Determination of electric and dielectric conductivity of fruits and vegetables

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Abstract. The article describes the research results to determine fruits and vegetables' electrical and dielectric conductivity. The electrical conductivity is characterized, and the experimental method of its determination and the equipment used are given. Also, the topic's relevance, keywords, methods of calculation in the experimental process, the electrical conductivity of crushed, cut varieties of fruits (apricots, apples, plums) and carrots, and the results of a study to determine the dielectric constant. MevaThe results of the dielectric properties of tula and cut varieties of different sizes (apricots, apples, plums) and vegetables (carrots, potatoes, beets, and onions) are presented. The curves of the dependence of the specific electrical conductivity of crushed fruits, plums, apples, and carrots on the EMF voltage are obtained. The specific electrical conductivity at cm is a maximum of 0.191 cm / m. Also, during the operation of the electrodes in the cell -30 s, the electrical conductivity first increases rapidly; after 10 seconds, the growth decreases, and at a certain maximum time - 18 s decreases, and the maximum size here is in the range of 0.209 to 0.230 cm/cm. The temperature dependence of the specific electrical conductivity of fruits and vegetables greatly affects their temperature on electrical conductivity.

1 Introduction

Uzbekistan has a potential of 15 million tons with its high agricultural potential per year tons of agricultural products are grown. The volume of fruit and vegetable products produced in our country not only satisfies the needs of the population of the Republic but also exports high-quality products to foreign markets. Over the past 5 years, fruit and vegetable production volume increased by 1.7 times, and 2019 amounted to 12.3 million tons. 1.7 million tons, or 14% of the product, was recycled. To date, 11.3% of vegetables, 18.2% of fruits, and 24.4% of grapes are processed. Processed fruits and vegetables add value to the product and allow for higher returns.

The gross harvest amounted to 1780.8 thousand tons, of which about 490.3 thousand tons were processed in 2019. Currently, the use of electrophysical methods in the

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production of food products is growing. We can specify high-frequency, high-frequency electric field energy, red light energy, electrodialysis, electroflotation, plasmolysis, electrostriction, and others from electrophysical methods.

Today, fruits and vegetables rich in natural vitamins, micro- and macronutrients, including fruits and vegetables, and theiragainProduction of processed products using modern technologies, including maximum preservation of natural components, as well as improving the quality of products, increasing their nutritional safety and biological value, development and implementation of technology for obtaining quality fruit and vegetable juices and concentrates, rational complex from local raw materials Research is being carried out in current areas such as obtaining high-quality products, ensuring the competitiveness of the product, reducing the cost and cost of the product.

Large-scale scientific developments on the introduction of technologies for the storage and processing of fruits and vegetables in the food industry of the Republic and the production of export-oriented juices have been prepared and introduced into production. The Action Strategy for the Further Development of the Republic of Uzbekistan sets the tasks of "deepening structural changes and consistent development of agricultural production, further strengthening food security, expanding the production of environmentally friendly products, significantly increasing the export potential of the agricultural sector" [1]. In this regard, in particular, research aimed at creating technologies for producing export-oriented products is important.

No. PF-4707 of the President of the Republic of Uzbekistan dated March 4, 2015, "On the Program of measures to ensure the restructuring, modernization, and diversification of production in 2015-2019", the Cabinet of Ministers of the Republic of Uzbekistan dated August 29, 2015, No 251 "Concept of measures to provide the population of the Republic of Uzbekistan with quality food in 2015-2020" and the President of the Republic of Uzbekistan No. PP-2716 of January 6, 2017, "On additional measures to develop the organization of storage and deep processing of fruit and vegetable products in 2017-2018", Decrees and Resolutions of the President of the Republic of Uzbekistan No. PF-4947 of February 7, 2017, "On the Action Strategy for the further development of the Republic of Uzbekistan", and to some extent, this study will serve to implement the tasks set out in other regulations related to this activity.

President of the Republic of Uzbekistan Sh. In Mirziyoyev's Address to the Oliy Majlis. (January 25, 2020). It is emphasized that we can achieve the transformation of Uzbekistan into a developed country only through the use of accelerated reforms and innovations. Adoption of the Concept of Development Strategy of the Republic of Uzbekistan until 2035: economic development focused on high technologies and exports, sustainable transition to industrial industry, development of innovations and technologies in all areas, the introduction of science and technology, etc.

In doing so, the selected topic for the use of promising electrophysical methods in the processing of fruits and vegetables, including juice processing: electrodialysis [2], EMF energy [3,4], electroflotation [5], electroplasmolysis [6], electrostriction is up to date.

The purpose of our work is to use the electrophysical method in producing juices from fruits and vegetables, to determine their kinetics, to determine the electrical and dielectric constant for developing technological regimes, and to design electrical processing equipment.

2 Research Methodology

In this research, we used logical analysis and synthesis methods, grouping, comparative and structural analysis, abstraction, factor analysis, induction, and deduction.

3 Analysis and results

The control of the specific electrical conductivity s of fruits and vegetables is determined by the electrical resistance- Re measured directly through the circuit of electric bridges. Or the indirect voltage of the electrodes is found by calculating -U and operating current -I [7].

For this purpose, an experimental stand based on an electrical circuit is especially connected: a rectangular dielectric working chamber, plate electrodes, laboratory autotransformer connected to them - LATR-1M, laboratory single-phase thyristor power supply (220 V, 50 Gts), sound generator GZ-33, high-frequency machine generator 93 GIM1, consisting of a dielectric ash electric pole and conductors connected to a resistance bridge. Fig. 1 shows the electrode chamber of the plate electrode and the geometric scheme of the probes for measuring the electrical conductivity.

During the experiment, the electrodes were also supplied with voltage from a D-5055 voltmeter, a D-5017 operating current ammeter, and a PV-53sh electric stopwatch.

Stopwatch, current wattmeter D-5004, working chamber size with the caliper, 500, specific electrical conductivity is measured using R38 rheochord bridge and MPP conductivity semiconductor, temperature symbol thermometer, and XK thermocouple KSP 4M uziozar potentiometer.

We can also measure with an indirect sensor, which is relatively inaccurate. In it, the probe shown in the figure is carried out by inserting two pins of the probe into the desired mass of material to its full height. To do this, you must first measure the probe, using a material with a known electrical conductivity. When scanning it, we immerse the instrument in the material through a bridge of known resistances, and the electrical conductivity for measurement through the probe, which is xxdx d0 = 20 x 15 x 1.0 mm. With the help of this, the electrical resistance of the mass of the product placed in the working chamber is now measured, and the electrical conductivity is determined by this formula. It should be noted that when determining the mass of the working chamber without movement and after the introduction of the sample, one should use the circuit diagram. $Let's\ identify$ σR . Size σ $= 7{,}46/$RRσσ

Temperature measurement is also important during this process. In measuring the temperature, we used the [12] thermistor (thermistor) MRT-54 instrument and method. The head diameter of the MRT-54 thermistor is 0.8 mm, and before use, we covered its head with epoxy resin, as it acts as a strong electrical insulation. According to the technical characteristics of the device, it can be used to determine the temperature of a product in the temperature range of 20 dn to 1000S. In this case, the electrical resistance varies from 10,000 Ohms to 800 Ohms. The graded graph of the thermistor and the circuit diagram of the structure are shown in Figures 1 and 2.

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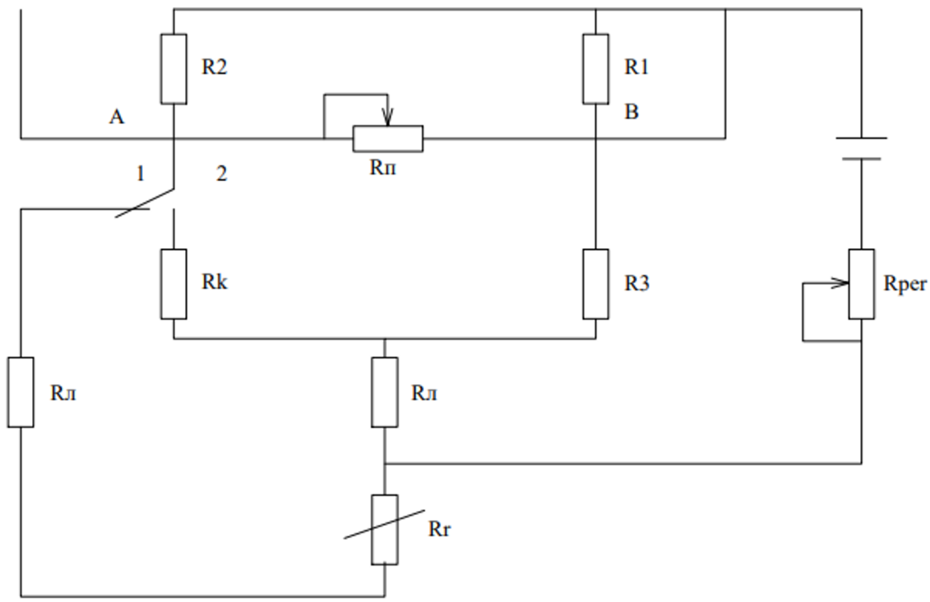

Fig. 1. Thermistor circuit diagram

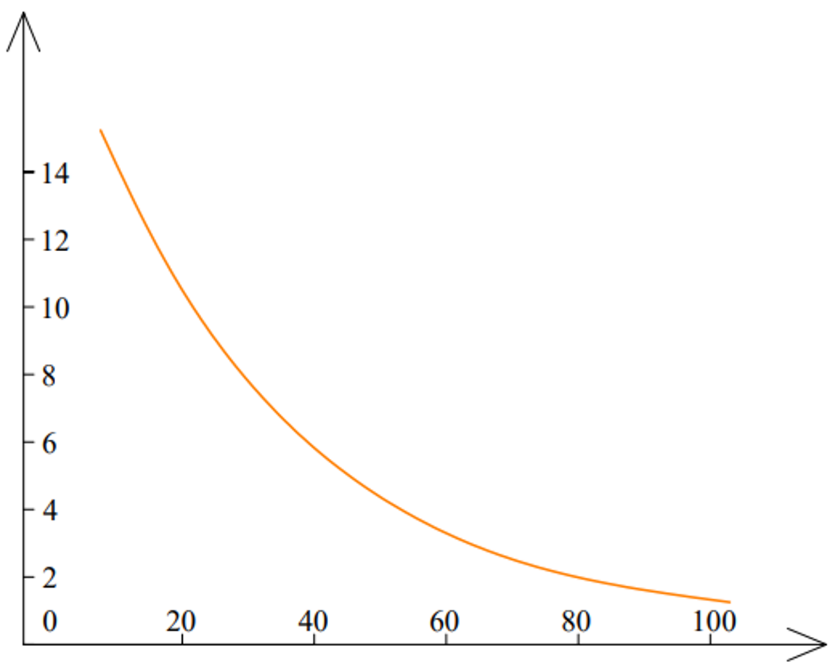

Fig. 2. Thermistor graded graph

The thermistor can be connected to an automatic measuring bridge with a constant electromagnetic field [8]. In this case, the maximum resistance of the thermistor must be less than the resistance of the rheochord R = 900.1 Ohm. If it is not low, it should be reduced by small resistances. This can be achieved by changing the state of the rheochord.

To measure and record the temperature, a thermistor must be connected to the shoulder of the electric bridge. In this case, the potential difference is given to the automatic potentiometer KSP-4M and the pair of thermocouples e.yu.k. is obtained.

To increase the accuracy of the automatic measurement, striving for a constant voltage in the system is necessary. To do this, using a stabilizer in the electrical system is advisable. Or, before each measurement, the Rreg must be adjusted, i.e., the voltage must be equal to the current coming from the power supply and kept at a constant magnitude.

At present, there is no universal methodology for measuring the dielectric properties of a variety of functions. Methods of measuring dielectric properties differ in the following main parameters. These include the frequency range in which they are measured; dielectric constant measurement limit and light absorption tangent angle; the accuracy of measuring these quantities; the amount of sample material used; experimental temperature range, even in the solid, liquid, and gaseous state of the products, the method's usability, the complexity of sample preparation, the cost of the instrument, the ease of experimentation, and the complexity of the calculation. Currently, Commonly accepted methods in the OUC range include resonant, wave, transmitter, free-wave method, and slow-wave methods.

In the composition of modern meters, modifications of waveguide methods are common. Such versatility is due to the cross-section of its various waveguides, which are: right-angled or filled with a fully or partially tested product. A separate modification of this method depends on the nature of the simultaneous propagation of electromagnetic waves (standing or running) in the waveguide. Also, based on the principle of research, whether the wave is transmitted from the dielectric or passed through the dielectric, at other times where the waveguide line and the sample are located: in a short-circuit line ("short-circuit method") and released ("single-phase" method) or their approved load combined with or absolutely absorbed; inspected product,

It is known that the permeability complex of the product ε^* is characterized by a dielectric constant, and the dielectric property of a dielectric (product) is characterized by its current conductivity.

In a complex text that is in a dielectric (all fruits and vegetables are dielectric)ε^*The complex dielectric property is characterized by a real vector and is characterized by polarization processes, and they are characterized by "mixed" currents and its "minimum" part conducting current [13]. In this case, the minimum part of the electromagnetic field (EMF) under the influence of the electric part represents the dielectric effect and is determined by. A tangent angle can also describe them; the larger the angle, the greater the energy expended on the dielectric effect (heating, breaking the cell, extracting the juice, etc.).

$$\varepsilon'\varepsilon'' = \frac{\sigma}{\vartheta}\text{tg}\delta = \frac{\varepsilon''}{\varepsilon'} = \frac{\sigma}{\vartheta}\cdot\frac{1}{\varepsilon'}\text{tg}\delta \tag{1}$$

Complex dielectric constant and its components $\varepsilon'$and depends largely on the frequency, temperature, and other physical and mechanical properties of the affected area ε''.

The dielectric constant measuring device works as follows. The device has a generator that is a source of measuring the player's signal. For the stable operation of the generator, a ferrite valve is used to eliminate the effect of returning the electromagnetic waves from the load. The directional valve serves to return some of the NO OYUCH energy. From there, the detector sends O through the head DT to the oscilloscope. O The oscilloscope serves as an indicator of the uniform supply of power from the generator. The controlled attenuator allows you to change the power regardless of the power of the ATT generator. The measuring line is the main element of the IL device; the wavelength in the waveguide, constant wave coefficient, and a minimum electric field is used to measure the displacement. The recording device RP fixes the stationary wave field's division and the field's propagation to obtain quantitative information. Kundalang cross-section is used in the search for liquid dielectrics to obtain the bending source of a rectangular copper waveguide - VI, the vertical position of the short-circuit wave N.GPD$_R$

Materials studied (apples, apricot, plums, carrots)was placed in a separate electrode chamber, and the laboratory was given a bipolar pulse voltage from the single-phase thermistor power supply to the electrodes. Their specific electrical conductivity was determined based on the above method.

Fruit and vegetable specific conductivity (σ) to EMF voltage (E), the dependence is shown in Figure 3, the graphs of their electrical response time (dependence in Figure 4, and the initial temperature (t) dependence are shown in Figure 5.

Crushed fruits of apricots, plums, apples, and carrots can be seen from the curves of the dependence of the specific conductivity (σ) on the EMF voltage (E), all of which are similar in nature, rising first and decreasing after reaching a certain maximum. At 83.1 V / cm EMF voltage, the specific conductivity is a maximum of 0.191 cm / m. They also have different sizes of fruits and vegetables. While the electrical conductivity of apples is slightly higher than others, plums are lower σ.

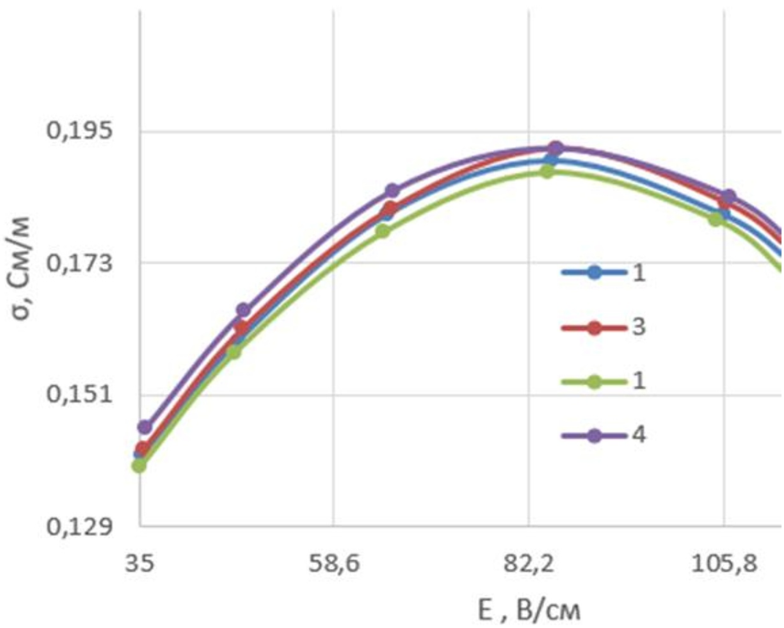

Fig. 3. Dependence of specific electrical conductivity (σ) of fruits and vegetables on EMF voltage (E): 1 is apricot; 2 is plum;3 is carrot; 4 is apple.

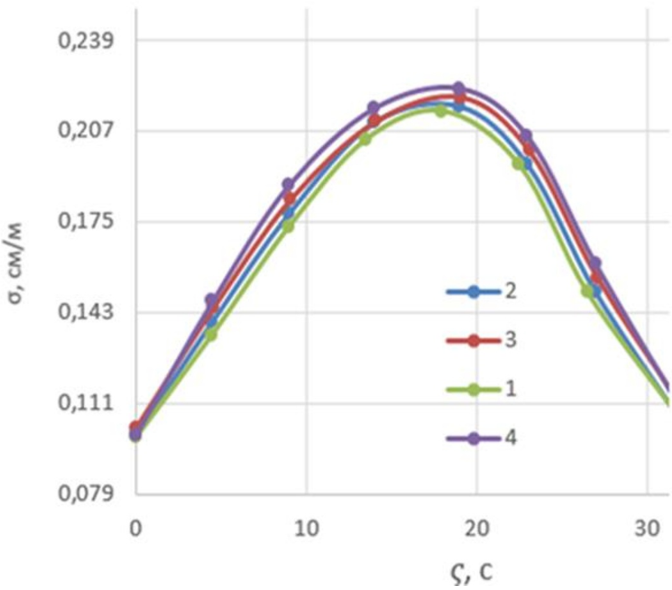

Fig. 4. EMF of specific electrical conductivity (σ) of fruits and vegetables electrical exposure time (t) dependence

Dependence of crushed fruits and vegetables' specific electrical conductivity (σ) on the EMF electrical exposure time (t). It turns out that during the operation of the electrodes in the cell -30 s, the electrical conductivity first increases rapidly; after 10 seconds, the growth decreases, and at a certain maximum time - 18 s. Here, too, the relative electrical conductivity of different fruits and vegetables varies, but they do not differ much from each other. Fruits and vegetables have a maximum specific electrical conductivity of 0.209 to 0.230 cm / cm.σekan.

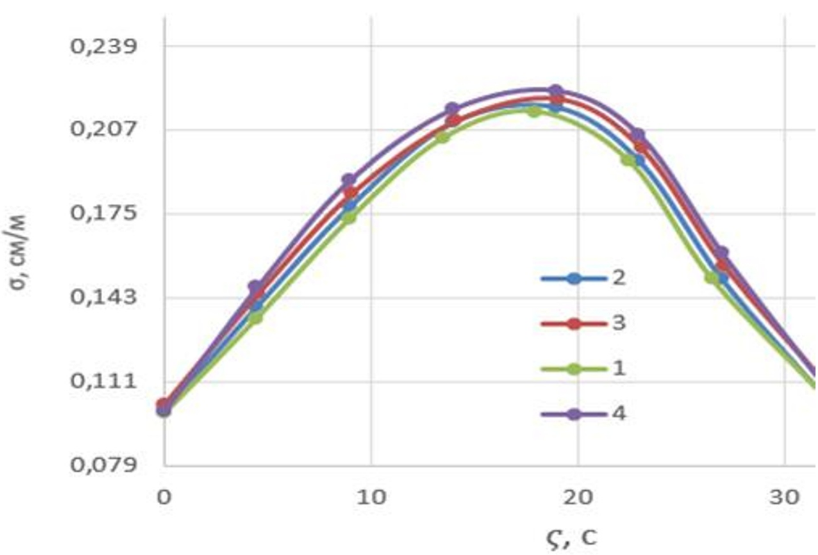

Fig. 5. Specific electrical conductivity of fruits and vegetables (σ) dependence on initial temperature (T): 1 is apricot; 2 is plum; 3 is carrot; 4 is apple.

When we consider that the specific electrical conductivity (σ) of fruits and vegetables depends on the initial temperature (T), we can see that their temperature greatly affects the electrical conductivity. Depending on the temperature of the crushed material, the specific electrical conductivity varies and reaches a maximum in different fruits and vegetables and gradually decreases over a range of temperatures.

The specific electrical conductivity of fruits and vegetables in the given graphs is directly affected by the EMF voltage, the duration of the electrical exposure, and its temperature, and at the initial time, its magnitude increases intensively in all processes. However, the general appearance of the images confirms that from a certain point in time, the growth slows down, and from a certain maximum point, the growth slows down rapidly.

In our opinion, the gradual evaporation of moisture from crushed fruits and vegetables during the process formation of vapor bubbles slows down the increase in electrical conductivity. It intensifies the decrease in vapor bubbles during the process, as if the "electro-raw material" system gradually changes to another state. It is known that fruits and vegetables belong to the group of colloidal capillary cavities, so their characteristic, theoretical, and practical scientific results for the kinetics of this group confirm this condition. The specific electrical conductivity of the apples we determined corresponds to the data of IV Kupadze, who obtained results of -0.197 Sm / m for apple varieties and 0.346 Sm / m [7] for other such varieties. Also. V.V. Bordian field (apple,

Determination of dielectric properties (conductivity) of fruits and vegetables was carried out by the following experimental method [12,13]:

1. When preparing the device for operation (Fig. 3), the GZ-10A VHF generator and the M95 microammeter, and its external rod are switched on for carrying out experiments.
2. A short-circular part not filled with a dielectric (product) is connected to the bent part of the waveguide.
3. After heating the generator, by changing the position of the waveguide detector, the position of the minimum of the standing wave inside the conductor relative to the arbitrary reference plane (D_R) is found.
4. Measure the distance between the contact minimum of the standing wave and the wavelength of the waveguide() is equal to twice the value of the distance obtained.λ_B
5. The short-circuited part of the waveguide was filled with the fruit and vegetable product under study to easily fit into the waveguide edges of the dielectric. To do this, cut the product into a predetermined rectangular shape and order it to the fox conductor.
6. Standing wave minimum D_1 is measured relative to the reference plane.
7. The standing coefficient of the standing fox is calculated $\rho_1 = (\frac{I_{max}}{I_{min}})^{-\frac{1}{2}}$.

In this case, - the indication of the microammeter at the maximum of the standing fox I_{max} - standing fox minimum I_{min}.

8. Similarly, the other thickness of the product being measured is determined $l_2 D_2$ and ρ_2.
9. Therefore, the size is calculated using the obtained.$\beta = 2\,\pi/\lambda_B$.
10. Calculate the quantities i to be determined using the following formulas$D_1 \rho_1$

$$\varphi_1 = 2\,\beta\,(D_1 - D_R - l_1) i. |G_1| = \frac{\rho_2 - 1}{\rho_1 - 1}$$

11. First. The complex is calculated using the following formula:

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

12. The relative solution of the equation is found.$C_1 < -\psi = \frac{th\,(T_1 < \tau_1)}{T_1 < \tau_1} T_1$and τ_1
13. Similarly, several complex numbers are calculated:

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

14. Similarly, it is calculated for a dielectric of thickness:l_2
$\varphi_2 = 2\,\beta\,(D_2 - D_R - l_2)$i.$|\Gamma_2| = \frac{\varphi_2 - 1}{\rho_2 + 1}$
15. The number of the second complex is:C_2
$C_2 < -\psi_2 == \frac{1}{j\beta l}\,(\frac{1-|\Gamma_2|e^{j\varphi_2}}{1+|\Gamma_2|e^{j\varphi_2}})$ and the solution of the following equation is found

$$C_2 < -\varphi_2 = \frac{\text{th}\,(T_2 < \tau_2)}{T_2 < \tau_2}.$$

Table 1. Dielectric conductivity of fruits and vegetables

№	Fruit is the name of a vegetable	Juice content,%	Dielectric conductivity f = 2300 MHt = 20^{0}C		
			ε'	ε''	tgδ
1	Apple: -Simirenko -Apport	 85.8 78.4	 60.2 59.6	 16.1 14.9	 0.26 0.25
2	Apricot: - diameter 24 mm with grains and husks - diameter 26 mm with grains and husks -merged 15mm, with grainsδ = -with soaked grains	 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 grains and husks - with grain and husk, diameter 30 mm -baked 18mm, with grainsδ = 16 mm without soaked stones,δ =	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 sticks	75.5	56.7	15.4	0.27
5	Potatoes: bar cubic- 15 mm 40 mm in diameter with potato peelings 15 mm in diameter with potato peelings	 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	Beets: Cuttingsbeets diameter 60 mm 80 mm	 84.5 84.5	 57.1 57.9	 14.9 15.2	 0.26 0.25
7	Onion Half ring	 89.4	 53.8	 14.3	 0.28

16. In this way, several complex numbers are found:

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

17. Now, using the following formulas corresponding to the found; is calculated; $y\varepsilon'\varepsilon''tg\delta$

$$y = g + j\beta \ ; \quad \varepsilon' = \frac{g + \left(\frac{\lambda_B}{2\,a}\right)^2}{1 + \left(\frac{\lambda_B}{2\,a}\right)^2} \ ; \varepsilon'' = \frac{B}{1 + \left(\frac{\lambda_B}{2\,a}\right)^2} \ ; \ tg\delta = \frac{\varepsilon''}{\varepsilon'},$$

where *y* is the length of the wide wall of the fox conductor

The results of the experimental study of the dielectric properties (conductivity) of fruits and vegetables, obtained and calculated by the above methodology, are included in the table:

As can be seen from the table, the dielectric constant of fruits and vegetables varies. Their value depends mainly on the amount of juice (water) in the composition of fruits and vegetables. There is also the effect of their components. Changes in the size of fruits and vegetables affect their value, but cutting them into different shapes does not change them. In general, it is possible to use the average value of the dielectric constant of fruits and vegetables in different calculations.

4 Conclusion

The curvature of the specific conductivity (σ) of EMF voltage (E) of crushed fruits, plums, apples, and carrots can be seen from the curves, all similar in nature, rising earlier and decreasing when they reach a certain maximum. The specific electrical conductivity at EMF voltage 83.1 V / cm is a maximum of 0.191 Sm/m. Also, during the operation of the electrodes in the cell -30 s, the electrical conductivity first increases rapidly; after 10 seconds, the growth decreases, and at a certain maximum time of 18 s it decreases, and the maximum size here ranges from 0.209 to 0.230 cm/cm. The variations of the specific electrical conductivity in fruits and vegetables have a large effect on their temperature differences and preservation times.

The dielectric conductivity of fruits and vegetables depends on their type and moisture content. The cell varies depending on the EMF frequency. Changes in the size of fruits and vegetables affect their value, but their different shapes do not change their dielectric constant. In technical calculations, it is advisable to use their average value.

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