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Dielectric spectroscopy of *trigonella foenum-graecum* linn. At 9.85 GHz frequency

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ABSTRACT

Values of dielectric constant ($\in'$), dielectric loss ($\in''$), relaxation time (τ_p), conductivity (σ_p) and moisture content of pulverized samples of Fenugreek were measured for different packing densities at 9.85 GHz microwave frequency and at different temperature (20˚C, 35˚C and 50˚C). 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. It is found that, there was fair agreement between the calculated values of dielectric parameters and the values obtained experimentally for solid bulk. This shows cohesion in the particles of *Trigonellia Foenum-Graecum* Linn. powder under investigation.

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Introduction

The dielectric properties of spicy-food materials and their constituents, describe their interaction with microwave energy [1, 8, 9] which depends on the frequency of electromagnetic field as well as nature of the material (Packing fraction, moisture content, temperature and composition).

Different workers [2, 5] correlated dielectric behavior of bulk materials and their powders. Landau - Lifshitz and Bottcher have explained useful information to correlate dielectric behavior of bulk materials and their powder forms. The dielectric properties of corn and wheat kernels, and soya beans were studied by [11] and [1] have reported dielectric properties of rapeseed and mustard seeds in powder form at various microwave frequencies.

During the present study, dielectric properties of Fenugreek seeds were determined at various packing fractions and temperature. The effects of temperature and density on the dielectric parameters correlation of dielectric parameter of Fenugreek seeds powder with solid bulk have been described. The results were compared with the values obtained from correlation formulae between powder and bulk derived independently by [3, 10].

Fenugreek **(***Trigonella foenun-graecum* Linn**.)** is the dried ripe fruit of an annual herb, native of South-eastern Europe and West Asia and now cultivated in India. The seeds are small and yellowish brown in colour. It has a pleasantly bitter taste and a peculiar odour and flavor of its own. The seeds are produced as a spice, as a vegetable for human consumption, as forage for cattle and to some extent, for medicinal purposes. Fenugreek has been used both as a food or food additive as well as in medicine. Fresh tender pods, leaves and shoots which are rich in Iron, Calcium, protein, vitamin A and C, are eaten as curried vegetable sine ancient time in India. As a spice, fenugreek seeds also add to the nutritive value and flavor of foods [13].

Composition :- Fenugreek seeds contains, Protein – 9.5%, Fat – 10.0%, Crude fibers-18.5%, Carbohydrates-42.3%, Calcium-1.3%, Phosphorus-0.48%, Iron-0.011%, Pottassium- 1.7%, Moisture-6.3% per 100gm.

Material and methods:-

The dielectric constant ($\in'$) and dielectric loss ($\in''$) were measured by using reflectometeric technique [4, 12, and 14]. Measuring the reflection co-efficient from air dielectric boundary of sample in the microwave X – band at 9.85 GHz frequency at 20ºC, 35ºC and 50ºC temperature. The following equations were used to determine the dielectric parameters.

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

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

Where,

λ_o - the wavelength in free space.

$\lambda_c = 2a$ is cut-off wavelength of the wave guide.

2a – is broader dimension of the rectangular wave guide.

α_d- is the attenuation introduced by the unit length of the materials.

$\beta_d = 2\pi/\lambda_d$ is phase shift introduced by the unit length of the dielectric materials,

λ_d = dielectric wavelength in powder.

Fig : Microwave X- band set-up for dielectric measurements.

In order to determine (λ_d) accurately, [6] have designed and developed a dielectric cell to hold sample powder so as to introduce it in the cell conveniently and to exert equal amount of pressure by the plunger on the powder column in the cell. During 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 this curve gave half the dielectric wavelength (λ_d = 2L).

For the determination of dielectric parameters of Fenugreek, three samples of various particles sizes were prepared by using sieves of different sizes. For the comparison of correlation formulae between powder and bulk, the packing fractions (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:

$$\sigma_p = \omega \in_0 \in'' \quad \text{.............. (3)}$$

$$\tau_p = \frac{\in''}{\omega \in'} \quad \ldots\ldots\ldots\ldots (4)$$

Where,

ω – is angular frequency of measurement (9.85 GHz)

$\in_0$ – is permittivity of vacuum.

Result and discussions:-

Dielectric constant ($\in'_p$), and dielectric loss ($\in''_p$) along with the values of relative packing fraction (δ_r) of Fenugreek are given in table 1. The values of ($\in'_p$), and ($\in''_p$) obtained experimentally for different grain sizes and temperatures showed that, there is simultaneous increase in dielectric constant ($\in'_p$) and loss factor ($\in''_p$) with increasing values of relative packing fraction (δ_r) while decrease in ($\in'_p$) and ($\in''_p$) with increasing temperature. This was expected, because with higher values of relative packing fraction (δ_r) 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 [7] for higher values of packing fraction.

An examination of values of relaxation time (τ_p) loss tangent (tan δ) 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 (δ_r). There was a systematic decrease in (σ_p), (τ_p) and (tanδ), moisture percentage with increasing values of temperature. Such behavior is expected because when polar molecules are very large, the rotatory 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 collision increase causes increase in energy loss and thereby decreasing relaxation time.

Table -2 gives measured and computed values of dielectric parameters for bulk from powder measurements. The results reported at δ_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 µm. 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 δ_r >1. The bulk values obtained for ($\in'_p$) and ($\in''_p$) are same to the measured values and those calculated from [10] 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 shown in Figure. There was a simultaneous decrease of dielectric constant, dielectric loss and conductivity with increase in the temperature.

Conclusions:-

Thus, it was found that experimentally measured values of ($\in'_p$) and ($\in''_p$) at (δ_r = 1) are similar to those calculated from Landau-Lifshitz-Looyenga formulae. There was a 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 ($\in'_s$) and ($\in''_s$) of powder materials at known bulk densities. It may thus predict that, Fenugreek seeds powder is having cohesion in its particles and may serve as a continuous medium.

Table -1

Values of dielectric constant ($\in'_p$), dielectric loss ($\in''_p$), loss tangent (tan δ), relaxation time (τ_p), conductivity (σ_p) and moisture percentage of Fenugreek powder at different temperature and packing fraction (δ_r)

Temp ˚C	Packing Fraction (δ_r)	$\in'_p$	$\in''_p$	tanδ	τ_p (p.s.)	σ_p (10^{-2})	Moisture (%)
20˚C	0.9063	2.727	0.243	0.089	1.44	13.30	0.881
	0.9531	2.860	0.271	0.095	1.53	14.86	0.857
	1.00	2.964	0.318	0.107	1.74	17.44	0.656
35˚C	0.9063	2.717	0.197	0.072	1.17	10.77	0.827
	0.9531	2.766	0.207	0.075	1.22	11.35	0.742
	1.00	2.903	0.259	0.089	1.45	14.20	0.632
50˚C	0.9063	2.510	0.144	0.055	0.89	7.90	0.810
	0.9531	2.542	0.171	0.067	1.09	9.35	0.711
	1.00	2.631	0.195	0.077	1.26	10.66	0.615

Table -2

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

Temp ˚C	Relative Packing fraction (δr)	$\in'_s$ 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	0.9063		2.959	2.940		0.283	0.278
	0.9531		2.978	2.958		0.293	0.291
	1.00	2.964	2.964	2.940	0.318	0.317	0.318
35˚C	0.9063		2.949	2.936		0.230	0.227
	0.9531		2.878	2.866		0.223	0.221
	1.00	2.903	2.903	2.890	0.259	0.258	0.259
50˚C	0.9063		2.849	2.840		0.168	0.165
	0.9531		2.639	2.630		0.184	0.183
	1.00	2.510	2.510	2.501	0.195	0.195	0.195

Graphical representations of Dielectric parameters:

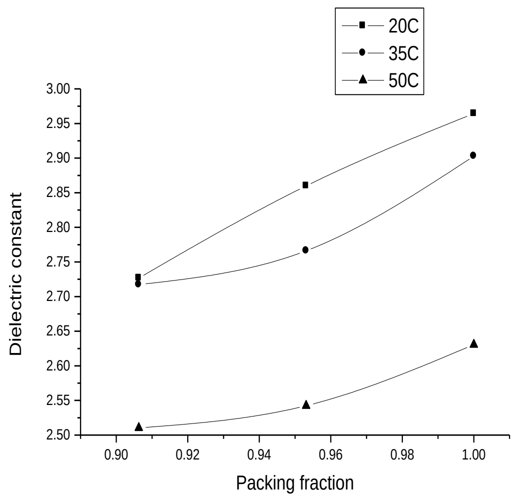

Fig.1: Packing fraction Vs Dielectric constant

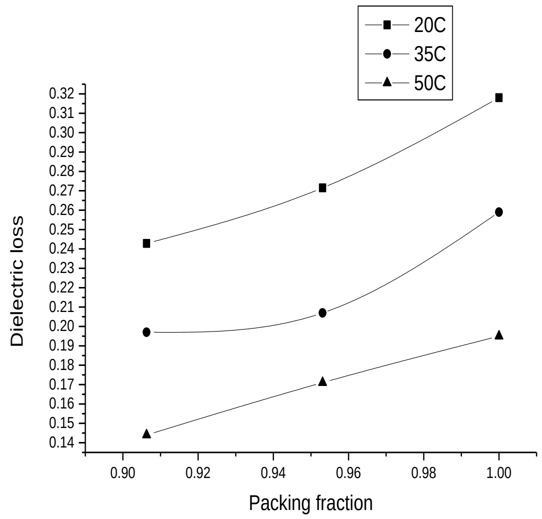

Fig.2 : Packing fraction Vs Dielectric loss

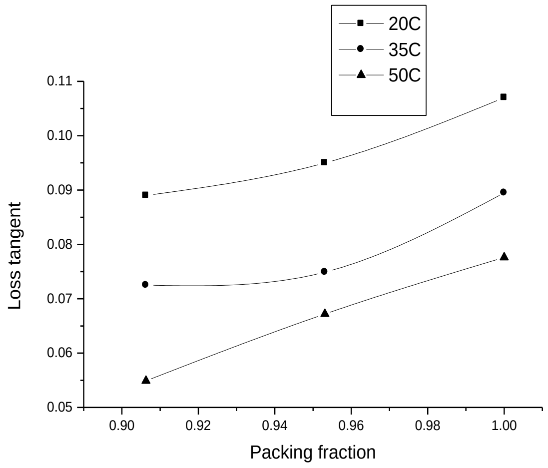

Fig.3 : Packing fraction Vs Loss tangent

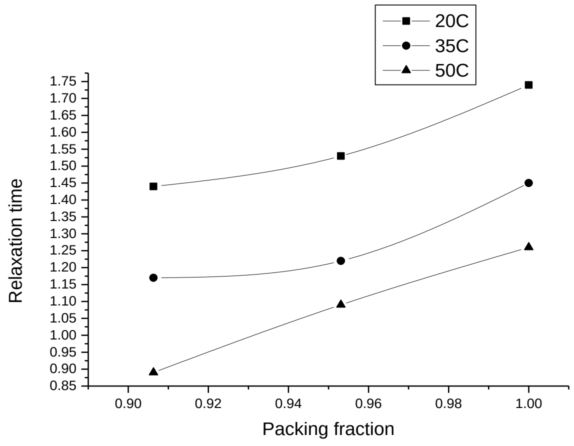

Fig.4 : Packing fraction Vs Relaxation time

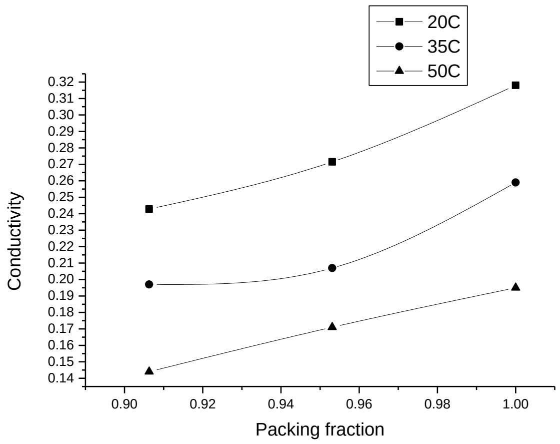

Fig .5 : Packing fraction Vs Conductivity

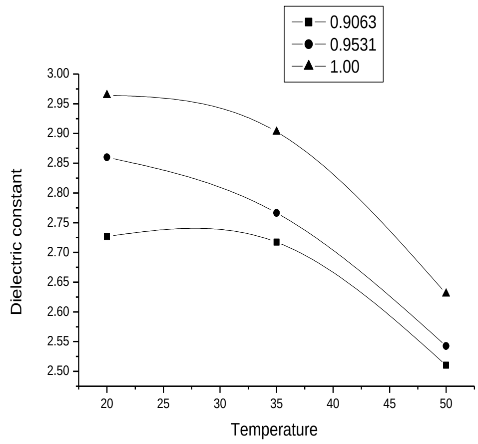

Fig.6 : Temperature Vs Dielectric constant

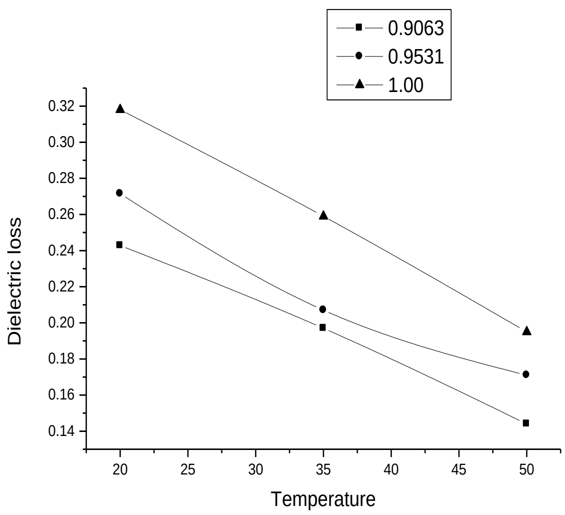

Fig.7 : Temperature Vs Dielectric loss

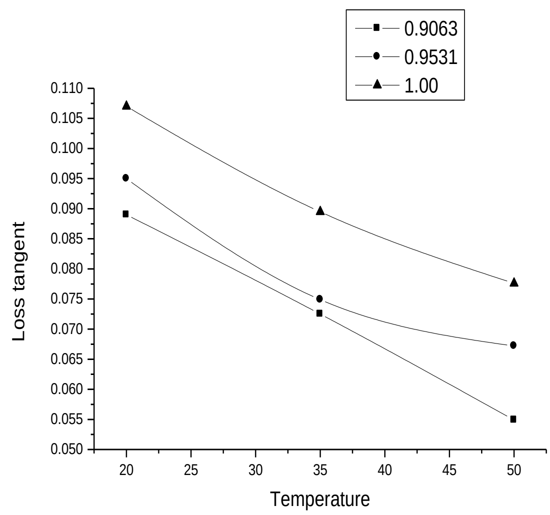

Fig.8 : Temperature Vs Loss tangent

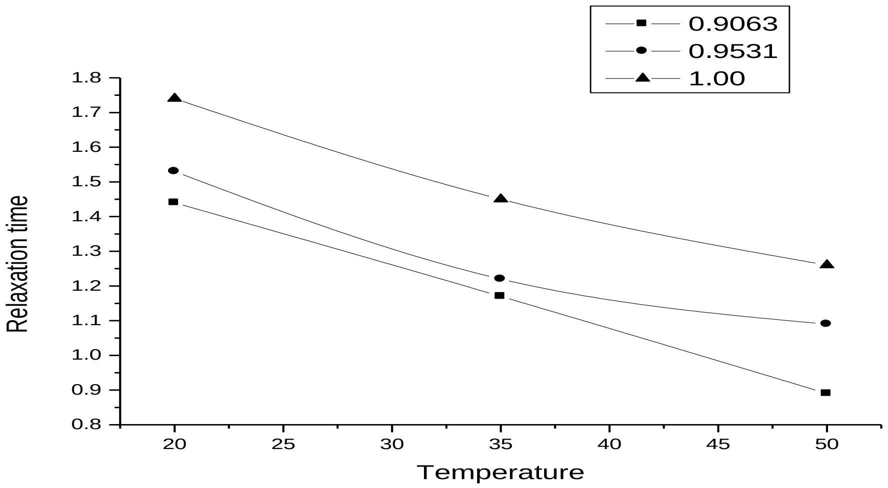

Fig.9 : Temperature Vs Relaxation time

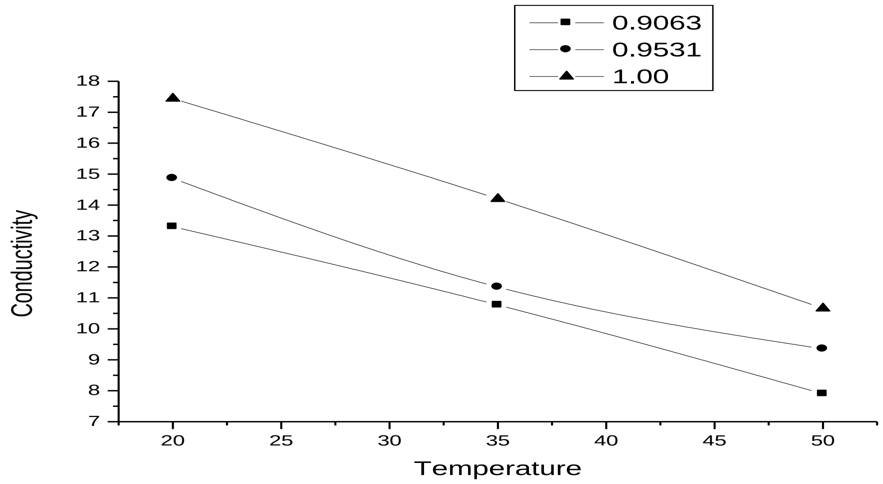

Fig.10 : Temperature Vs Conductivity

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