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Research Article

DIELECTRIC STUDY OF GINGER *(ZINGIBER OFFICINALE)* AT 9.85 GHZ FREQUENCY

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ABSTRACT

The values of dielectric constant ($\in'$), dielectric loss ($\in''$), relaxation time (τ_p), conductivity (σ_p) and moisture content of pulverized spicy product Dry Ginger (*Zingiber officinale*) were measured for different packing densities at 9.85 GHz microwave frequency and different temperature (20˚C, 35˚C and 50C). Experimental results on powders of different packing fractions (δ_r) were used to obtain transformation to 100% solid bulk using correlation formulae of Landau- Lifshitz-Looyenga and Bottcher. There is fair agreement between the calculated values of dielectric parameters and the values obtained experimentally for solid bulk. This shows cohesion in the particles of spicy products under investigation.

Key Words: *Dry Ginger, Dielectric Constant, Dielectric Loss, Moisture Content*

INTRODUCTION

Ginger, one of the world's best medicines, is used since time immemorial and cultivated extensively in India. The rhizomes of ginger are used in both fresh and dried forms. Ginger eases the transport of substances through the digestive tract thus decreasing the irritation to intestinal walls. Ginger also improves production and secretion of bile, which aids in the digestion of fats. It is believed to absorb and neutralize toxins in stomach also an essential ingredient in most of the Ayurveda medicines (Purthi).

For the development of microwave process control, it is important to know the dielectric properties of Ginger materials and the actual process at molecular level. The dielectric properties of agricultural spicy materials and their constituents describe their interactions with microwave energy (Bansal, 2001; Kraszewski, 1994 and Landau *et al.*, 1996) and depend on the frequency of electromagnetic field as well as materials packing fractions, moisture content, temperature and composition of the material.

Moisture content is important parameter of pulverized spicy products affecting their suitability for storage, transport and processing, if spicy products are stored at high moisture content they can spoil because of action of micro-organism and the value is degraded. Therefore, it is essential to determine the moisture content.

Different workers (Bhatnagar, 1996; Jangid, 1996 and Kalamse, 2007) have tried to correlate dielectric behavior of bulk materials and their powders. Due to non-availability of required size of bulk materials for mounting in wave -guide brings restrictions for the analysis. Bottcher (1952) and Nelson (1993) have given useful relations to correlate dielectric behavior of bulk materials and their powder form. The dielectric properties of corn and wheat kernals and soybeans were studied by Nelson (1992) and Bansal *et al.,* (2001).

In the present paper, dielectric properties of Dry Ginger were determined at various packing fractions and temperatures. The effects of temperature and density on the dielectric parameter were reported. We correlated dielectric parameter of spicy products powder with solid bulk. This type of correlation is useful because it makes possible to correlate without the necessity of making big enough samples of the bulk materials for the dielectric measurement. We compared measured values with the values obtained from the correlation formulae between powder and bulk derived independently by Landau-Lifshitz-Looyenga and Bottcher (Nelson, 1992).

MATERIALS AND METHODS

The dielectric constant ($\in'$), and dielectric loss ($\in''$), were measured by using reflectrometric technique (Chelkowski, 1980; Jangid, 1996; Sisodia,1990 and Yadhav, 1992) of measuring the reflection co-efficient from the air dielectric boundary of the sample in the microwave X – band at 9.85 GHz frequency and at (20˚C, 35˚C and 50˚C) temperatures. The following relations were used to determine the dielectric parameters of materials.

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

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

Where, λ_0 – is the wavelength in free space. $\lambda_c = 2a$ – is the cut-off wavelength of the waveguide. β_a – is the broader dimension of the rectangular waveguide. α_d – is the attenuation introduced by the unit length of the materials.$\beta_d = 2\pi/ \lambda_d$ - is the phase shift introduced by the unit length of the dielectric material. λ_d – is the wavelength in dielectric powder. To determine relative packing fractions (δ_r), density (ρ) for each spicy sample is measured. The moisture percentage of material is measured using thermo-gravimetric method (Reynold, 1970). For accurate measurement of dielectric wavelength (λ_d), the dielectric cell is designed and fabricated by Kalamse G. (2007) is used. Such that one can introduce the sample in the cell conveniently by simply raising up the plunger without taking it outside the cell. For the determination of dielectric parameters of Dry Ginger (Zingiber *officinale*) of three particle sizes were prepared by using sieves of different sizes. For the comparison of correlation formulae between powder and bulk, the packing fractions (δ_r) is taken as the ratio of density of powder and the density of the finest crushed closely packed particle assembly of the spicy products. The conductivity (σ_p) and relaxation time (τ_p) were obtained by using the following equations.

$$\sigma_p = \omega \in_o \in'' \quad \text{---------------- (3)}$$

$$\text{And, } \tau_p = \frac{\in''}{\omega \in'} \quad \text{-------------- (4)}$$

Where, ω- is the angular frequency of measurement 9.85 GHz. $\in_0$ - is the permittivity of vacuum.

RESULTS AND DISCUSSION

Dielectric constant ($\in'$), and dielectric loss ($\in''$), along with the values of relative packing fraction (δ_r) of Dry Ginger are listed in table (1). The values of ($\in'_p$) and ($\in''_p$) obtained experimentally for different grain sizes and temperatures show that there is systematic increase in dielectric constant ($\in'_p$) and loss factor ($\in''_p$) with increasing values of relative packing fraction (δr) and there is systematic decrease in ($\in'_s$) and ($\in''_s$) with increasing temperature. This is expected because with higher values of relative packing fraction the interparticle hindrance offered to the dipolar motion of the material in an electromagnetic field at microwave frequencies for compact medium will be much higher than for a material constituting less bounded particles.

An examination of values of relaxation time (τ_p), loss tangent (Tanδ), conductivity (σ_p), moisture content values with relative packing fraction and different temperatures revealed that there is systematic increase in σ_p, τ_p, and Tanδ with the increasing values of packing fraction (δ_r) and temperature. There is systematic decrease in σ_p, τ_p, and Tanδ and moisture content with increasing values of temperature. Such behavior is expected because when polar molecules are very large, due to increasing hindrance to the process of polarization, the rotatory motion of the molecules is not sufficiently rapid for the attainment of equilibrium with the field. The increase in conductivity 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 increase in temperature may be due to increase in the effective length of dipole. Again, due to increasing temperature number of collision increase causes increase in energy loss and thereby decreasing relaxation time.

Table 1: Values of dielectric constant (∈′), dielectric loss (∈″), loss tangent (tanδ), relaxation time (τ_p), conductivity (σ_p), Moisture percentage of Dry Ginger powder at different temperature and relative packing fraction (δ_r)

Temp. °C	Relative 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	0.300	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	0.520	0.166	2.692	28.43	0.913
35°C	0.9324	2.888	0.249	0.086	1.390	13.61	0.797
	0.9565	2.902	0.286	0.098	1.592	15.64	0.657
	0.9752	2.937	0.335	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	0.641
	0.9565	2.898	0.236	0.082	1.319	12.94	0.482
	0.9752	2.907	0.301	0.103	1.670	16.44	0.258
	1.00	2.746	0.308	0.112	1.815	16.89	0.206

The table shows list of measured and computed values of dielectric parameters for bulk from powder measurements. The result show at $\delta_r = 1$ 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 three powder samples of different packing fractions, the samples having minimum particle size is defined as finest which is about 0.70 micrometer. 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 values for δr > 1. The bulk values obtained for ($\in'_s$) and ($\in''_s$) are same to the measured values calculated from Landau-Lifshitz-Looyenga formulae (Nelson, 1992) and closer to the values calculated from Bottchers formulae (Bottcher, 1952).

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Table 2: Measured and calculated values of dielectric constant (Є'$_s$), and dielectric loss (Є''$_s$) 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

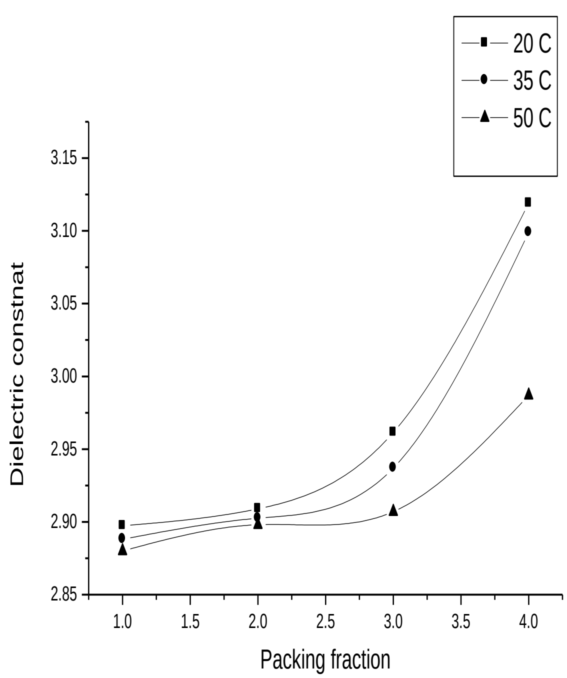

Figure 1: Packing fraction Vs Dielectric constant

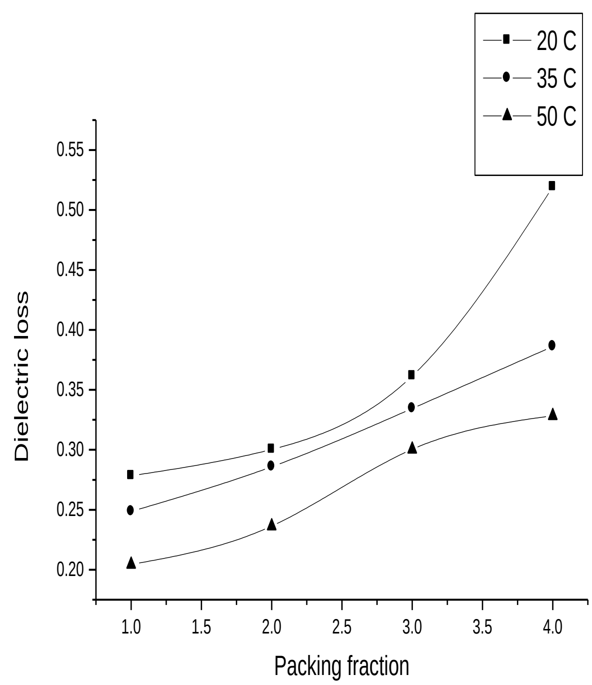

Figure 2: Packing fraction Vs Dielectric loss

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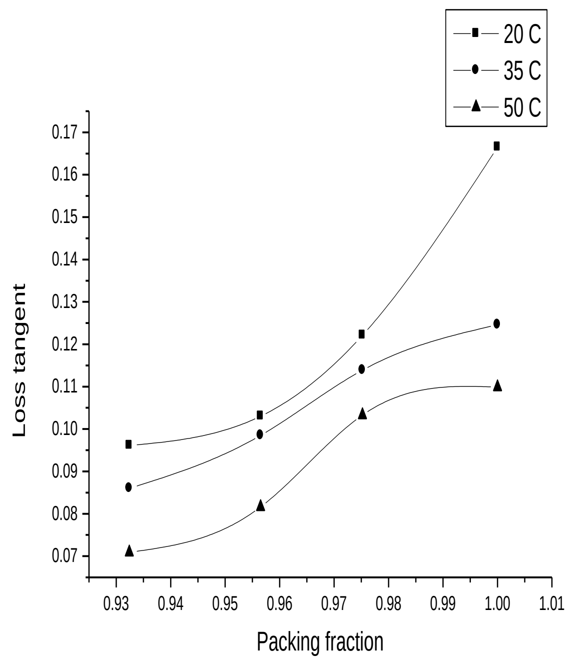

Figure 3: Packing fraction Vs Loss tangent

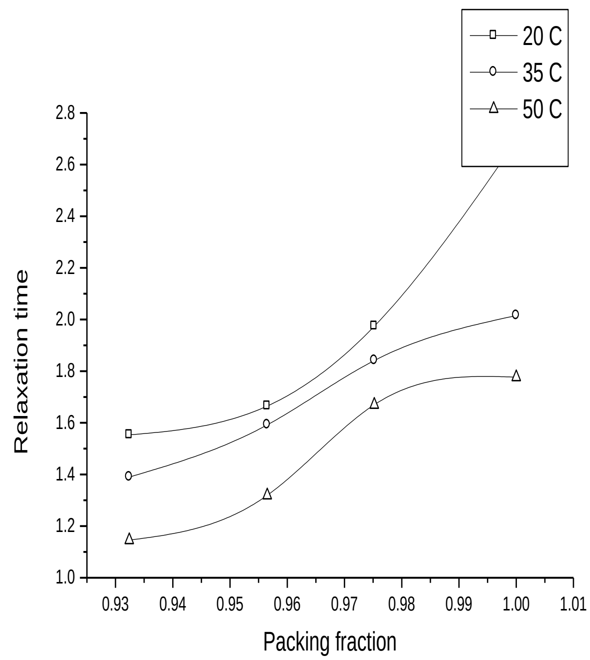

Figure 4: Packing fraction Vs Relaxation time

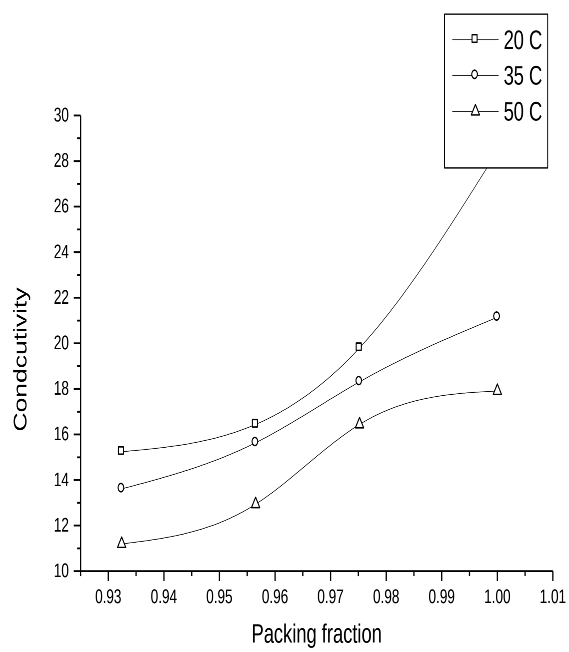

Figure 5: Packing fraction Vs Conductivity

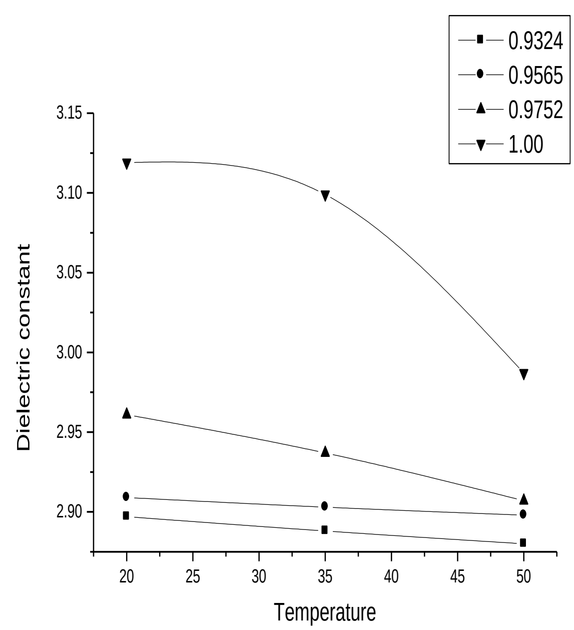

Figure 6: Temperature Vs Dielectric constant

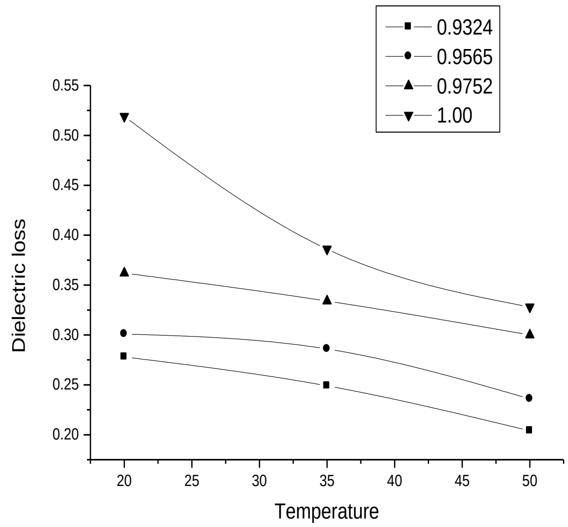

Figure 7: Temperature Vs Loss tangent

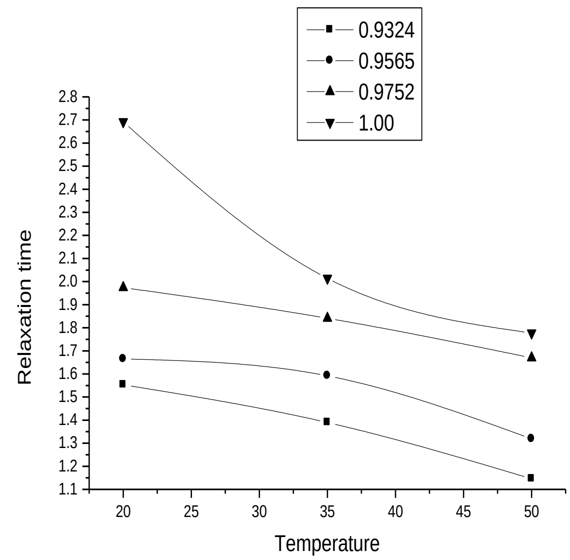

Figure 8: Temperature Vs Relaxation time

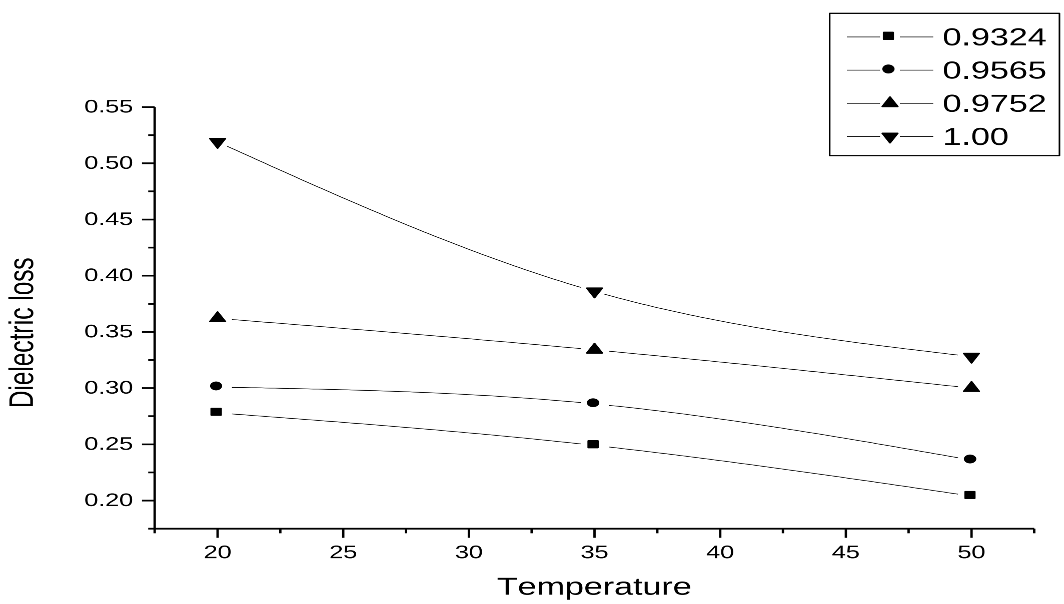

Figure 9: Temperature Vs Dielectric loss

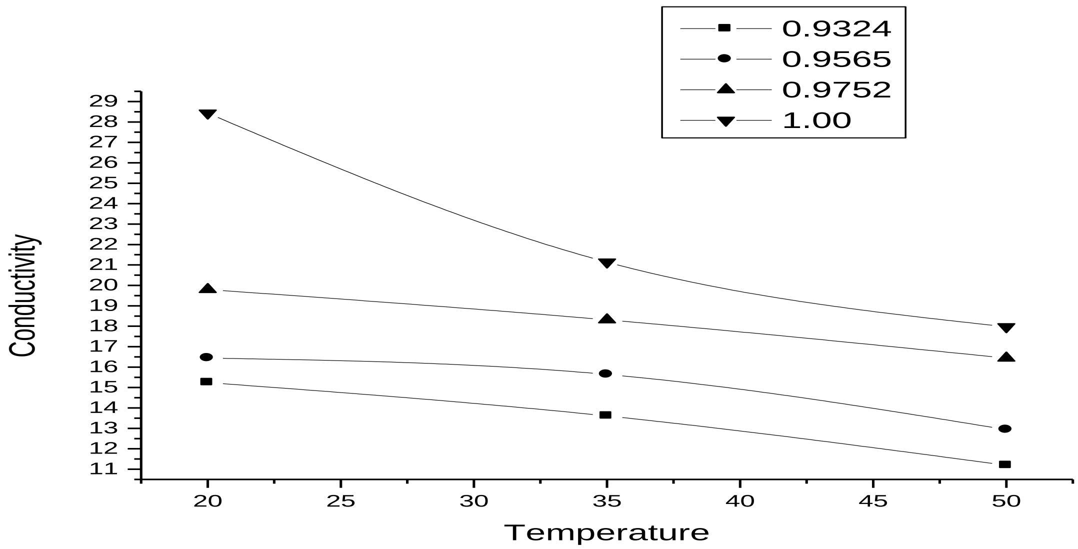

Figure 10: Temperature Vs Conductivity

Finally, it may be predicted that spicy product powder is having cohesion in its particles and may serve as continuous medium. There is fair agreement between the values obtained experimentally and calculated theoretically by using Bottchers formulae. The correlation formulae of Landau-Lifshitz and Bottcher can be used to provide accurate estimates of ($\in'_s$) and ($\in''_s$) of powdered material at known bulk densities.

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