Automatizing process of electroimpulse treatment of plant raw materials

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Abstract. Extraction of juice and removal of excess liquid from vegetable raw materials (vegetables, fruits, melons and crops, etc.) are the main technological operations during juice processing. The quality and quantity of the finished product depend on the efficiency of its implementation, for example, the drying process that determines the prime cost of its production. Therefore, technologies that allow solving this problem automatically in the most efficient way are relevant and require close attention not only of processing enterprises of various ownership forms, but also of research scientists. Such technologies include electric impulse processing of raw materials of plant origin before extraction or removal of moisture in the manufacture of juices, mashed potatoes, pastes, the drying of melons and fruits, etc. This technology has a great prospect, as it is characterized by low energy consumption, environmental cleanliness, food safety and can be fully automated. The control system of electric impulse processing, first of all, should receive primary information about the depth of the effects and the destruction of the intracellular structure of plant raw materials. The application of the received information allows electric impulse processing to adjust the frequency of the acting pulses and the voltage amplitude. This approach leads to reduction in the electrical energy input into the vegetable raw material for the destruction of cellular structures and, accordingly, to decrease in its consumption. The conducted studies allow asserting that it is best to use information on the change in the phase angle as the received information on the change in the electrophysical properties of plant tissue. The designed automatic system can be integrated with minimal constructive modifications into already existing lines for the processing of vegetable raw materials.

1. Introduction
Today, all over the world, there is growing interest in the implementation of automation systems operating on the basis of digital technologies in various operations and technologies of agricultural production, as well as the implementation of measures to save energy and increase efficiency, against the background of increased demand for finished products with improved properties and safe food qualities. Therefore, the search for new technological efficient, environmentally friendly and implemented with minimal energy costs solutions is acquiring special relevance. One of the most promising directions in the production, processing and storage of agricultural products is the use of various physical factors affecting primary raw materials, which make it possible to improve the quality and increase the amount of obtained products, which include the electric impulse processing of plants.
and raw materials from them [1]. Such processing is a variant of electrocontact processing of plant raw materials, when, as a result of organized destructive electrical effect on the raw material, technological effect is observed - increase in the output of intracellular solution (juice) into the intercellular space. The subsequent mechanical or thermal effect on the processed raw materials, organized by any traditionally used methods, allows obtaining an increased amount of juice, reducing the drying time, preserving the maximum possible amount of vitamins and nutrients, etc. The process itself is accompanied by minimal consumption of electrical energy and the ability to sterilize products without the use of heat or chemical reagents, solvents [2-6].

The purpose of the article is to substantiate method for assessing the electrophysical parameters of plant tissues after the destructive effect of high-voltage impulses and to develop an algorithm for the operation of the automated control system for the process of electro-pulse treatment of plant raw materials.

2. **Material and methods**

To conduct research on the study of the effect of high-voltage electrical impulse processing on the electrophysical properties of plant material, an experimental laboratory setup was assembled [7].

The schematic diagram of the laboratory installation includes the following electrical devices, apparatus and instrumentation (Figure 1): laboratory autotransformer; high-voltage test transformer TVI 15/20; digital multimeter MTX 3282; high voltage capacitor; processing chamber; switching unit; switch control unit; precision LCR-meter LCR-820; personal computer for collecting data and analyzing the results of their processing.

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**Figure 1.** Scheme of the experimental laboratory setup for studying the treatment process by high voltage impulses of plant raw materials

In the working chamber, designed for processing plant materials, there are two flat electrodes, one of which is rigidly attached to the base, and the other is movable, adjustable in height. The plant material was placed between two electrodes and the upper electrode created the required pressing force of the
processed volume of material. The LCR-meter was connected to the contact clamps of the electrodes to measure the initial parameters of the treated raw material, which was turned off after measurement and applying high-voltage impulse action to the electrodes. The designed switch control unit made it possible to set the required impulse repetition rate and their number. The value of the capacitor charge voltage was set using laboratory autotransformer according to the readings of the digital multimeter, which was connected to the resistive high-voltage voltage divider. After the completion of the treatment process, the working chamber was disconnected from the high-voltage circuit and connected to the LCR-meter to measure the changed electrophysical parameters of the raw material.

The preliminary preparation of the processed material for research consisted in cutting out cylindrical blanks of the same diameter using device specially designed for this purpose. After that, the cylindrical workpiece was cut into specimens 8 mm high. In the absence of deviations from the permissible values, the sample was considered fit for the experiment. In all experiments, the setup was tuned to the impulse repetition rate of 15 Hz, the number of impulses was set by a counter, the shape of high-voltage impulses was the impulse with a steep front and exponential decay, and the capacitor charge voltage was 8.5 kV. Carrot and apple fruits were used as plant material in the study.

3. Results and discussion
In the course of the research, it was decided to control and measure two electrophysical parameters that could most accurately reflect the changes that have occurred in plant raw materials. After electric impulse effect on the cell, pores of the critical radius are formed in the cell wall and membrane. As a result the cytoplasm and other intracellular components flow into the intercellular space and mix with the intercellular solution. The complex resistance of plant raw materials should decrease due to an increase in free liquid in raw materials. Since the basic electrical circuit of plant cell substitution is series-connected and parallel-connected components whose prototypes are resistors and capacitors [8-9], the released intracellular fluid should affect decrease in the capacity of "biological capacitors" and, as a consequence, increase in the phase shift angle due to reducing the capacitive component.

The results of the carried out research are presented in Figures 2 and 3.

![Figure 2](image)

**Figure 2.** Dependences of the complex resistance and phase shift angle on the number of acting high-voltage impulses for carrots
According to the results of the conducted experiments and the analysis of the processing of the collected data, it can be noted that the assumption of decrease in the complex resistance and increase in the phase shift angle is correct. Therefore, using these parameters to assess the state of the processed plant tissues, the degree of damage to plant raw materials can be evaluated. In the figures, a sharp decrease in the values and the same similar nature of changes in the characters of the dependences of the parameters of plant raw materials in the range of up to 100 acting impulses, followed by this slight decrease, can be observed. At the same time, in carrots, the complex resistance decreased 26 times, and in an apple - 53 times. The phase shift angle for carrots changed 6 times, and for apples - 3 times. From the obtained experimental data, it can be assumed that it is more convenient to track damage to cells of plant materials based on the measured resistance, not on the phase shift angle, since it is easier for an automatic control system to record significant changes in resistance instead of small changes in the phase shift angle.

Evaluation of the viability or damage of plant materials based on the measurement of complex resistance is not new and occurs in different variations, such as the polarization coefficient, the degree of damage and the degree of destructuring [8-10]. These methods for assessing plant tissue damage have been proven and are an effective indicator for assessing the depth of damage.

Nevertheless, due to the low speed of measuring complex resistance, these methods are not suitable for in-line production. Assessment of damage to plant raw materials by measuring the change in the phase angle can occur at high speed and sufficient accuracy for the purposes set. The proposed method for measuring the phase shift angle is based on the transformation of the shift angle, between signals, in the time intervals between impulses, the duration of which is measured by the microprocessor used for these purposes.

To implement the system of automatic control over the parameters of the electric impulse treatment process, it is proposed to install measuring sensors at the entrance to the chamber and exit from it to measure the initial and changed phase angle. This approach will make it possible to assess quickly the degree of damage to plant materials and quickly respond to changes in the phase shift angle; to change the amplitude of the high-voltage impulse or the impulse repetition rate in order to achieve maximum processing efficiency. Figure 4 schematically shows the automatic system for processing plant raw materials.
materials. Figure 5 shows the simplified algorithm for the operation of the automated electrotechnical installation.

Figure 4. Block diagram of the automatic system for processing plant raw materials

The presented algorithm of automatic operation (Fig. 5) consists in finding and maintaining the optimal degree of damage to plant materials. When the unit is turned on, the maximum impulse repetition rate and the technologically justified processing voltage are set. The raw material is processed, after which the maximum damage is calculated, which is in the range from 0 to 1, after which, as it can be seen from the experimental graphs, the most serious damage occurs abruptly. And further increase of the acting energy does not greatly affect the damage to the raw material. Therefore, the installation, relying on the value of the maximum damage, first begins to reduce the frequency of the acting impulses, and then the processing voltage, selecting the optimal mode of operation. Moreover, it further maintains the optimal value of the damage by increasing or decreasing the frequency and voltage of high-voltage impulses.
Figure 5. Simplified algorithm for the functioning of the automatic system for processing plant raw materials

4. Conclusion
The results of the conducted experiments allow one to state that the change in the complex resistance and the phase shift angle from the number of impulses during processing can be proposed as an alternative system for assessing the degree of damage to the plant tissue of raw materials. The algorithm for the functioning of the automatic installation for electrical impulse processing of raw materials is proposed for implementation, the basis of which consists in measuring the difference in the phase shift angle.

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