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DIELECTRIC PROPERTIES OF CEREALS AT MICROWAVE FREQUENCY AND THEIR BIO CHEMICAL ESTIMATION

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Abstract: Dielectric properties of a material are intrinsic electrical properties that describe its polarization status when subjected to an electric field. At microwave frequencies, this polarization is orientational resulting from rotation of free water molecule in presence of electric field or reorientation of bound water molecules in association with the food molecules. The dielectric properties are represented by dielectric constant and dielectric loss factor. They affect the degree of coupling of microwave energy with the food particles, energy absorbed and heat produced. These depend upon the composition of material and are affected by the presence of free water, bound water, surface charges, electrolytes, non electrolytes and hydrogen bonding in the food products. In order to establish a correlation between nutrient composition and dielectric properties, studies were made on three different food grains viz barley, pearl millet and sorghum. Dielectric properties at microwave frequency (9.32 GHz) were determined in powder form using two point method and nutrients (viz. carbohydrate, protein, fat and moisture) of these grains were determined using standard biochemical methods.

INTRODUCTION

Dielectric properties of materials are those electrical characteristics of poorly conducting materials that determine their interaction with electric fields. These are the main parameters that provide information about how materials interact with electromagnetic energy. During heating by microwaves or high frequency electromagnetic radiations, many variables in food affect the heating performance. The most significant variable is the permittivity of the food, which describes how a material interacts with electromagnetic radiation. Dielectric properties can be expressed in terms of permittivity. The permittivity is a complex quantity represented by

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

where ε' is the dielectric constant, ε'' is dielectric loss factor.

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ε' is the measure of the ability of the dielectric material to store energy in the electric field. ε'' is associated with the energy dissipation i.e., conversion of electrical energy into heat in dielectric material [1].

Cereals are plants belonging to the 'grasses family' which are cultivated for their edible grains. In most countries, cereal grains are grown in big quantities as staple food. When the entire grain is used (whole grain), most cereals are rich in vitamins, minerals, carbohydrates, fats, oils and proteins. But often the bran and germ are removed, leaving just the carbohydrates which are just a source of energy.

Dielectric properties of food products depend on the frequency of the microwaves, temperature, composition, and density of the materials [2-3].

Carbohydrate, Fat, Moisture, Proteins and salt contents are the major components of food materials. Proteins have low dielectric activities at microwave frequencies [4]. There have been several attempts to develop relationships between the dielectric properties and components of food, based on weighted averages of the dielectric properties of individual components [5-6].

MATERIALS

Pearl millet (HHB 62), Sorghum (CH5), Barley (RD 2508) 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 [7]. 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.

METHOD

Two point method [8-9] 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.

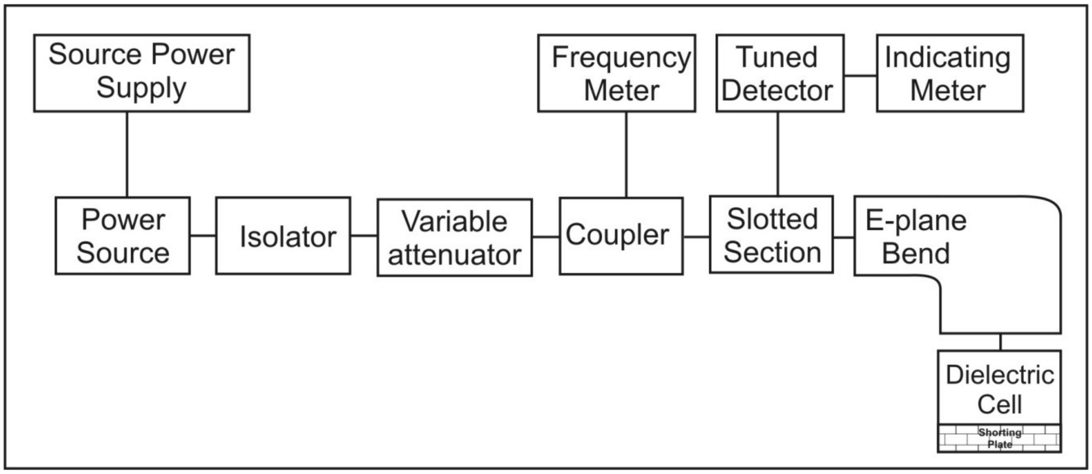

Fig.1. Experimental setup for determination of dielectric properties by two point method

Experimental setup for determination of dielectric properties of food stuff in powder form by two point method

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

$$C\angle -\psi = \frac{1}{j\beta l_{\epsilon}}\frac{1-|\Gamma|e^{j\varphi}}{1+|\Gamma|e^{j\varphi}} = \frac{\tan X\angle\theta}{X\angle\theta}$$

where C and Ψ represent respectively the magnitude and phase of the complex quantity and $X\angle\theta$ represents the solution of this transcendental equation . This equation provides several solutions for $X\angle\theta$.

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

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

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 this equation in to real and imaginary parts, which provide the values of ε' and ε'' in the following form:

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

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

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''). Nutrients of food grains were determined by employing following methods, which are well established for the analysis of food nutrients

Table 1: Bio-Chemical Methods used for Proximate Analysis

S.No.	Name of Nutrient	Method	Reference
1.	Protein	Micro Kjheldal Method	AOAC,2005
2.	Fat	Ether extractive method	AOAC,2005
3	Moisture	Oven drying	AOAC,2005
4	Carbohydrate	Calculation Method	AOAC,2005
5	Crude fibre	Acid Alkali Method	AOAC,2005

RESULTS AND DISCUSSION

Table II : Values of nutrients obtained from biochemical estimation and dielectric properties for samples of sorghum, pearl millet and barley

Sample	Moisture (%)	Protein (%)	Fat (%)	Crude Fibre(%)	Carbohydrates(%)	ε'	ε''
Sorghum (CH5)	11.46± 0.27	10.20±0.08	2.34±0.03	2.00±0.04	70.34±.79	3.16	0.24
Pearl Millet (HHB 62)	10.66±0.22	11.64±0.11	5.23 ±0.12	2.52±0.06	65.50±.62	3.03	0.41
Barley (RD 2508)	11.69±0.26	9.32±0.08	2.04±0.03	6.04±0.08	66.99±.59	2.28	0.28

It is observed from table II that the value of dielectric constant is highest for sorghum and lowest for barley. Both, the dielectric constant and dielectric loss factor increase with increase in moisture content. Therefore, dielectric constant for sorghum (moisture content-11.46%) is more than pearl millet (moisture content-10.66%), Barley has low value of dielectric constant in spite of having highest moisture content. This can be attributed to the high fibre content that it has. The proteins and fats have low dielectric properties. The low value of ε' for pearl millet as compared to sorghum is due to high protein and fat contents. Pearl millet has highest value of dielectric loss which shows that loss increases with increase in the fat content. This shows that as fat content increases, the ability to convert electromagnetic energy into thermal energy decreases..

CONCLUSION

Dielectric properties of food materials depend on a number of factors and cannot be easily predicted just based on its proximate analysis and composition. The dielectric properties of fat and proteins are very low. Bound water contributes less to the dielectric constant than free water in the microwave region because the irrotational bound water is unable to respond to the alternating electric field as such frequency.

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