Migration Letters

Volume: 20, No: S8(2023), pp. 1529-1534

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Determination of Dielectric Properties of Food Products

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Abstract

The article presents the results of a study on the determination of the dielectric properties of food products. The complex dielectric permittivity is characterized, the methodology of the study and the equipment used are given, in the course of the experiment, a method for calculating the dielectric properties of food products is given: fruits, vegetables and grain products.

Keywords: *dielectric, dielectric properties (dielectric conductivity), EMF (electromagnetic field) energy of microwave (ultrahigh frequency) frequency ranges, microwave heating, depth of penetration of microwave empole, resonance, waveguide, method of free and slow waves.*

INTRODUCTION

The use of ultra-high frequency (microwave) heating allows to intensify the technological process of food production.

Currently, in order to widely introduce ultra-high-frequency heating for food processing, such as thermal heating, pasteurization, sterilization, blanched, as well as baking, cooking, etc., a number of industrial heating installations are being developed and produced, the action of which is based on the use of microwave EMF energy, the efficiency of which is reached up to 72%, together with 48% of traditional.

One of the most important technological processes in the food industry is the heat treatment of products. Based on traditional methods of heat treatment of food products, it is becoming increasingly difficult to achieve a significant effect when improving production processes, since their capabilities in some cases have already been exhausted. Therefore, extensive scientific research has been intensively conducted recently on the use of electro physical methods in order to reduce the duration of heat treatment processes. Heating in microwave fields can significantly reduce the duration of heat treatment, will increase the quality of finished products, reduce the area of production workshops of enterprises, improve sanitary and hygienic working conditions of service personnel, will increase the economic performance of enterprises.

To design the working chambers of dielectric heating installations, to determine the speed of movement of transport bodies and the specific power supplied to the processed products, as well as to calculate the modes of heat treatment of food products, information about their dielectric properties (dielectric conductivity) is required. This information in the ultra-high-frequency heating range can be determined experimentally

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To design the working chambers of dielectric heating installations, to determine the speed of movement of transport bodies and the specific power supplied to the processed products, as well as to calculate the modes of heat treatment of food products, information about their dielectric properties (dielectric conductivity) is required. This information in the ultra-high-frequency heating range can be determined experimentally by various methods, the choice of which depends on the composition of the studied products, temperature and frequency ranges of measurements.Based on the above, the determination of the dielectric properties of food products is an urgent task.

For processing food products: fruits, vegetables and grain products by electrophysical methods, it is especially important to know their dielectric properties. Dielectric properties or permittivity is characterized by a complex ε* dielectric permittivity and takes into account both the conductive and dielectric properties of the dielectric (which are food products). [1].

MATERIALS AND METHODS

On the complex plane, ε* is expressed by the vector of the real ε* and characterizes the polarization processes occurring in the dielectric, determined by displacement currents, and the imaginary one by conduction currents (Fig. 1).

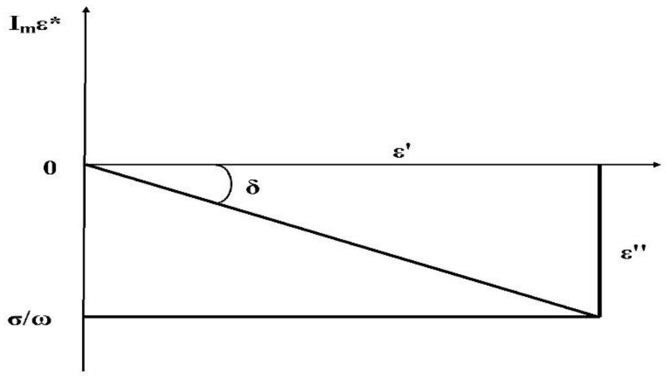

Fig. 1. Complex permittivity.

The imaginary part determines the heating of the dielectric when exposed to the electric component of the field and is denoted. The dielectric can also be characterized by the tangent of the dielectric loss angle t tg $\delta = \frac{\varepsilon''}{\varepsilon'} = \frac{\sigma}{\omega}\frac{1}{\varepsilon'}$ The larger the value, the greater the proportion of energy consumed for heating the dielectric[2]. Complex permittivity and its components ε' and ε" to a greater extent, they depend on the frequency of the acting electric field, temperature and other physical and mechanical properties. We determined the dielectric properties of fruits using the "Short circuit" method [3]: apples of two varieties and vegetables: carrots and beets, cabbage, as well as grain products at the installation, the general view of the equipment of this installation is shown in Fig. 2.

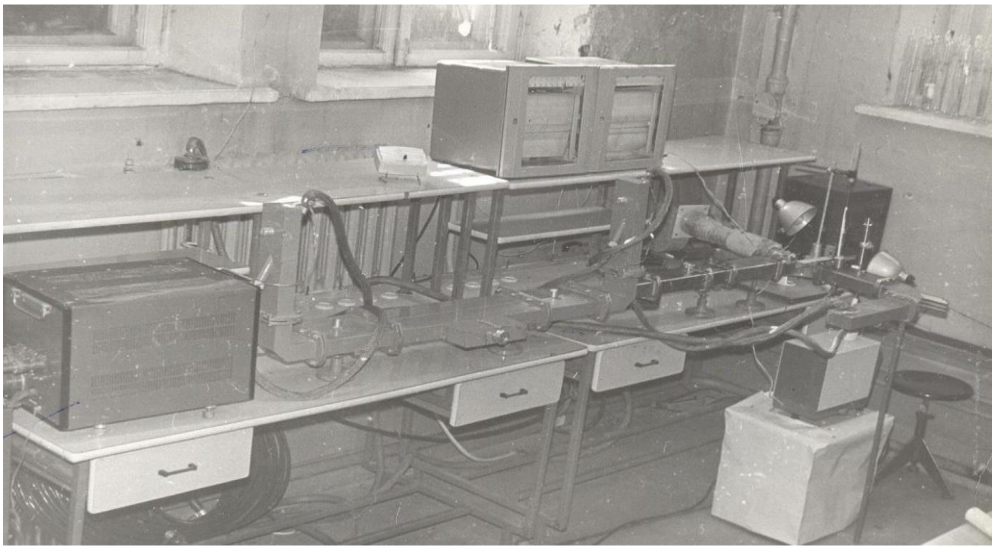

Fig.2. General view of the equipment of the stand for measuring the dielectric permittivity of food products.

The block diagram is shown in Fig. 3. In the installation, the measuring generator G is the source of the microwave signal. The ferrite valve serves to exclude the influence of electromagnetic wave reflections from the load on the stability of the generator. A directional coupler BUT is necessary for the removal of part of the microwave energy, which is fed through the detector head DG to the oscilloscope O, which is an indicator of the constancy of the power level given by the generator. The adjustable attenuator ATT makes it possible to change the power level entering the load, regardless of the power of the generator. The IL measuring line is the main element of the installation necessary for measuring the waveguide wavelength λb of the standing wave coefficient p of the displacement of the minimum electric field. The RP recording device allows you to record the distribution of the standing wave field and obtain quantitative values. The waveguide bend VI is needed to obtain the vertical position of the segment of the short-circuited waveguide H, which is necessary for studies of food dielectrics.

Experimental research and discussions of measuring the dielectric properties (permeability) of food products were carried out according to the following experimental method[4,5]:

After preparing the installation (Fig. 2), the GZ-10A generator and the M95 microammeter were turned on for the experiments, having previously turned on the external shunt.

A short-circuited section of the waveguide, not filled with a dielectric (product), was connected to the bend of the waveguide.

After warming up the generator, by changing the position of the waveguide line detector, the position of the minimum of the standing wave with respect to an arbitrary reference plane (D_R) was found.

Having measured the distance between the adjacent minimum of the standing wave, we calculated the wavelength in the waveguide (λ_b) equal to twice the value of the distance obtained.

A short-circuited section of the waveguide was filled with the food product under study in such a way that the dielectric fit snugly to the edges of the waveguide. To do this, having cut the product into a certain rectangular shape, it was decomposed into a waveguide in order.

The position of the minimum of the standing wave relative to the reference plane was measured.

The standing wave coefficient was measured $\rho_1 = (\frac{I_{max}}{I_{min}})^{-\frac{1}{2}}$,

Где I_{max} – microammeter readings at the maximum of the standing wave;

I_{min} – readings in the minimum of the standing wave.

1. Similarly , measurements were carried out with a different thickness of the dielectric l_2 and measured D_2 and ρ_2.
2. The value was calculated $\beta = 2\,\pi\,/\lambda_в$.
3. For measured values D_1 and ρ_1 calculated

$\varphi_1 = 2\,\beta\,(D_1 - D_R - l_1)$ и $|\Gamma_1| = \frac{\rho_2 - 1}{\rho_1 - 1}$.

4. We have determined a complex number

$C_1 < -\psi_1 = \frac{1}{j\,\rho\,l}\,(\frac{1 - |\Gamma_1|\,e^{j\,\varphi_1}}{1 + |\Gamma_1|\,e^{j\,\varphi_1}})$.

5. Solved the equation $C_1 < -\psi = \frac{th\,(T_1 < \tau_1)}{T_1 < \tau_1}$ regarding T_1 и τ_1.

15. We calculated several values of a complex number:

$$y_{1.} = \left(\frac{T}{\beta\,l_1}\right)^2\ [\cos 2\,(\tau_1 - 90^0) + \ j \sin 2\,(\tau_1 - 90^0)]$$

6. Similarly for the thickness of the dielectric l_2 calculated

$\varphi_2 = 2\,\beta\,(D_2 - D_R - l_2)$ и $|\Gamma_2| = \frac{\rho_2 - 1}{\rho_2 + 1}$.

7. Определили комплексное число

$C_2 < -\psi_2 == \frac{1}{j\,\beta\,l}\,(\frac{1 - |\Gamma_2|\,e^{j\,\varphi_2}}{1 + |\Gamma_2|\,e^{j\,\varphi_2}})$

and solved the equation $C_2 < -\varphi_2 = \frac{th\,(T_2 < \tau_2)}{T_2 < \tau_2}$.

8. We calculated several values of a complex number:

$$y_2 = \left(\frac{T_2}{\beta\,l_2}\right)^2\ [\cos 2\,(\tau_2 - 90^0) + \ j \sin 2\,(\tau_2 - 90^0)].$$

9. Selected matching valuesy and calculated ε' ; ε'' ; tgδ

$y = g + j\,\beta$;

$$\varepsilon' = \frac{g + \left(\frac{\lambda_в}{2\,a}\right)^2}{1 + \left(\frac{\lambda_в}{2\,a}\right)^2} ;$$

$$\varepsilon'' = \frac{B}{1 + \left(\frac{\lambda_в}{2\,a}\right)^2};$$

$$\operatorname{tg}\delta = \frac{\varepsilon''}{\varepsilon'},$$

where a - the length of the wide wall of the waveguide.

Experimental research and discussions. According to the conducted studies of the above experimental setup and calculation, the obtained and calculated data of the experimental results are summarized in the table.

We measured the dielectric properties of apples of the Simirenko and Apport varieties with a humidity of 85.8 and 78.4%, respectively, carrots of the Chantenet and Vitamin varieties with a humidity of 83.6 and 85.2%, as well as beets of the Bordeaux and Dutch varieties with a humidity of 80.8 and 83.4%., as well as grain products with various low humidity: wheat grain 12%, wheat flour 14%, bread crusts 1-2%.

The dielectric properties of food products were determined experimentally on the basis of the "Short circuit Method", the results obtained are included in

Table 1: Dielectric properties (dielectric conductivity) of food products

№	Name of food products	Amount of moisture (juice)%	Dielectric conductivity $f = 2300$ мГц $t = 20^0$C		
			ε'	ε''	tgδ
Fruits and vegetables					
1.	Apple tree - Simirenko - Apport	85,8 78,4	60,2 59,6	16,1 14,9	0,26 0,25
2.	Apricot - 24 mm in diameter with a stone and a peel - 26 mm in diameter with a stone and a peel - divided, δ= 15, with a bone - split, pitted	80,5 80,5 80,5 80,5	63,7 62,5 64,1 64,4	17,1 17,8 18,2 18,3	0,28 0,28 0,29 0,29
3.	Plum - 34 mm in diameter with a stone and a peel - 30 mm in diameter with a stone and a peel - divided, δ= 18, with a bone - divided, δ= 16, without a bone	80,0 80,0 80,0 80,0	61,4 61,1 62,3 61,8	16,8 16,7 16,9 16,7	0,27 0,26 0, 26 0,26
4.	- Carrots cut into strips	75,5	56,7	15,4	0,27
5.	Potatoes: brusochka cube- 15 mm -potatoes with a peel with a diameter of 40 mm -potatoes with a peel with a diameter of 15 mm	81,0 81,0 81,0	59,6 59,3 56,7	15,8 15,6 14,7	0,26 0,27 0,27
6.	Beetroot: straw				

	- beetroot with a diameter of 60 mm 80 mm	84,5 84,5	57,1 57,9	14,9 15,2	0,26 0,25
7.	Onion - half of the ring	89,4	53,8	14,3	0,28
Grains, flour and bakery products					
8.	Wheat grain	12	2,46	0,66	0,18
9.	Wheat flour: The highest grade Grade 1 Grade 2	14 14 14	3,6 3,9 4,1	0,1 0,2 0,4	0,03 0,05 0,1
10.	Bread: Crust crushed soft part	4-6 42	0,8 41	0,09 16	0,11 0,39

Analysis of the obtained data on the dielectric properties of fruits and vegetables, as well as wheat grains, flour, bread (ground) and soft parts in accordance with the experimental research methodology showed that the dielectric conductivity of food products differ depending on their types, humidity and frequency of microwave EMF. Changing the size of food products affects their quantity, because the amount of moisture changes, and the different shape of food products does not change the dielectric conductivity.

CONCLUSION

Therefore, it can be concluded that when designing and developing, i.e. designing microwave installations, for technical (engineering) calculations, averaged values of dielectric conductivity can be used, by product groups, depending on their humidity..

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