tanδ	τ_p (p.s.)	σ_p (10^{-2})	Moisture (%)
20˚C	0.9324	2.897	0.278	0.096	1.553	15.24	1.150
	0.9565	2.909	0.301	0.103	1.665	16.44	1.030
	0.9752	2.961	0.362	0.122	1.974	19.80	0.947
	1.00	3.119	0.519	0.166	2.692	28.43	0.913
35˚C	0.9324	2.888	0.249	0.086	1.390	13.61	0.979
	0.9565	2.903	0.286	0.098	1.592	15.64	0.657
	0.9752	2.937	0.334	0.114	1.841	18.31	0.437
	1.00	3.099	0.386	0.125	2.014	21.14	0.412
50˚C	0.9324	2.880	0.204	0.071	1.146	11.19	0.640
	0.9565	2.898	0.236	0.082	1.319	12.94	0.482
	0.9752	2.907	0.300	0.103	1.670	16.44	0.257
	1.00	2.987	0.328	0.110	1.777	17.97	0.206

TABLE: 3

Measured and calculated values of dielectric constant ($\in'_s$), and dielectric loss ($\in''_s$) for bulk from powder at different temperatures and packing fraction (δ_r)

Temp ˚C	**Relative Packing fraction (δ_r)**	**$\in'_s$ For solid bulk**			**$\in''_s$ For solid bulk**		
		Measured	**Calculated From Bottcher's formula**	**Calculated From Landu, et al formula**	**Measured**	**Calculated From Bottcher's formula**	**Calculated From Landu, et al formula**
20˚C	0.9324		3.077	3.054		0.311	0.307
	0.9565		3.022	2.997		0.322	0.320
	0.9752		3.026	2.990		0.376	0.375
	1.00	3.119	3.119	3.060	0.519	0.519	0.519
35˚C	0.9324		3.067	3.049		0.278	0.275
	0.9565		3.015	2.992		0.306	0.304
	0.9752		3.001	2.970		0.348	0.347
	1.00	3.099	3.009	3.064	0.386	0.386	0.386
50˚C	0.9324		3.058	3.050		0.228	0.226
	0.9565		3.010	2.994		0.253	0.252
	0.9752		2.970	2.950		0.312	0.311
	1.00	2.987	2.987	2.981	0.328	0.328	0.328

Fig. Graphical representation of Temperature Vs Dielectric parameters.

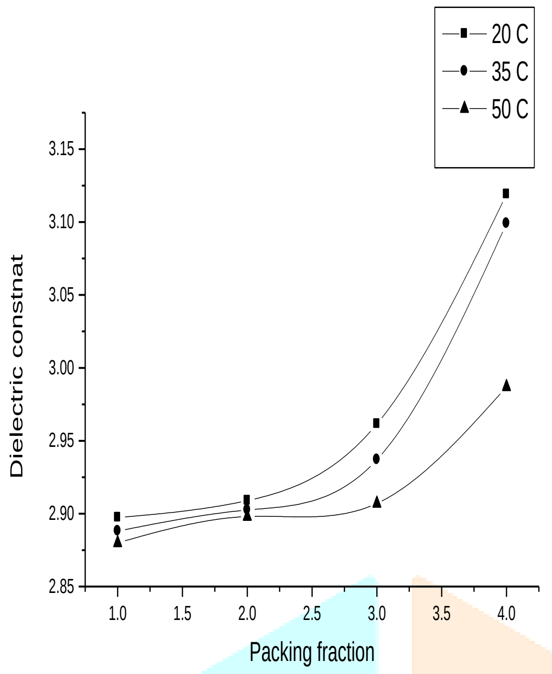

Fig.1: Packing fraction Vs Dielectric constant

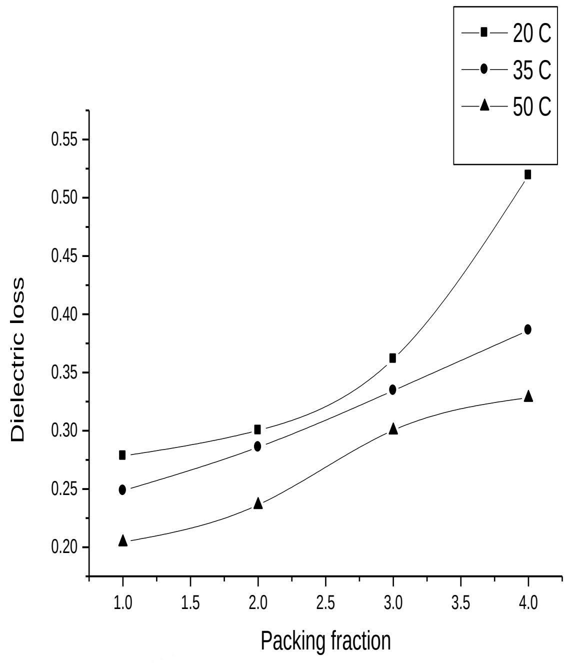

Fig.2 : Packing fraction Vs Dielectric loss

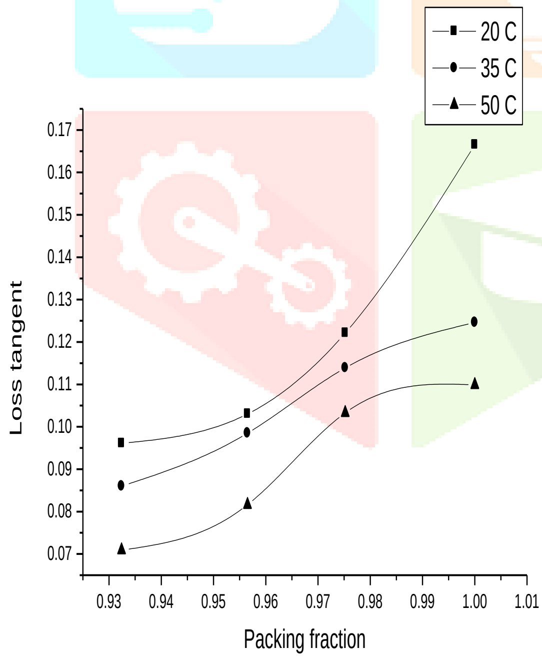

Fig.3 : Packing fraction Vs Loss tangent

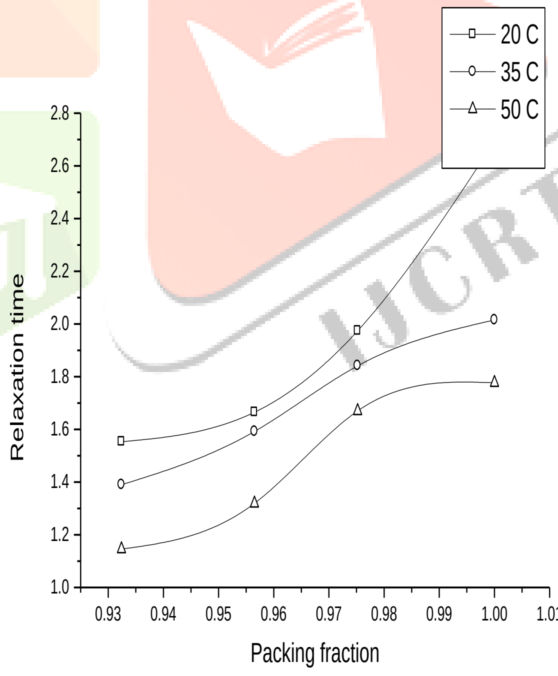

Fig.4 : Packing fraction Vs Relaxation time

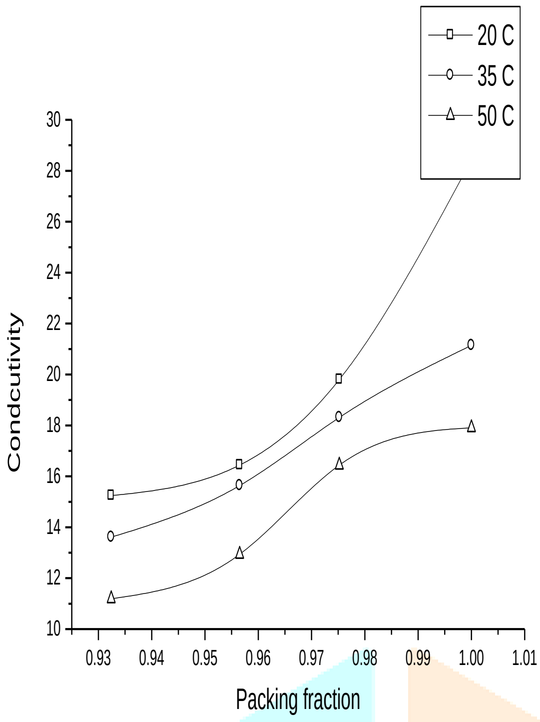

Fig.5 : Packing fraction Vs Conductivity

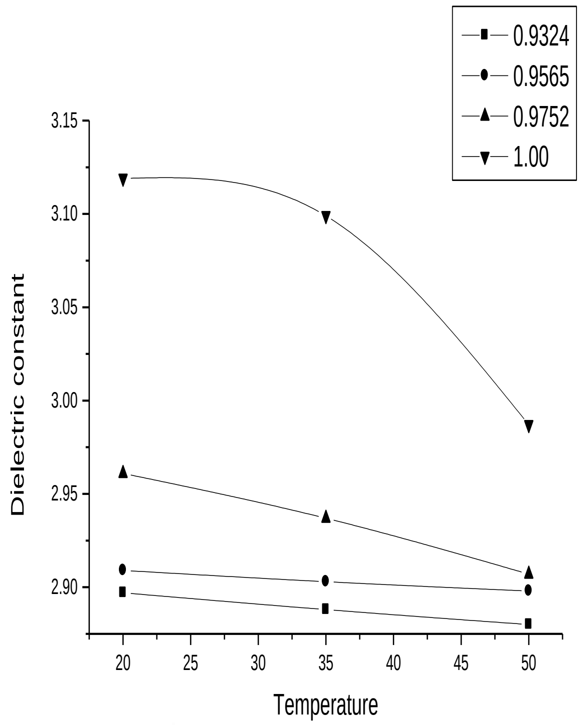

Fig.6 : Temperature Vs Dielectric constant

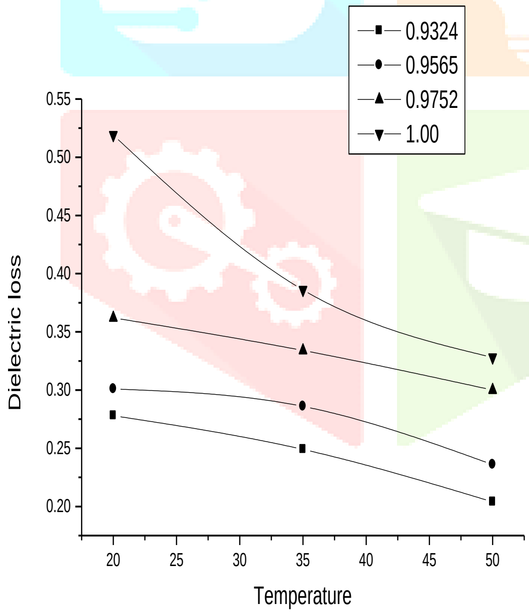

Fig.7 : Temperature Vs Loss tangent

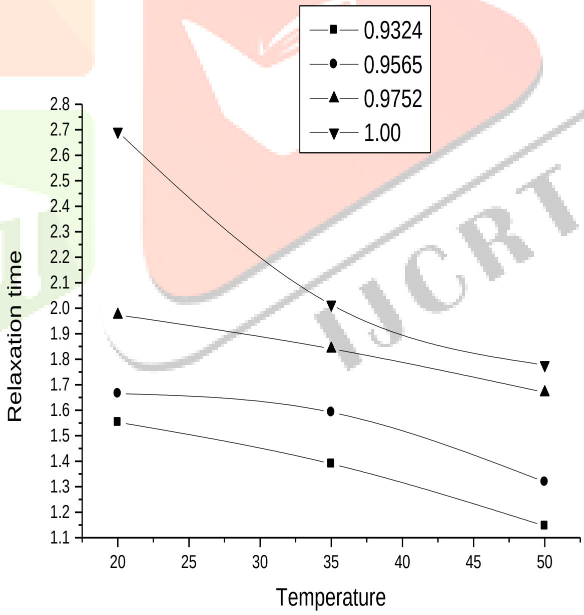

Fig.8 : Temperature Vs Relaxation time

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