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Effect of Frequency and Moisture Variation on Dielectric Properties of Pearl Millet in Powder Form

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Abstract

Values of dielectric constant (ε'), dielectric loss (ε''), relaxation time (τ), conductivity (σ) of Pearl millet (HHB 62) were measured at room temperature at four different frequencies viz 4.65 GHz, 7.00 GHz, 9.35 GHz and 14.98 GHz in microwave region, using two point method and employing a specially designed dielectric cell for powders. Also, effect of variation of moisture content on dielectric properties of Pearl millet in powder form was studied at room temperature at 9. 35 GHz.. Both, the dielectric constant and loss factor are found to decrease with increase in frequency and to increase with increase in moisture content. The present values of dielectric constant are in good agreement with the values reported by other authors.

Keywords *: Conductivity, Dielectric constant, Dielectric loss, Pearl millet, Relaxation time*

1.INTRODUCTION

Dielectric properties of materials are those electrical characteristics of poorly conducting materials that determine their interaction with electric fields. The two properties of major interest are the dielectric constant and the dielectric loss factor of materials. These properties are important in any processes involving radio-frequency or microwave dielectric heating. They determine how well energy can be absorbed from the high-frequency alternating electric fields and thus how rapidly the materials will be heated. Since dielectric properties of materials are highly correlated with the amount of water in materials, sensing the dielectric properties can be used for rapid measurement of moisture content in materials such as agricultural products and food materials.

Pearl millet (Pennisetum glaucum) is the most widely grown type of millet. It survives in soils with high salinity, low soil fertility and drought. India continues to be the single largest producer of perl millet in the world. It is high inprotein as compared to other cereals .Bajra helps maintain cardiovascular health and helps reduce acidity problems.

Many factors, including frequency, temperature and moisture content, influence the dielectric properties of agroproducts and food Materials. (Venkatesh & Raghvan, 2004). Knowledge of the relationship between frequency and dielectric properties is helpful in determining the optimum frequency range in which the material in question has the desired dielectric characteristics for intended applications (Nelson, 2005). The moisture-dependent dielectric properties in specific frequency ranges can be used to develop online moisture meters (Nelson *et al*, 1992), which may be applied not only in drying processes but also in other unit operations in the food industry. Several investigations on dielectric properties of agricultural products have been reported. Dielectric properties of chickpea flour in compressed form

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were determined by Guo et al (2008) and it wasobserved that dielectric constant and loss factor of the sample decreased with increase in frequency frequency at all temperatures and moisture levels . Recently, dielectric constant and loss factor of Raj-4120 variety of Indian wheat have been determined by Sharma et al., (2010), in powder form of grain size 125 to 150 microns at room temperature by employing the technique proposed by Yadav and Gandhi (1991) at three different frequencies lying in C-band, X-band and Ku-band .

The purpose of this research was to study effect of frequency variation and moisture content variation on dielectric properties of pearl millet in powder form at room temperature.

2. MATERIALS & METHODS

Pearl millet of variety HHB 62 used for the present study were obtained from Durgapura Agriculture Research Station of Rajasthan Agriculture University, Bikaner. It is difficult to measure the dielectric properties of the whole grains because of their irregular shape. The measurement errors are reduced by using a grinded sample of these grains (Nelson, 1992).These grains were grinded and converted into flour. Samples of grain size 250 -300 microns were prepared using sieves of mesh size 300 microns and 250 microns respectively.

To obtain the samples of different moisture contents, pearl millets were first ground and kept over distilled water in covered dessicators at room temperature. The flours were stirred to ensure that the moisture absorbtion is uniform. After keeping the flour in dessicator for a few days for desired moisture content, they were sealed in plastic bags and equilibrated at room temperature. The moisture content was measured using moisture analyzer

Two point method (Behari, 2005) used in the present study is a technique involving measurement of reflection coefficient of a solid material placed in a wave guide, backed by a short circuiting conducting plate. In order to use this method for powders, the wave guide is bent through90° by means of a E-plane bend and terminated by a dielectric cell in which powder sample is filled up. This method is suitable for low and medium loss dielectrics and can be adopted for measurement of dielectric properties of food stuff in powder form. In this method, the set-up for measurement of dielectric properties of powders is shown in Fig. 1. Let for an empty short-circuited wave guide dielectric cell , a voltage minimum is obtained with the probe located at position D_R in the slotted section. The same waveguide dielectric cell containing the sample (powder of pearl millet in the present case) of length lε will have the probe located in the slotted section at a new position, say D, for a voltage minima in this case.

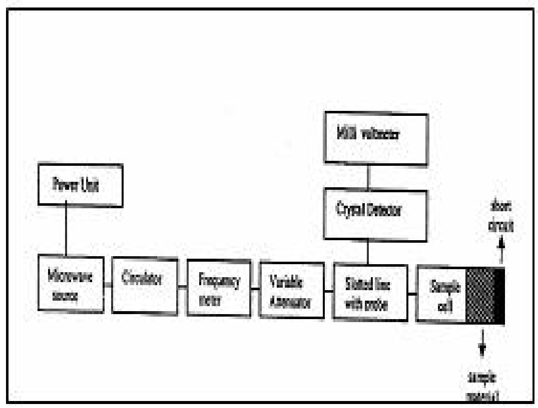

Fig. 1: Experimental setup for determination of dielectric properties by two point method

Then, from impedance matching at the air –powder boundary, we obtain

$$\frac{\tan\beta(D_R - D + l_\epsilon)}{\beta l_\epsilon} = \frac{\tan\beta_\epsilon l_\epsilon}{\beta_\epsilon l_\epsilon} \qquad (1)$$

Where the phase factor β = (2π / λg), λg being the guide wavelength for the waveguide containing air .

The phase factor β_ε for the waveguide filled with the dielectric is given by

$$\beta_\varepsilon = (2\pi / \lambda_0) \{ \varepsilon_r \mu_r - (\lambda_0 / \lambda c)^2\}^{1/2} \quad (2)$$

Here λ_0 represents free space wavelength, λ_c is the cut off wavelength of the waveguide and for the non-magnetic materials μ_r =1. The phase difference φ in the waves travelling in the guide with and without dielectric material in the cell is given by

$$\varphi = 2\, \beta\, (\text{“}\, x - l\varepsilon) \quad (3)$$

where “ x is the shift in minimum.

Voltage standing wave ratio(S) is determined for the load (food powder in this case) and then magnitude of the reflection coefficient (%Ã%) is computed by employing the relation.

$$|\Gamma| = \frac{(S -}{(S+1)} \quad (4)$$

In the two point method, the complex dielectric constant is given by

$$C\angle -\psi = \frac{1}{j\beta l_\in} \frac{1-|\Gamma| e^{j\varphi}}{1+|\Gamma| e^{j\varphi}} = \frac{\tan X\angle\theta}{X\angle\theta} \quad (5)$$

where C and Ψ represent respectively the magnitude and phase of the complex quantity in the middle of Eq. (5) and $X \angle \theta$ represents the solution of this transcendental equation . This equation provides several solutions for Xθ, which can be found by employing graphs and tables provided for solution of such equations by Hippel [1953] or alternatively the problem can be solved by using a computer based mathematical tool like MATLAB/ Mathematica.

The admittance (Y_ε) of the material of the sample is given by

$$Y_\in = \left(\frac{X}{\beta l_\in}\right)^2 \angle 2(\theta - 90°) = G_\in + jS_\in \quad (6)$$

where G_ε and S_ε are respectively the conductance and susceptance of the sample. The values of G_ε and S_ε are obtained by separating Eq. (6) into real and imaginary parts, which providethe values of ε' and ε'' in the following form:

$$\in' = \frac{G_\in + (\lambda_g / 2a)^2}{1 + (\lambda_g / 2a)^2} \quad (7)$$

$$\in'' = \frac{-S_\in}{1 + (\lambda_g / 2a)^2} \quad (8)$$

In the present study ,a computer program in MATLAB was written to solve the transcendental equation and obtain the values of dielectric constant (ε') and loss factor (ε''). The conductivity (σ) and relaxation time (τ) were obtained by using the following relations.

$$\sigma = \omega\, \varepsilon_0 \varepsilon'' \quad (9)$$

$$\tau = (\varepsilon'' / \omega\varepsilon') \quad (10)$$

Where,
$\omega = 2\pi \times 9.35$ GHz
$\varepsilon_o = 8.85 \times 10^{-12}$ F/m .

3. RESULTS AND DISCUSSION

The values of the dielectric constant and loss factor for pearl millet are reported in Table 1 for grain size 250-300 micrometers at four different frequencies in frequency bands C, J , X and Ku in the microwave region. From the table we observe that both the values of dielectric constant and loss factor decrease with increase in frequency.

Table 1. Dielectric values of pearl millet in powder form for grain size 250 – 300 micrometers

Band	Frequency (G Hz)	ε'	ε''	τ (ps)	Σ
C	4.65	4.31	0.65	2.60	0.3367
J	7.00	4.03	0.58	2.50	0.3004
X	9.35	3.03	0.41	2.30	0.2124
Ku	14.98	2.48	0.03	0.20	0.0155

The dependence of ε' on frequency is shown in Fig. 2, which shows that variation of ε' is almost linear with negative slope. This isindicative of the fact that as frequency is increased ,the capacity of the material to store energy decreases. An important phenomenon contributing to the frequency dependence of the dielectric properties is the polarization of molecules arising from the orientation with the imposed electric field, which have permanent dipole moments. Water is the major absorber of microwave energy in the foods .When the frequency is increased, water molecules are not able to keep up with the changes of the direction of the electric field, because of their inertia that is described by relaxation time τ . This is the possible reason for a decrease in the electric field energy storage and hence the value of dielectric constant decreases. Variation of ε'' with frequency is shown in Fig. 3.

The value of conductivity is found to decrease with increase in frequency showing that polarization in the powder decreases at high frequencies.The relaxation time is also found to decrease with increase in frequency ,being lowest in K_u band. This is apparent from low value of ε'' at this frequency showing that polarization is less prominent as compared to other frequencies and therefore system takes minimum time to return to equilibrium state after the fields are removed.

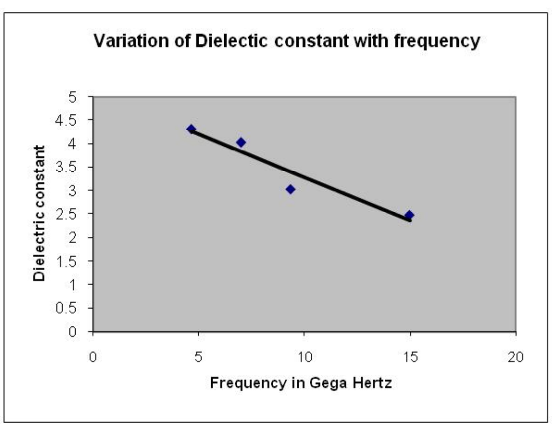

Fig. 2: Variation of dielectric constant with frequency for pearl millet

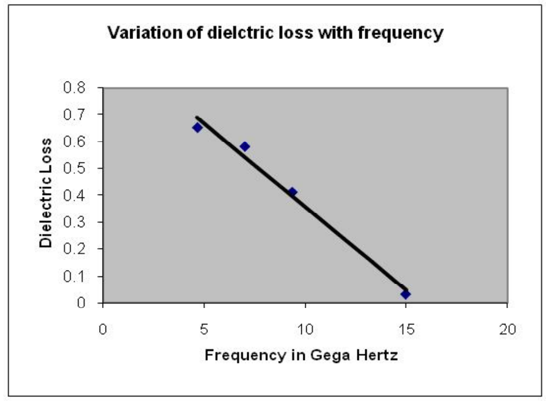

Fig. 3: Variation of dielectric loss with frequency for pearl millet

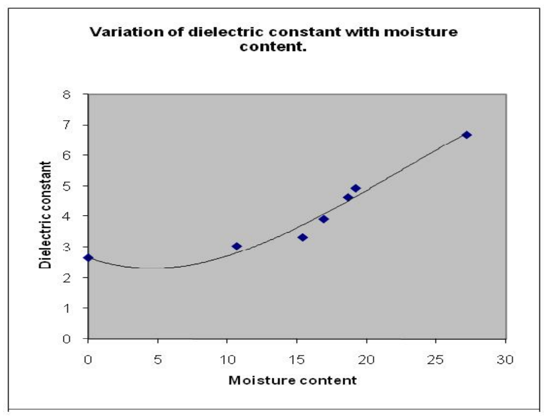

Fig. 4: Variation of dielectric constant with moisture content for pearl millet.

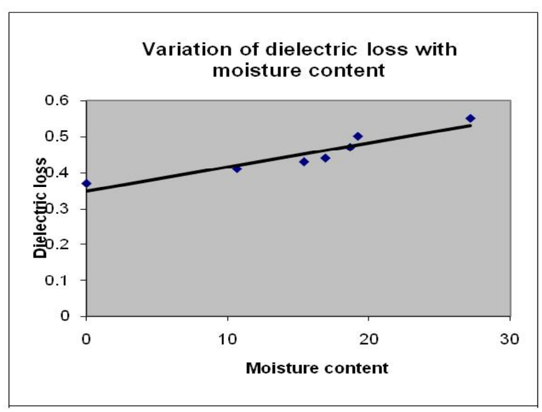

Fig. 5: Variation of dielectric loss with moisture content for pearl millet

Table II gives the values of dielectric constant and dielectric loss factor for different moisture contents. The presence of free moisture in a substance greatly affects its dielectric properties since the dielectric constant of free water is quite high (78 at room temperature and 2.45 GHz). The moisture relationship is consistent in that higher moisture leads to higher values of both the dielectric constant and the loss factor. In general, higher moisture content results in higher dielectric constant and loss factor of the food (Komarov et al., 2005). This is clear from Fig.4 & 5 respectively.

Table 2. Dielectric values for pearl millet in powder form for different moisture contents

S.No.	Moisture Content(%)	ε'	ε''
1	0	2.65	0.37
2	10.66	3.03	0.41
3	15.39	3.32	0.43
4	16.9	3.91	0.44
5	18.65	4.64	0.47
6	19.2	4.93	0.5
7	27.16	6.68	0.55

REFERENCES

Behari, J., Microwave Dielectric Behaviour of Wet Soil , *Springer*. 43, (2005).

Guo, W., Tiwari, G., Tang J. and Wang, S., Frequency, Moisture and Temperature-Dependent Dielectric Properties of Chickpea flour, "*Biosystems Engineering*", 101, 217-224, (2008).

Hippel, A. R.V., *Hippel*, *Dielectric* Materials and Applications, *The Technology Press of M.I.T. and John Wiley and Sons, Inc.,. New York*, (*1954)*.

Komarov, V., Wang, S., Tang, J., Permittivity and Measurement. In: Chang, K.(Ed.), The Wiley Encyclopedia of RF and Microwave Engineering, vol. 4. *John Wiley Sons, Inc*., New York, 3693–3711 (2005).

Nelson, S. O., Measurement and Applications of Dielectric Properties of Agricultural Products, *IEEE Trans. Instrum. Measur.*, 41, 116, (1992).

Nelson, S.O., Kraszewski, A.W., Kandala, C.V.K., and Lawrence, K.C., High-frequency and Microwave Single-Kernel Moisture Sensors, "*Trans. ASAE*", 35 (4), 1309–1314, (1992).

Nelson, S.O., Dielectric spectroscopy in agriculture, "*J. Non. Cryst. Solids*", 351, 33-36, 2940–2944, (2005).

Sharma, K., Jain, R., Bhargava, N., Sharma, R., and Sharma, K.S., Dielectric Studies of Wheat in Powder form at Microwave Frequencies, "*Indian J. Exp. Biol.*", 48 (10), 1002-7, (2010).

Venkatesh, M.S. and Raghavan, G.S.V., An overview of microwave processing and dielectric properties of Agri-food materials "*Biosystems Engineering*", 88(1), 1-18, (2004).

Yadav, J.S. and Gandhi, J.M., Simple Microwave Technique for Measuring the Dielectric Parameters of Solids and their Powders, *Indian J. Pure App. Phy*., 30 ,427 -431, (1992).