Journal of Rajasthan Academy of Physical Sciences
ISSN: 0972-6306; URL: http://raops.org.in
Vol.21, No.3&4, July-December, 2022, 155-162

STUDY OF DIELECTRIC PROPERTIES OF VARIETIES OF ALMONDS AND THEIR CORRELATION WITH NUTRIENTS

Swechchha Gupta[*1], Ritu Jain[2] and Nidhi Bhargava[3]
[123]Department of Physics, IIS (Deemed to be University), Jaipur, India
Email : [1]swechchhagupta95@gmail.com (*Corresponding Author),
[2]ritu.jain@iisuniv.ac.in, [3]nidhi.bhargava@iisuniv.ac.in

Abstract: Dielectric properties of agricultural products determine their interaction with electromagnetic energy when they are subjected to microwave heating. Dielectric properties of food material depend on the frequency, grain size, moisture, temperature, composition and density of the materials. In the present study, dielectric properties of five varieties of almonds viz American, Mamra giri, Salora, Satarbai and Kagzi were determined at microwave frequency and their correlation was studied with food nutrients. This was done to study the dependence of dielectric properties on composition of almonds. The nutrients analyzed were moisture, protein, fats, ash, fiber and carbohydrate. Moisture was estimated by moisture analyzer, protein by nitrogen estimation method (KELPLUS), fats by ether extraction method (SOCSPLUS), ash by burning method (muffle furnace), fiber by acid alkali method (FIBRAPLUS) and the carbohydrate was estimated by the calculation method.

Keywords: Correlation, Dielectric properties, Microwave, Nutrients

Mathematics Subject Classification: 32A05, 33B10

1. Introduction

Dielectric properties of materials are used for evaluating their interactions with electromagnetic energy. Dielectric properties of food materials are required for various applications in food industry such as microwave, radio wave and magnetic field processing. Dielectric properties are the main parameters which give information about a material interaction with electromagnetic energy. The dielectric properties include dielectric constant and dielectric loss. Interaction between a food product and microwave energy is given by the relative complex permittivity ($\varepsilon^* = \varepsilon' - \varepsilon''$) of the product. The real component of the complex permittivity ε' is known as the dielectric constant and the imaginary component ε'' is the loss factor. In order to understand the response of food materials to electromagnetic energy, dielectric constant and dielectric loss must be determined as a function of frequency, temperature, composition, grain size and moisture content. [8] The main applications of dielectric properties of food materials are dielectric heating, protection from insects, moisture determination etc. [12] The effect of moisture, fat, protein, carbohydrate etc. on dielectric behavior is interested because it can explain the interaction between the food matrix and electromagnetic fields, which may be useful for formulating functional food. Food components such as, carbohydrate, protein, fat content etc. are important parameters to design, and improve the microwaved food quality and also develop new microwave process [9, 11-13].

Almonds are nutritious and cholesterol free nuts, which makes them a great choice for everyone. Almonds are high in healthy monounsaturated fats, fiber, protein and various important nutrients. Our cells require protection from oxidative damage that is major contributor to aging & disease. Almonds are used as antioxidants that protect cells. Almonds have abundant Vitamin E so this is considered best source for Vitamin E. 28.4 g of plain almonds provide 7.27 mg of Vitamin E. Almonds also contain calcium, magnesium, copper, vitamin K, protein, and zinc, all of which contribute to bone health. In India Jammu & Kashmir and Himachal Pradesh are the chief producers of almonds but its cultivation also take place in Maharashtra, Tamilnadu, Kerela, Karnataka and Andhra Pradesh as well [5-7].

Dielectric properties of agricultural products have been studied for different frequency, temperature and moisture content. Dielectric properties of four varieties of wheat and correlation with nutrients were measured by Bhargava et al. [4]. They found that the dielectric properties of food grains are found to depend on food nutrients. Ling et al. [8] observed the dependence of moisture, temperature and frequency with salty and non-salty pistachio kernels. Dielectric constant and dielectric loss of Indian wheat ‘Raj-4120’ at different frequencies were measured by Sharma et al. [10]. A correlation between nutrient (viz. carbohydrate, protein, fat and moisture) and dielectric properties at microwave frequency 9.32 GHz for three different food grains viz. barley, pearl millet and sorghum were determined using standard biochemical methods [2].

The objectives of this study were - (1) To determine the dielectric constant and dielectric loss of five varieties of almond by two point method at frequency 9.76 GHz. (2) To estimate nutrients moisture, protein, fat, fiber, ash content and total carbohydrates of all five varieties of almonds. (3) To correlate dielectric properties of varieties of almonds and their nutrients.

Since the emphasis of this paper is to find out the dependence of dielectric properties on various nutrients. It was decided to take the values of dielectric constant and dielectric loss at single frequency only. The nutrients were determined for the five varieties of almond and the correlation coefficients between dielectric constant and nutrients and between dielectric loss and nutrients were determined.

2. Materials and Method

Dielectric properties of five varieties of almonds viz American, Mamra giri, Salora, Satarbai and Kagzi were determined at microwave frequency and their correlation was studied with food nutrients. The nutrients analyzed were moisture, protein, fats, ash, fiber and carbohydrate. Moisture was estimated by moisture analyzer, protein by nitrogen estimation method (KELPLUS), fats by ether extraction method (SOCSPLUS), ash by burning method (muffle furnace), fiber by acid alkali method (FIBRAPLUS) and the carbohydrate was estimated by the calculation method. Two point method [1, 3] used for determine the value of dielectric constant and dielectric loss.

Two point method [1, 3] was used to measure the values of dielectric properties of varieties of almond. For apply this method powder sample is filled up in a dielectric cell. The value of complex dielectric constant is given by

$$C\angle\text{-}\psi = \frac{1}{j\beta l\varepsilon}\left(\frac{1-|\Gamma|e^{j\varphi}}{1+|\Gamma|e^{j\varphi}}\right) = \frac{tanX\angle\theta}{X\angle\theta} \tag{1}$$

C represent the magnitude, ψ represent phase of the complex quantity and $X\angle\theta$ represents the solution of transcendental equation.

The admittance is given by

$$Y_{\varepsilon} = \left[\frac{x}{\beta l\varepsilon}\right]^2 \angle\, 2(\theta - 90°) = G\varepsilon + jS\varepsilon \tag{2}$$

Where $\mathbf{G}_{\varepsilon}$ is defined as conductance and $\mathbf{S}_{\varepsilon}$ is susceptance of the sample. The value of G_{ε} and S_{ε} are determined by separating this equation in to real and imaginary parts, which gives the values of ε’ and ε” in following forms:

$$\varepsilon' = \frac{G\varepsilon + (\lambda g/2a)^2}{1+(\lambda g/2a)^2} \tag{3}$$

$$\varepsilon'' = \frac{-Sg}{1+(\lambda g/2a)^2} \tag{4}$$

Where ε’ is Dielectric Constant and ε" is Dielectric Loss.

A computer program in Matlab used to solve this equation and determines the values of dielectric constant and dielectric loss.

Correlation is useful in discovering possible connections between two or more variables. The dielectric properties of almonds may show significant correlation with certain nutrients at a particular frequency. Correlation between the dielectric properties and nutrients of almonds was established by using SPSS software. The module of SPSS used was SPSS 28.0. SPSS is one of the most widely used software for statistical analysis. The correlation is estimated in terms of the Pearson product-moment correlation coefficient, which measures the linear relationship between two variables X and Y and varies between +1 and −1 inclusive; the value 1 showing a total positive correlation, 0 shows no correlation and −1 represents the total negative correlation. The correlation between the dielectric properties of almonds with their food nutrients will be beneficial for product and process development for the requirements of intended applications.

3. Results and Discussion

The values of dielectric constant (ε') and dielectric loss (ε") at frequency 9.76 GHz of five varieties of almonds determined by two point method are reported in Table 1. The values of nutrients estimated by different methods viz moisture by moisture analyzer, protein by nitrogen estimation method (KELPLUS), fats by ether extraction method (SOCSPLUS), ash by burning method (muffle furnace), fiber by acid alkali method (FIBRAPLUS) and the carbohydrate by the calculation method are also reported in table 1.

Table 1: Values of Dielectric properties of different varieties of almond along with the estimated values of food nutrients

Name of Almond variety	Dielectric Constant(ε')	Dielectric Loss(ε'')	Moisture (%)	Fiber (%)	Ash (%)	Protein (%)	Fat (%)	Carbo-hydrate (%)
Salora	2.07	0.24	7.58	5.50	3.56	3.50	42.50	37.36
Satarbai	2.12	0.29	5.68	6.50	3.27	5.25	38.18	41.12
American	1.72	0.56	6.77	6.26	3.21	24.94	44.41	14.41
Mamra giri	2.16	0.08	6.06	4.16	3.52	3.06	24.33	58.87
Kagji	2.00	0.18	5.90	5.80	3.10	3.50	18.03	63.67

From Table 1, it is clear that dielectric constant has the highest value for Mamra giri almond and lowest value for American almond while the dielectric loss has the highest value for American almond and lowest vales for mamra giri almond. The reason for this variation may be attributed to compositional difference which can be observed from the estimated values of different nutrients reported in Table 1. One reason for high value of dielectric loss in American almond may be high protein content (24.94%) in it since as the protein content is increased, loss factor is increased [11]. In Mamra almond, the lowest value of dielectric may be because of lowest value of protein (3.06%). In order to determine the correlation between dielectric properties and various nutrients, correlation analysis was done using SPSS software. The values of the correlation coefficient 'r' and significance parameter 'p' for five varieties of almonds viz American, Mamra giri, Salora, Satarbai and Kagzi are reported in Table 2.

Table 2: Results of Correlation Analysis of dielectric properties of different varieties of almond with their food nutrients

		Moisture	Protein	Fat	Carbohydrate	Ash	Fiber
ε'	r	-0.298	-0.932*	-0.408	0.725	0.520	-0.495
	p	0.627	0.021	0.496	0.166	0.369	0.397
ε''	r	0.299	0.928*	0.728	-0.925*	-0.405	0.709
	p	0.625	0.023	0.163	0.024	0.499	0.180

*Correlation is significant at the 0.05 level (2-tailed)

From Table 2, if the value of p is more than 0.05, this shows that no significant correlation is obtained between dielectric constant (ε') and the nutrients, i.e., moisture content, proteins, fats, fiber, ash and carbohydrates. Similarly, no significant correlation is obtained between dielectric loss factor (ε") and the food nutrients. It is clearly visible from the table that dielectric constant is having the correlation with the protein and it is -ve. On the other hand, dielectric loss is having correlation with the protein and carbohydrate. This is having +ve correlation with protein while –ve with the carbohydrate.

Results of correlation analysis on five varieties of almond are tabulated in Table 2. From this table, it is observed that the dielectric constant (ε') is significantly correlated with proteins at 5% level of significance, as apparent from the value of significance parameter $p = 0.021$. Other nutrients like moisture, fats, carbohydrates and proteins show no significant correlation with dielectric constant. Similarly dielectric loss shows significant correlation with proteins and carbohydrates. The correlation between dielectric constant and proteins are graphically depicted by a regression line in Figure 1 and predictive equations obtained for the linear relationship.

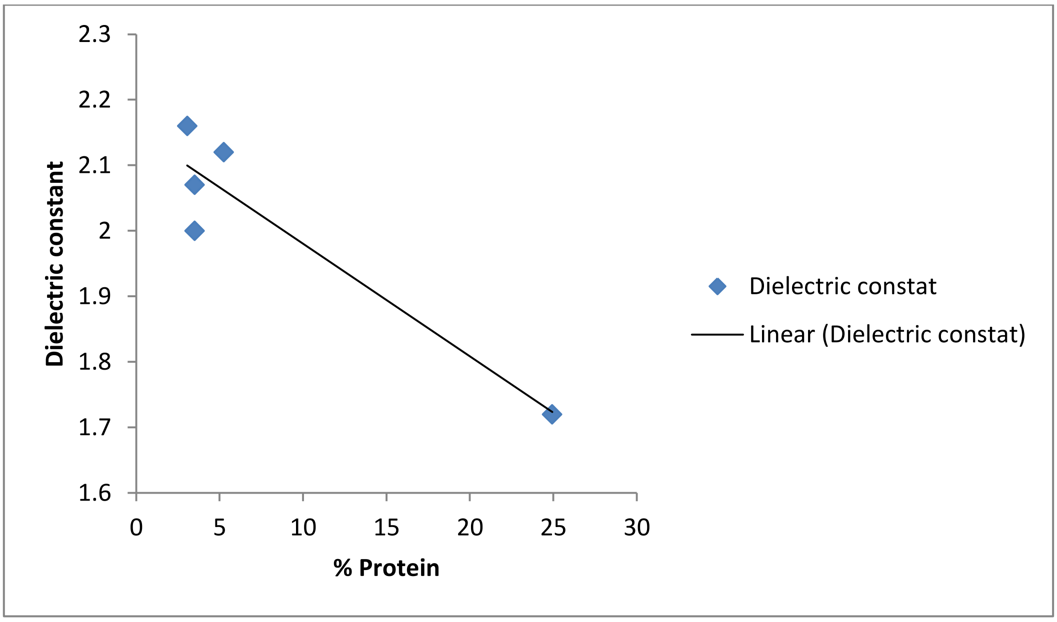

Fig. 1: Regression line between dielectric constant (ε’) and percentage protein for almonds

From Fig. 1, it is clear that dielectric constant (ε’) of varieties of almond can be represented by a linear function of % protein at frequency 9.76 GHz; the equation for this linear regression is given by

$$\varepsilon' = -0.017*P + 2.152 \quad (5)$$

Equation (5) shows that ε’ is negatively correlated with protein, the slope of the regression line being 0.017. Fig. 1 shows that ε' is negatively correlated with protein. The value of both the correlation coefficient ($r = 0.932$) and the significance coefficient ($p = 0.021$) between ε’ and % protein show that the significance for this correlation is within 5% level of significance.

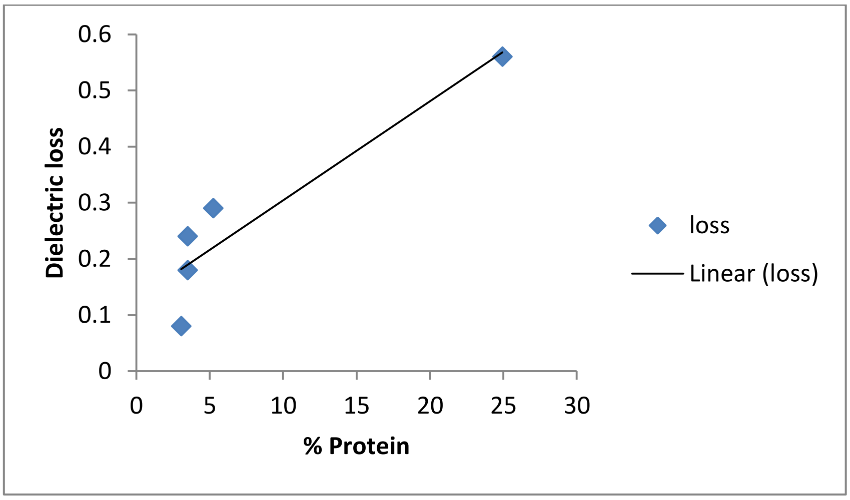

Fig. 2: Regression line between dielectric loss (ε'') and percentage protein for almonds

From Fig. 2, it is clear that dielectric loss (ε") of varieties of almond can be represented by a linear function of % proteins at frequency 9.76 GHz; the equation for this linear regression is given by

$$\varepsilon'' = 0.018*P + 0.128 \quad (6)$$

Equation (6) shows that ε" is positively correlated with proteins, the slope of the regression line being 0.018. Fig. 2 shows that ε" is positively correlated with proteins. The value of both the correlation coefficient (r=0.928) and the significance coefficient (p = 0.023) between ε" and % proteins show that the significance for this correlation is within 5% level of significance.

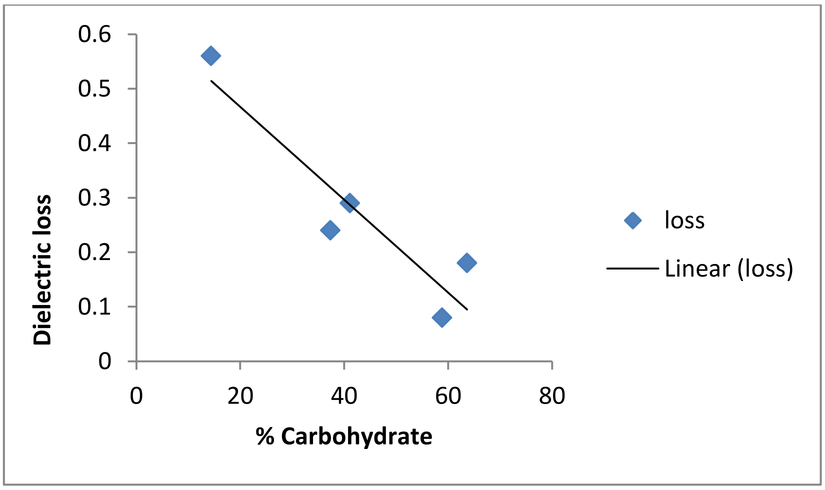

Fig. 3: Regression line between dielectric loss (ε'') and percentage carbohydrate for almonds

From Fig. 3, it is clear that dielectric loss (ε”) of varieties of almond can be represented by a linear function of % carbohydrate at frequency 9.76 GHz; the equation for this linear regression is given by

$$\varepsilon'' = -0.009*C + 0.637 \quad (7)$$

Equation (7) shows that ε” is negatively correlated with carbohydrate, the slope of the regression line being 0.009. Fig. 3 shows that ε” is negatively correlated with carbohydrate. The value of both the correlation coefficient (r=0.925) and the significance coefficient (p = 0.024) between ε” and % carbohydrate show that the significance for this correlation is within 5% level of significance.

4. Conclusion

Dielectric properties of a food material depend on a number of nutrients, like moisture, fat, protein, carbohydrate etc. ε” is positively correlated with proteins and negatively correlated with carbohydrate. ε' is negatively correlated with protein. Molecular structures and chemical compositions of the nutrients effects differ for different nutrients.

Acknowledgement

The authors are thankful to the referee for valuable comments and suggestions.

The authors express their thanks to the Chancellor, IIS (Deemed to be University), Jaipur for providing necessary facilities for this work. Swechchha Gupta gratefully acknowledges the financial assistance provided by the CSIR to her for this work.

References

[1] Behari, J. (2005). Microwave dielectric behaviour of wet soil, *Microwave Measurement Techniques and Applications* (Edited by J. Behari), **73**.

[2] Bhargava, N., Jain R., Joshi, I. and Sharma, K. S. (2013a). Dielectric Properties of Cereals at Microwave Frequency and Their Bio Chemical Estimation, *International Journal of Science, Environment and Technology* **2**, 369-374

[3] Bhargava, N., Jain, R., Joshi, I. and Sharma, K. S. (2013b). Effect of Frequency and Moisture Variation on Dielectric Properties of Pearl Millet in Powder Form, *Journal of Environmental and Nanotechnology* **2**, 01-05.

[4] Bhargava, N., Jain, R., Joshi, I. and Sharma, K. S. (2014). Investigation of Dielectric Properties of Some Varieties of Wheat and their Correlation with Food Nutrients, *International Journal of Engineering Science and Innovative Technology*, **3**, Issue 2.

[5] Gao, M., Tang, J., Johnson, J. A. and Wang, S. (2012). Dielectric properties of ground almond shells in the development of radio frequency and microwave pasteurization, *J. Food Eng.* **112,** 282-287.

[6] Javaid, T., Mahmood, S., Saeed, W. and Alam, M.Q. (2019). A Critical Review on Varieties and Benefits of Almond (Prunus dulcis), *Acta Scientific Nutritional Health* **3**(11), 70-72.

[7] Li, R., Zhang, S., Kou, X., Ling, B. and Wang, S. (2017). Dielectric properties of almond kernels associated with radio frequency and microwave pasteurization, *Sci. Rep*. **7**, 42452.

[8] Ling, B., Guo, W., Hou, L. and Li, R. (2015). Dielectric properties of pistachio kernels as influenced by frequency, temperature, moisture and salt content, *Food Bioprocess Technol*. **8,** 420-430.

[9] Sahin, S. and Sumnu, S.G. (2006). Physical properties of foods. Springer **173**.

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

[11] Teseme, W.B. and Weldeselassie, H.W. (2020). Review on the Study of Dielectric Properties of Food Materials, *American Journal of Engineering and Technology Management* **5(5)**, 76-83.

[12] Tıras, B, Dede, S. and Altay, F. (2019). Dielectric Properties of Foods, *Turkish Journal of Agriculture - Food Science and Technology* **7**(11), 1805-1816.

[13] Zhang, S., Zhou, L., Ling, B. and Wang, S. (2016). Dielectric properties of peanut kernels associated with microwave and radio frequency drying, *Biosyst. Eng*. **145,** 108-117.