ISSN:2319-2607 IISUniv.J.Sc.Tech. Vol.2(1),84-88 (2013)

RESEARCH ARTICLE

Dependence of Dielectric Properties of Wheat Powder on its Grain Size and Density at Microwave Frequency

[1]Nidhi Bhargava*, [1]Ritu Jain, [2]Ila Joshi, [1]K.S. Sharma

[1]Department of Physics

[2]Department of Home Science

The IIS University, Gurukul Marg, SFS, Mansarovar, Jaipur-302020 INDIA

Abstract

A simplified method is proposed for determination of dielectric properties of the food grains in powder form by employing a specially designed dielectric cell and using two point method. Dielectric constant(ε′) and loss factor(ε″) of five different varieties of Indian wheat in powder form have been determined and their dependence on the density of powder, applied pressure and grain size has been investigated. It is observed that both dielectric constant(ε′) and loss factor (ε″) increase with density and increase in grain size.

Keywords

Density, Dielectric constant, Grain size, Indian wheat, Loss factor

Introduction

The dielectric properties of agricultural materials and food products have been of primary importance in predicting heating rates and describing the behavior of food materials when subjected to high-frequency radiation. Microwaves are often used in thermal treatment of agriculture food materials due to the high rates of energy transfer and efficiency compared to conventional technologies. The dielectric properties of food grains and seeds are used in many applications, such as moisture content estimation, protection of stored grains from insects, dielectric heating, sorting, cleaning etc (Nelson,1977). So, for the development of microwave process control, it is important to know dielectric properties of the materials.

Wheat is the major food component of most of the people worldwide, as it is rich in carbohydrates and in dietary proteins, being only next to the pulses in protein contents. India is one of the principal wheat producing and consuming countries in the world. Wheat products are used to prepare different food items, like breads, biscuits, cookies, cakes, breakfast-cereal, pasta, noodles etc.

In view of the above mentioned applications of wheat in our diet, its dielectric properties are very important. A little information on the dielectric properties of wheat, cultivated in India, is available in literature. Therefore, it was considered desirable to study the dielectric properties of wheat cultivated in India. The present paper reports dielectric properties of five varieties of wheat at room temperature (32°C) and frequency 9.34 GHz.,

Various factors influence the dielectric properties of the food materials such as frequency of the applied electric field, temperature, moisture content, bulk density, ionic nature, density, structure and constituents of food materials.(Jha *et al,*2011)The first quantitative data on the dielectric properties of food grains were reported by Nelson et al in 1953 for barley in the frequency range 1 to 50 MHz (Nelson *et al,*1953). Trabelsi and Nelson (2006) studied dependence of dielectric properties of wheat, soybeans and corn on their bulk densities and found that both the dielectric constant and loss factor vary appreciably with the bulk density of these species. Dielectric properties of chickpea flour in compressed form were determined by Guo *et al,*2008 and it was observed that dielectric constant and loss factor of the sample decreased with increase in frequency at all temperatures and moisture levels. Guo *et al,* 2010 measured dielectric properties of flour samples from four legumes (chickpea, green pea, lentil and soybean) at four different moisture contents, frequency ranging from 10 to 1800 MHz and temperatures 20 to 90 °C by using open ended coaxial probe method. 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 (1992) at three different frequencies lying in C-band, X-band and Ku-band.

*Corresponding Author : Email : nidhi.bhargava@iisuniv.ac.in

However, the Yadav Gandhi method proposed for powders was not found to be suitable for the powders of food grains, as the dielectric cell is required to be opened each time for adding the wheat powder till the required setting is obtained with powder heights h_1 and h_2 giving equal displacement of minima on the two sides of the minima with empty cell. As such, the need for trying a new method for the powders of food grains was realized. Therefore, it was decided to apply two point method by using a specially designed dielectric cell.

Materials and Method

Grains of four different varieties of farm type wheat (viz LOK 1, UP 2382, RAJ 3765, RAJ 2384) required for the present studies were obtained from Durgapura Agriculture Research Station of Rajasthan Agriculture University, Bikaner and one sample of local variety of fresh crop (Sharbati) was included in the study for the sake of variety of samples .

Sample Preparation

It is difficult to measure the dielectric properties of the whole grains of wheat because of the irregular shape of the grains. The measurement errors are reduced by using a grinded sample of seeds (Nelson *et al* 1991).To determine dielectric properties of food grains accurately, powder of food grains or flour is therefore taken. Sample of particular grain size is then obtained with the help of sieves. Known weights of grinded flour is placed in the cell with the cross sectional area 1.00 cm x 2.28 cm and depth of 4.50 cms.

In the present study, samples of four farm varieties of wheat viz LOK 1, UP 2382, RAJ 3765, RAJ 2384 and one sample of local variety of fresh crop were prepared by grinding and sieving the same, employing sieves of different hole sizes. For every variety samples of three different grain sizes (viz; 90 to 150 microns, 250 to 300 microns and 355 to 425 microns) were prepared for the study of dielectric properties.

Dielectric Cell

For the present study, a dielectric cell was fabricated by closing an X- band wave guide piece of about 5 cm depth at one end by a short circuiting metallic plate and attaching wave guide flange at the other end so as to connect it to the slotted section by means of a E-plane bend. The powder of food grains was compressed in the cell by means of a plunger of almost the same cross section as the wave guide, using a hydraulic press.

Two point method (Sucher and Fox, 1963; 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 waveguide is bent through 90° 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.The error estimated by this method is ± 5 % .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 food grains in the present case) of length l_ε will have the probe located in the slotted section at a new position D for a voltage minima in this case.

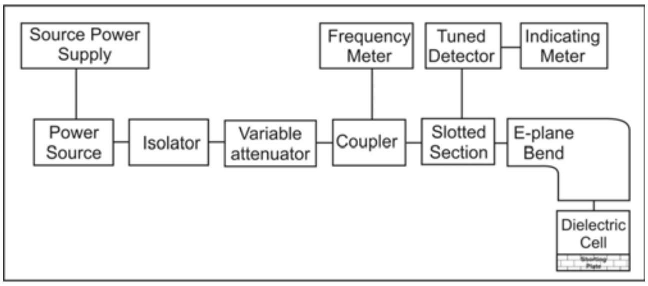


Fig.1. Experimental setup for determination of dielectric properties of powders by two point method.

The transcendental equation obtained by impedance matching can be written as

$$\frac{\tan\beta(D_R - D + l_g)}{\beta l_e} = \frac{\tan\beta_e l_e}{\beta_e l_e} \qquad (1)$$

where the phase factor $\beta = (2\pi/\beta\lambda_g)$, βl_g being the guide wavelength for the waveguide containing air ; and the phase factor β_e for the waveguide filled with the dielectric is given by

$$\beta_e = (2\pi/\lambda_0)\{\varepsilon_r\mu_r - (\lambda_0/\lambda_c)^2\}^{1/2} \qquad (2)$$

Here λ_0 represents free space wavelength, λ_c is the cut off wavelength of the waveguide , ε_r is the relative dielectric constant and for the non-magnetic materials μ_r=1.

The phase difference φ in the waves traveling in the guide with and without dielectric material in the cell is given by

$$\varphi = 2\beta(\Delta x - l_g) \qquad (3)$$

where Δx is the shift in minimum.

Voltage standing wave ratio is determined for the load (food powder in this case) and then magnitude of the reflection coefficient (| Γ |) is computed by employing the relation:

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

where S is the VSWR for the sample in the waveguide.

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

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

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 $X\angle\theta$, which can be found by employing graphs and tables provided for solution of such equations by Hippel (1954) or alternatively the problem can be solved by using a computer based mathematical tool like MATLAB/ Mathematica. The experiment is performed for two different heights of powder sample and the common root obtained from solutions for the two cases, is used for evaluation of the admittance of the material of the sample. Alternatively, we may perform the experiment for a given height of the sample at two different frequencies to obtain the correct root $X\angle\theta$

The admittance (Y_{ε}) of the material of the sample is given by

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

where G_{ε} and S_{ε} are the conductance and susceptance of the sample respectively .

The values of G_{ε} and S_{ε} are obtained by separating Eq. (6) in to real and imaginary parts, which provide the values of ε′ and ε′′ in the following form:

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

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

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′′).

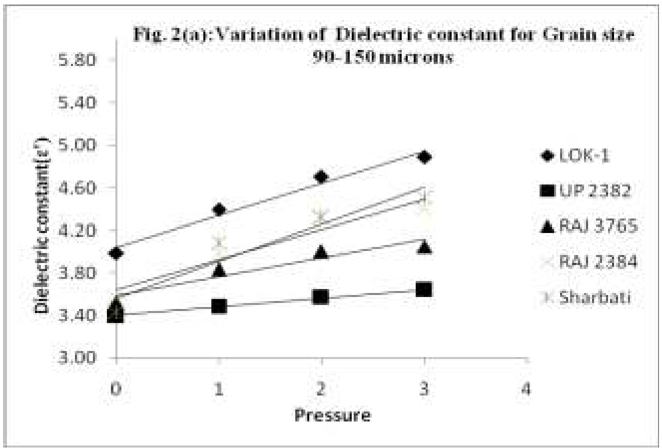
Results and Discussion

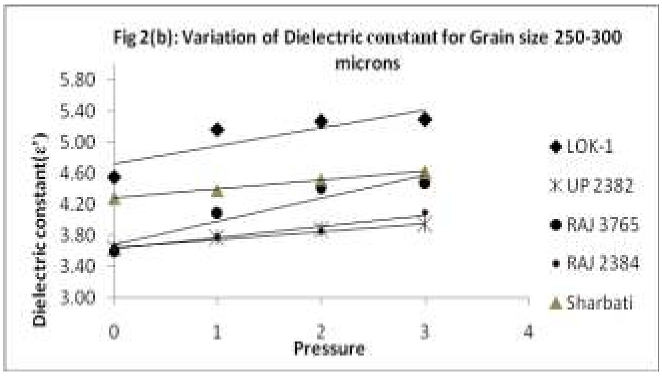
The Dielectric properties of four varieties of farm wheat (LOK 1, UP 2382, RAJ 3765, RAJ 2384) and one sample of local variety (Sharbati) of fresh crop of wheat, as determined at room temperature by employing a specially designed dielectric cell and two point method for three grain sizes, viz., 90 to 150 microns, 250 to 300 microns and 355 to 425 microns are displayed in Table 1. It may be observed from the table that both the dielectric constant(ε′) and loss factor(ε″) depend on the density of the wheat flour for all the five samples, increasing with increase in density. The effect of grain size is also clearly visible from the table, the general trend is that both ε′ and ε″ increase with increase in grain size ,the only exception being in case of RAJ 2384 where ε′ is found to decrease for grain size 250-300μm as compared to 90-150 μm on applying pressure. However, to conclude any underlying

Table 1. Variation of ε′ and ε′′ for different varieties of wheat with applied pressure (in units of 4.298x10[4] kg/m[2] for grain size (a) 90-150 μm (b) 250-300 μm (c) 355-425 μm

Grain size (microns)	Pressure (in units of 4.298 x 10^4 kg/m^2)	LOK-1			UP 2382			RAJ 3765			RAJ 2384			Sharbati (local variety)		
		ε'	ε''	Density	ε'	ε''	Density	ε'	ε''	Density	ε'	ε''	Density	ε'	ε''	Density
355-425	0	4.9560	0.1487	0.6798	3.6681	0.1865	0.6503	3.6022	0.1990	0.6312	4.6290	0.1586	0.6112	4.7427	0.1618	0.6315
	1	5.1693	0.1597	0.7126	3.7191	0.2115	0.7742	3.8498	0.2011	0.6507	4.6600	0.1868	0.6275	4.9550	0.1710	0.7193
	2	5.2861	0.1626	0.7294	3.7754	0.2244	0.8049	3.9213	0.2029	0.6575	4.7761	0.2068	0.6340	5.2865	0.1890	0.7646
	3	5.3206	0.1680	0.7326	3.8442	0.2534	0.8424	4.0000	0.2049	0.6644	4.8987	0.2188	0.6471	5.3350	0.2016	0.8035
250-300	0	4.5544	0.1548	0.6073	3.6262	0.1797	0.5698	3.5829	0.1536	0.5730	3.6575	0.1518	0.5805	4.2806	0.1580	0.5912
	1	5.1673	0.1608	0.6353	3.7622	0.1855	0.5899	4.0797	0.1636	0.5870	3.7692	0.1625	0.5984	4.3801	0.1696	0.6497
	2	5.2706	0.1641	0.6489	3.8630	0.1960	0.6061	4.4011	0.1737	0.6018	3.8552	0.1702	0.6150	4.5247	0.1760	0.7123
	3	5.2925	0.1644	0.6516	3.9326	0.2058	0.6180	4.4654	0.1848	0.6056	3.9008	0.1878	0.6229	4.6159	0.1895	0.7390
90-150	0	3.9877	0.1027	0.5810	3.3991	0.1453	0.4652	3.5167	0.1079	0.5231	3.5749	0.1498	0.5075	3.4323	0.1411	0.5473
	1	4.3930	0.1227	0.6603	3.4808	0.1505	0.5539	3.8365	0.1247	0.5864	3.9835	0.1517	0.5614	4.0878	0.1741	0.5898
	2	4.7067	0.1356	0.7174	3.5691	0.1637	0.5758	4.0064	0.1315	0.6396	4.3147	0.1667	0.6220	4.3253	0.1791	0.6081
	3	4.8902	0.1441	0.7450	3.6410	0.1714	0.6623	4.0516	0.1357	0.6490	4.4080	0.1788	0.6344	4.5123	0.1916	0.6220

phenomenon from such an anomaly an effective comparison at equal densities is required. In the absence of such a data it may be taken due to some random error in observations. It is also apparent from the table that different varieties of wheat have different values of dielectric parameters ε′ and ε″. The value of dielectric constant (ε′) for all the varieties increases with increase in density irrespective of the grain size. This may be due to increase in compaction, resulting in increase in absorption of the radiation when exposed to microwaves. Such observations have also been made by Karhale *et al*, 2012.





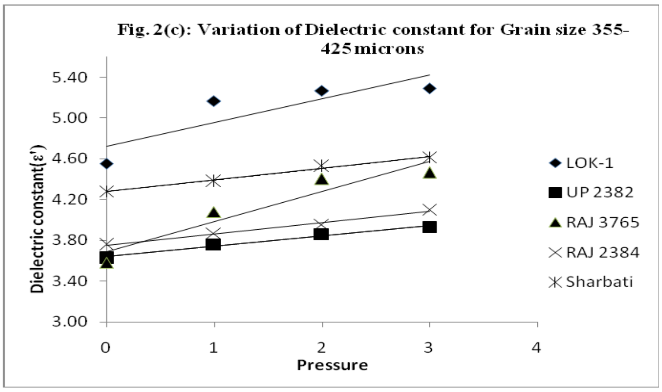
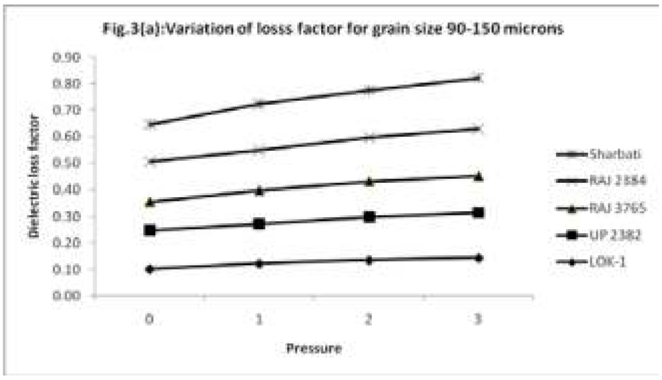
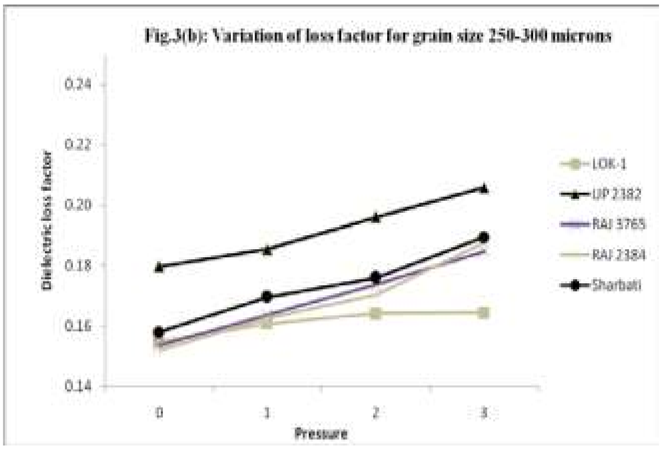


Fig.2. Variation of ε″ for different varieties of wheat with applied pressure (in units of 4.298 x 10^4 kg/m^2 for grain size (a) 90-150 μm (b) 250-300 μm(c)355-425 μm

The loss factor (ε″) is observed to follow a regular trend in the variation with respect to grain size and density, the variation being close to linear but not necessarily linear in all cases. The value of ε″ decreases with the decrease in grain size and increases with increase in the pressure for all the five varieties of wheat. This may be due to the fact that on decreasing the grain size, total surface area of the grains decreases which decreases absorption.





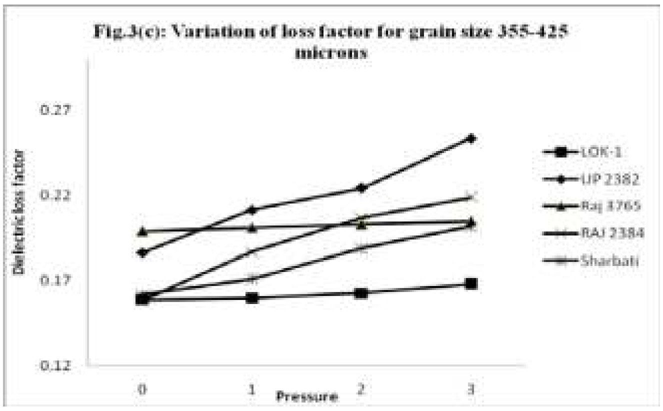


Fig. 3. Variation of ε″ for different varieties of wheat with applied pressure (in units of 4.298 x 10^4 kg/m^2 for grain size (a) 90-150 μm (b) 250-300 m (c)355-425 μm

Variation in ε′ with pressure for all the varieties of wheat considered in the present work has been shown in Fig.2. It may be observed that the variation of ε′ with pressure shows linear regression for all the three grain sizes. The lines shown in figures (a) (b) and (c) of Fig.2 indicate that the value of ε′ is highest for LOK-1 and lowest for UP 2382 variety .The variation of with pressure for the three grain sizes has been shown in Figures 3(a) to 3(c), from where it is apparent that the dependence on pressure is almost linear for grain size 90 – 150 µm. For other grain sizes, the behavior is close to linear but shows deviations, indicating that as the grain size increases, surface area per unit mass of grains decreases causing a decrease in reflection of microwaves, whereas the absorption depending on mass of grains may not change appreciably. This may be the probable cause for irregular behavior of losses.

Conclusion

The simplified method proposed in this work for the determination of Dielectric properties of the food grains in powder form provides values of dielectric parameters with greater ease and increased accuracy. The studies have further potential to involve temperature and frequency dependence of the dielectric parameters and to develop mathematical modeling for the same.

Acknowledgement

KSS and NB are grateful to the UGC for providing necessary financial assistance by sanctioning a major research project to them. The authors are thankful to the Vice chancellor, The IIS University for providing necessary facilities for this work.

References

Behari, J. (2005) Microwave dielectric behavior of wet soil, Springer, 43.

Guo, W., Wang, S., Tiwari,G., Johnson J. A.,Tang,J. (2010) Temperature and moisture dependent dielectric properties of legume flour associated with dielectric heating . *Food science and technology*, **43**:193-201.

Guo,W., Tiwari,G., Tang,J. , Wang,S. (2008), Frequency moisture and temperature dependent dielectric properties of chickpea flour. *Biosystems Engineering* **101**:217-224.

Hippel ,A. R. V.(1954) Dielectric properties and waves, John Wiley, New York.

Jha,S.N., Narsaiah, K., Basadiya ,A.L.,Sharma ,R.,Jaiswal, P.,Kumar, R., Bhardwaj R.(2011) Measurement techniques and application of electrical properties for nondestructive quality evaluation of foods,*J. Food Science Technology*, **48**(4):387-411.

Nelson, S. O.(1977) Use of electrical properties for grain moisture measurement. *Microwave Power* **12**:67-72.

Karhale, G.A., Fugare, M.K., Kalamse, G.M.(2012) Microwave dielectric study of Pearl Millet (Pennisetum typhoides) at 9.85 GHz. *International Multidisciplinary Research Journal* **2**(6):13-17.

Nelson, S.O. (1991) Dielectric properties of agricultural products: Measurements and applications, *IEEE Trans Elect Insul* **26**:845.

Nelson, S. O., Soderholm, L. H. Yung, F. D.(1953) Determining the dielectric properties of grains. *Agric Eng* **34**:608-610.

Sharma, K., Jain, R., Bhargava N., Sharma R., Sharma, K.S.(2010),Dielectric Properties of wheat in powder form at microwave frequencies. *Indian J Exp Biol* **48**(10)**:**1002-7.

Sucher, M ., Fox ,J.(1963) Handbook of microwave measurements, Polytechnic Press of the Polytechnic institute of Broklyn, New York, 504.

Trabelsi,S., Nelson, S.O. (2006) Nondestructive sensing of physical properties of granular materials by microwave permittivity measurement, *IEEE*, *Trans Instrum Measu* **55**:953.

Yadav, J.S., Gandhi, J.M . (1992) Simple microwave technique for measuring the dielectric parameters of solids and their powders. *Indian J Pure App Phy* **30:** 427-431.