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Temperature Dependence of Dielectric Properties of Gluten Free Grains at Microwave Frequency

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Abstract

Yadav and Gandhi Method is proposed for determination of dielectric properties of gluten free grains in powder form by employing a specially designed dielectric cell. Effect of temperature variation has been studied from 30˚C to 80˚C of gluten free grains included finger millet, amaranth and buckwheat at frequency 9.76GHz. It has been observed that both the dielectric constant and dielectric loss increase with increase in temperature.

Keywords: *Dielectric constant, Dielectric loss, Gluten free grains, Microwave*

INTRODUCTION

The permittivity or dielectric properties of food materials play an important role in understanding the behavior of these materials when they are exposed to electromagnetic fields in the process of microwave cooking or in other processes involving radio–frequency (RF) or microwave dielectric heating. Dielectric properties are also important in quality sensing by RF and microwave instruments. Food materials are so complex in their composition and in their dielectric behavior, that it is usually necessary to measure the permittivity under the particular conditions. Dielectric properties of food grains are important as they depend on frequency, temperature and such other properties of food grains, which in turn depend on their biochemical composition, viz., carbohydrates, proteins, fats, vitamins and minerals.

A gluten-free diet is a diet that strictly excludes gluten. Containing more gluten in diet can cause Celiac disease. 6 to 8

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million Indians suffer from it. It is estimated that every 1 out of 100 people suffers from celiac disease. So for treating the patients who are suffering from this disease, gluten free diet is asked to take. Because of increasing numbers of patients of celiac disease, demands for gluten-free products is increasing. The other reason for increasing the demand is increase in non-celiac gluten sensitivity & gluten allergy. So after researching on same, it is focusing on the application of that grains which potentially healthy to gluten-free products.

Dielectric properties can be expressed in terms of permittivity. The permittivity is a complex quantity represented by-

$$\varepsilon^* = \varepsilon' - j\varepsilon''$$

The permittivity of a dielectric material has both real and imaginary expressions where , real part ε' is the dielectric constant (the measure of the ability of the dielectric material to store energy in the electric field), imaginary part ε'' is dielectric loss factor (associated with the energy dissipation i.e., conversion of electrical energy into heat in dielectric material).

Temperature dependence of the dielectric properties of Barley, Chickpea and Mustard seeds at frequencies 4.65 GHz, 7.01 GHz and 9.42 GHz and temperature range 30°C to 80°C were observed by Bhargava et al. They have studied the variations in the dielectric properties of above mentioned samples with different temperatures. Both dielectric constant (ε') and the loss factor (ε'') were found to increase with increase in temperature. Measurements of the dielectric properties of whole grain wheat at moisture content from 12 to 18 % were observed by Shrestha and Baik for the temperature range from 15°C to 75°C.

From the literature survey it is found that the dielectric properties of gluten free food grains have not been reported at microwave frequencies. The purpose of this paper is to describe one technique for determining the temperature dependence of the dielectric properties of food materials and present data obtained for a few different kinds of food materials.

MATERIALS AND METHOD

In gluten free grains finger millet, amaranth and buckwheat used for the present study. The grains were grinded to bring them in powder form. A method proposed by Yadav and Gandhi was used for temperature range 30°C to 80°C in the present work. A liquid dielectric cell is

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used in this method. Jacket is provided to the dielectric cell for giving circulation of water at required temperatures. When the sample powder filled in dielectric cell, hot water circulate around it. A water bath fitted with a digital temperature controller for measurements at different temperatures.



The experimental arrangement is shown in Fig. 1. Microwave power was obtained from a microwave source, viz. Klystron tube. The temperature of the cell was maintained by circulating hot water in the jacket surrounding the cell from a water bath by means of a motor. Then, a small quantity of food grain powder was introduced in the dielectric cell.

The height ‘h’ of the powder in the dielectric cell was determined from the difference of readings on the scale of micrometer screw taken with and without food powder in the cell. The powder was added slowly in the dielectric cell till for a height ‘h’ of the powder in the cell, the position of minima in the slotted section is the same as for the empty cell. For this position,

$$h = \frac{\lambda d}{2} \text{ Or } \quad \lambda_d = 2h \qquad ...(1)$$

The value of λ_d. Was determined by using equation (1). The phase factor in the dielectric (β_d) is then given by $\beta_d = 2\pi / \lambda_d$

In order to calculate the value of attenuation constant in the dielectric (α), the plunger was kept at the bottom of the empty cell and the probe was located at one of the maximas, i.e., at the position of a voltage antinode in the waveguide slotted section, and reading ‘ x1’ of the indicating meter was noted. The food powder (flour of the food grains in the present case) was then added slowly in the dielectric cell and position of the maxima in the slotted section was noted every time.

The height of the powder column in the dielectric cell (h') was accurately adjusted so that the probe position locating the maxima in the slotted section was again the same as with the empty cell. The deflection ‘x2’ of the indicating meter in this state, for such height ‘h' of the powder column, was noted.. The value of the attenuation constant in the dielectric (αd) is then given by

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$$\alpha_d = \frac{2.303}{2h'} \log \frac{\sqrt{x_1}}{2\sqrt{x_2} - \sqrt{x_1}} \quad ...(2)$$

On using the measured values of αd and βd ,the values of ε' and ε" of food grain powder were calculated by the following equations

$$\varepsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \left[1 - \left(\frac{\alpha_d}{\beta_d}\right)^2\right] \quad ...(3)$$

$$\varepsilon'' = 2\left(\frac{\lambda_0}{\lambda_d}\right)^2 \left(\frac{\alpha_d}{\beta_d}\right) \quad ...(4)$$

where λo represents the wavelength of electromagnetic waves in free space and λc is the cutoff wavelength given by λc = 2a, where a is the width of the waveguide.

The values of λd and αd for this powder samples were determined by following the procedure as described above, which when used in equations (3) and (4) for determination of dielectric properties at different temperature.

RESULTS AND DISCUSSION

Results of permittivity measurements for samples are presented in Table 1 as examples of the data obtained on different types of food materials. Values for the dielectric constant and loss factor of the Gluten free grains are shown. The variation of ε' and ε" with temperature shown in Fig. 1-2. . It has been observed that both the dielectric constant and dielectric loss increase with increase in temperature.

Sahin and Sumnu4 stated that free and bound water and the ionic conductivity affect the rate of change of dielectric constant and loss with temperature. If bound water is present, the increase in temperature leads to increase in the values of the dielectric parameters. But in the presence of free water, the increase of temperature causes a decrease in the values of the dielectric properties (ε' and ε"). Since food grain powder is taken in dry form, it contains the moisture in bound form; hence it is found that the dielectric properties increase with increase in temperature. Water molecules that are chemically bound have less influence on the dielectric properties of food powder than free water molecules, since free water molecules can rotate freely when an electric field is applied, while bound water molecules cannot7.

As temperature increases, the molecular mobility increases and relaxation frequency which is strongly related to the molecular mobility decreases8. Hence, the values of ε' and ε" both increase as the temperature is increased.

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Table 1 Values of dielectric constant and dielectric loss of gluten free grains at 9.76 GHz frequency

Temperature (°C)	Finger millet		Amaranth		Buckwheat	
	ε'	ε''	ε'	ε''	ε'	ε''
30	2.12	0.13	2.50	0.19	2.38	0.18
40	2.24	0.18	2.68	0.21	2.45	0.21
50	2.42	0.23	2.82	0.32	2.56	0.25
60	2.58	0.29	2.99	0.38	2.60	0.26
70	2.84	0.40	3.09	0.43	2.81	0.31
80	2.98	0.54	3.15	0.51	2.85	0.34

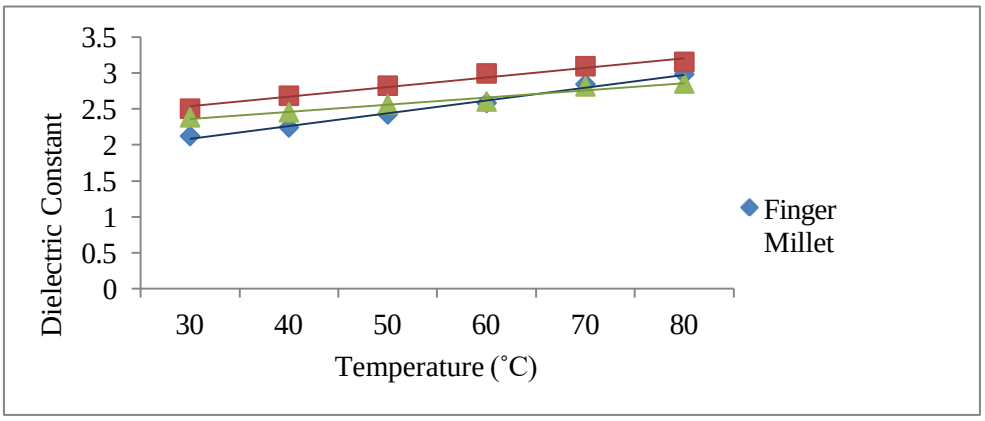


Figure:-1 Temperature dependent dielectric constant of finger millet, amaranth and buckwheat at 9.76 GHz frequency

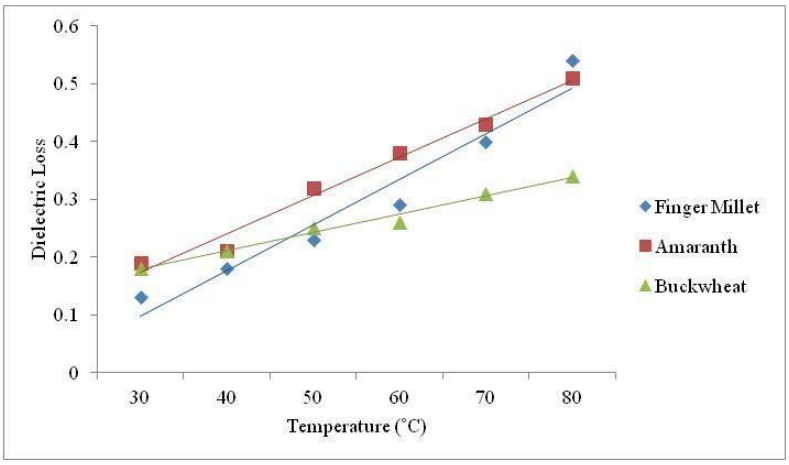


Figure:- 2 Temperature dependent dielectric loss of finger millet, amaranth and buckwheat at 9.76 GHz frequency

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CONCLUSION

It can be concluded that the dielectric properties of finger millet, amaranth and buckwheat vary with the change in temperature. The change in dielectric constant (ε') with temperature is small since the moisture content in these grains is quite low. It can be inferred that both dielectric constant (ε') and dielectric loss factor (ε'') increase with increase in temperature for gluten free grains. The knowledge of temperature dependence of dielectric properties helps in design of microwave processes and control and also in material characterization.

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