Effect of Size and Temperature on Dielectric Parameters of Pigeon and Chick Pea at Microwave Frequency

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Abstract: ***The dielectric properties are measured by using x-band microwave bench reflectometer technique. Dielectric values are calculated at different temp. (20^{o}c to 50^{o}c) and packing density and then compared with co-relation formulae. There was a good agreement is found between theoretical and experimental values of dielectric parameters. The result shows there was a systematic increase in ε' and ε" with increasing value of δr and decrease in ε' and ε" with increasing temperature.***

Keywords: Dielectric, pigeon pea, chick pea, x – microwave band

1. Introduction

The various measurement techniques can be used to determine dielectric constant (ε') and dielectric loss (ε"). The choice of the appropriate technique depends mainly on the application, nature of material and desired accuracy. The dielectric properties of liquid are well known. The dielectric properties of agricultural products and its applications are studied by Nelson [1]. We have prposed a simple technique for estimating the dielectric properties of pigeaon pea or red gram (tur) and chick pea [2, 3] in the form of powders at microwave frequency. Dielectric properties of zea maysl and hard winter wheat at various packing density have been determined by venkatesh [4]. The purpose of this paper is to present the measured and computed values of dielectric parameters for bulk from powder measurements, and co-relate these parameters of pigeon and chick pea powder with solid bulk.

We have used Reflectometric technique of x-band microwave bench at 9.85 GHz frequency.

Pigeon and chick pea are the important pulse crops cultivated all over India, and are the important source of dietary proteins.

Chemical composition of (values are per 100 gm) pigeon and chick pea respectively:

Moisture	= 13.4, 9.8
Protein	= 22.3, 17.1
Fat	= 1.7, 5.3
Minerals	= 3.5, 3
Fiber	= 3.9, 15
Carbohydrates	= 57.6, 60.9
Calcium	= 73, 202
Phosphorus	= 304, 312
Iron	= 2.7, 4.6 (μgm)

2. Literature Survey

The survey of literature shows that P. C. Jain and J. P. Shukla have measured dielectric properties of groundnut, sesame, linseed, and rapeseed by Bansal A. K. [5]

The result are obtained are not so much agree with the computed values by employing the relations given independently by Landau-Lifshitz-Looyenga and Bottcher, to correlate dielectric behavior of bulk material and its powder form.

Thus to provide accurate estimation of dielectric properties of pulverized materials at known bulk densities, we have designed and developed the dielectric cell. We observed that there is fair agreement between experimentally and theoretically. Such type of work has been studied by many researchers [6, 7].

3. Materials and Methods

For the determination of dielectric and thermodynamic parameters of pigeon and chick pea, four samples of various particle sizes were prepared by using sieves of different sizes and transferred to the glass bottles and sealed immediately to avoid moisture intake. They were opened only at the time of use. To determine the relative packing factor δr density for each powder sample was measured. Measurement of dielectric constant (ε') and dielectric loss (ε"), for these powder samples of different packing fractions was made using reflectometric techniques at 9.85 GHz, of x-band [3, 8]. Microwave frequency and at different temperature (20-50^{o}c).

For better results, accurate measurement of dielectric wavelength (λd) is necessary. This was done by introducing the powder slowly in the sample holding dielectric cell in steps and applying constant 98 N force on the sample. The relationship between reflected power and the sample column position is approximately given by damped sinusoidal curve.

The distance between two adjacent minima gives half the dielectric wavelength (λd). We have fabricated the cell to hold the powder sample such that one can introduce the sample in the cell. Conveniently by raising up the plunger without taking cell outside. Due to this arrangement equal pressure was applied by the plunger on powder column of the cell. We provided a jacket to the cell for giving circulation of water at required temperature.

To determine the dielectric constant (ε') and dielectric loss (ε") for pigeon and chick pea powder at microwave frequency the following relations were used [8].

$$\varepsilon' = [\lambda_o/\lambda_c]^2 + [\lambda_o/\lambda_d]^2 \quad ....(1)$$

$$\varepsilon'' = 2[\lambda_o/\lambda_d]^2 \, . \, [\alpha_o/\beta_d]^2 \quad ....(2)$$

The conductivity (σ_p) and relaxation time (τ_p) were obtained by using the following relations [5].

$$\sigma_p = \omega\varepsilon_o\varepsilon'' \quad ....(3)$$

$$\tau_p = \varepsilon''/\, \omega\varepsilon' \quad ....(4)$$

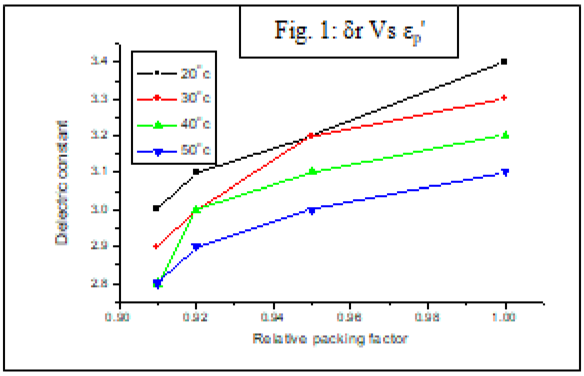
where, ω = 9.85 GHz angular frequency and; ε_o is permittivity of free space.

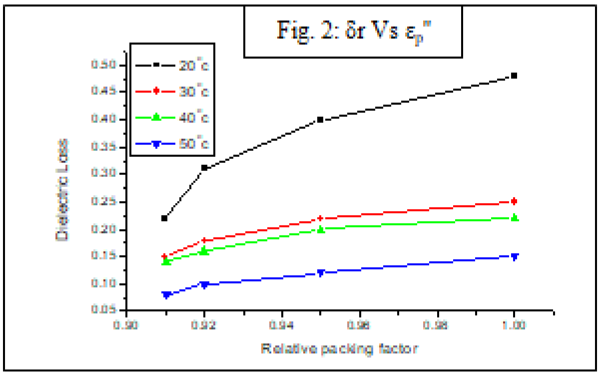
These ε' and ε" for bulk materials can be co-related for powder by using relations given by Botcher and L-L-L [9, 10, 11, 12, 13].

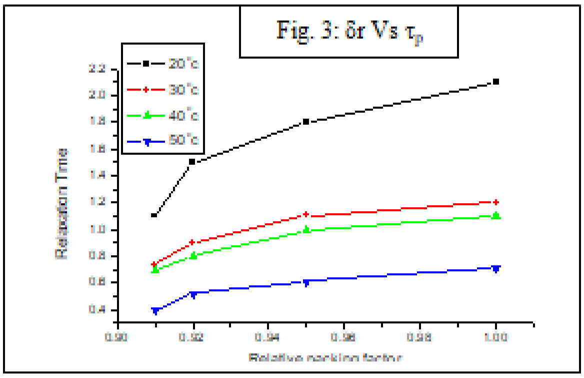
4. Result and Discussion

Table 1: Values of dielectric and thermodynamic parameter of pigeon pea at temperature 20°c to 50°c and at different δr

Temp. (°c)	δr	ε_p'	ε_p''	τ_p (P.S.)	σ_p (10^{-2})	ΔF kcal/m	ΔH kcal/m	ΔS cal/k/m
20 °c	0.91	3.0	0.22	1.1	13.0	1.0	5.6	15.5
	092	3.1	0.31	1.5	18.1	1.3	6.0	16.2
	0.95	3.2	0.40	1.8	23.3	1.4	6.2	16.5
	1.00	3.4	0.48	2.1	28.3	1.5	6.2	16.3
30 °c	0.91	2.9	0.15	0.73	8.6	0.92	5.6	15.6
	0.92	3.0	0.18	0.90	10.8	1.00	6.0	16.4
	0.95	3.2	0.22	1.10	12.9	1.11	6.2	169
	1.00	3.3	0.25	1.20	15.1	1.20	6.2	16.6
40 °c	0.91	2.8	0.14	0.70	8.1	0.94	5.6	15.0
	0.92	3.0	0.16	0.80	9.8	1.04	6.0	160
	0.95	3.1	0.20	0.99	11.4	1.115	6.2	16.2
	1.00	3.2	0.22	1.10	13.1	1.19	6.2	16.1
50 °c	0.91	2.8	0.08	0.40	4.5	0.63	5.6	15.5
	0.92	2.9	0.10	0.52	5.9	0.80	6.0	16.2
	0.95	3.0	0.12	0.61	7.3	0.90	6.2	16.5
	1.00	3.1	0.15	0.71	8.7	1.00	6.2	16.2







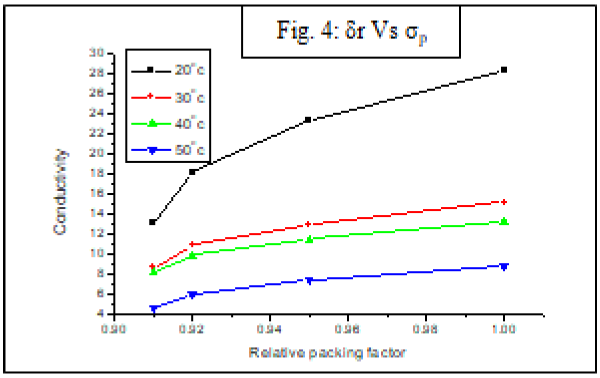
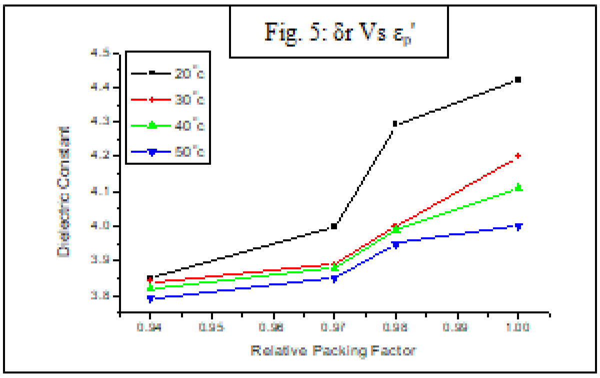


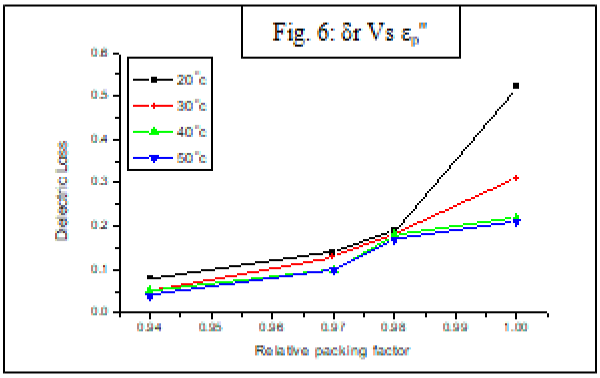
Figure 1, 2, 3, 4 are of the pigeon pea sample

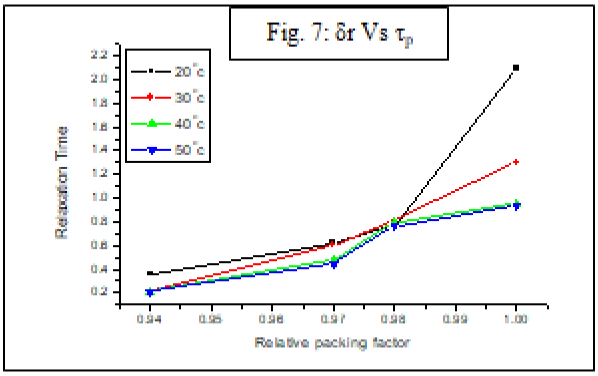
Table 2: Values of dielectric and thermodynamic parameter of chick pea at various temperature and packing fraction

Temp. (°c)	δr	ε_p'	ε_p''	τ_p (P.S.)	σ_p (10^{-2})	ΔF kcal/m	ΔH kcal/m	ΔS cal/k/m
20 °c	0.94	3.85	0.08	0.36	3.92	0.46	4.50	13.78
	097	4.00	0.14	0.62	6.97	0.77	1.41	2.19
	0.98	4.29	0.19	0.77	9.23	0.90	0.98	0.31
	1.00	4.42	0.52	2.10	25.92	1.50	7.60	20.90
30 °c	0.94	3.84	0.05	0.22	2.37	0.19	4.50	14.20
	0.97	3.89	0.13	0.60	6.47	0.79	1.41	2.58
	0.98	4.00	0.18	0.81	9.06	0.98	0.98	0.03
	1.00	4.20	0.31	1.30	15.34	1.26	7.60	20.90

40 °c	0.94	3.82	0.05	0.21	2.23	0.19	4.50	13.70
	0.97	3.88	0.10	0.48	5.19	0.70	1.41	2.27
	0.98	3.99	0.18	0.80	8.93	1.02	0.98	-0.12
	1.00	4.11	0.22	0.95	10.99	1.13	7.60	20.70
50 °c	0.94	3.79	0.04	0.21	2.22	0.22	4.50	13.30
	0.97	3.85	0.10	0.45	4.84	0.31	1.41	3.43
	0.98	3.95	0.17	0.76	8.49	1.05	0.98	-0.19
	1.00	4.00	0.21	0.94	10.57	1.18	7.60	19.90







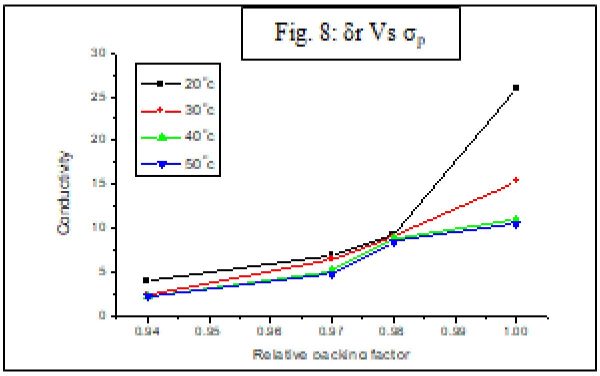


Figure 5, 6, 7, 8 are of the Chick pea sample

Table 3: Measured and calculated values of ε' and ε" of pigeon (P) and chick (C) peas at 20°c to 50°c temperature

Temp. (°c)	ε_s'						ε_s''					
	Measured		Bottcher's formula		L-L-L formula		Measured		Bottcher's formula		L-L-L formula	
	P	C	P	C	P	C	P	C	P	C	P	C
20 °c	3.41	4.41	3.36	4.37	3.4	4.41	0.48	0.52	0.47	0.51	0.47	0.512
30 °c	3.26	4.20	3.24	4.18	3.264	4.21	0.25	0.30	0.25	0.30	0.25	0.30
40 °c	3.15	4.11	3.14	3.95	3.15	4.10	0.22	0.20	0.22	0.21	0.22	0.20
50 °c	3.05	3.99	3.04	3.98	3.05	3.99	0.15	0.21	0.15	0.22	0.15	0.212

Form table 1 and table 2 it is clear that by increasing temperature for 20°c to 50°c, there is a decrease in ε', ε", τ_p and σ_p because -

1) According to Debye, when polar molecules are very large then under the influence of electromagnetic field of high frequency, the rotary motion of polar molecules of system is not sufficiently rapid to attain the equilibrium with the field.
2) Decrease in τ due to increase in effective length of dipole and increases energy loss due to number of collisions.

By increasing the value of δr, the ε', ε", τ and σ also increases – (1) it is due to increasing hindrance to the process of polarization. (2) As mechanical pressure increases, no micro cracks developed in sample and hence at higher compaction the conductivity increases.

5. Conclusion

1) There is fair agreement between the values obtained experimentally and calculated by using Bottcher and Landau-Lifshitz-Looyenga relations.
2) The temperature and size of the product samples influences the dielectric parameters.
3) This work confirms that one can estimate the dielectric values for pulverized materials as a solid bulk.

6. Future Scope

1) The dielectric parameters can be used as an indicator for moisture content in agri-products.
2) The accurate measurement of moisture content in the grain which is important for quality control factors.
3) The permittivity of the agri-product can be calibrated for the measurement of moisture percentage in the sample.

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