Determination of the influence of the electrohydraulic effect on succulent plant raw materials

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Abstract. The study is aimed at assessing the influence of the electrohydraulic effect on succulent plant raw materials. Experimental data show that the use of electrohydraulic effect helps to increase the juice yield of raw materials due to the active effect on the protoplasm of cells and increasing their permeability. It has been established that the optimal processing mode using the electrohydraulic method at 7 kV and 1 μF provides maximum juice yield, especially for pulp with a liquid consistency, such as grape pulp. Microscopy results revealed changes in cell structure, confirming the effectiveness of this treatment method. The developed experimental electrohydraulic effect installation takes into account the scientific findings obtained and represents a promising means for processing grape pulp in a stream. Thus, the study confirms the significance and potential of using the electro-hydraulic method to improve the production process in the food industry.

1 Introduction

One of the main links in the production technology of a number of industries (food, wine, pharmaceutical, perfume, etc.) is the process of extracting juice from plant cells. To obtain the most complete yield of juice, it is necessary to first destroy the protoplasm of the cells. This is achieved by grinding, blanching, treatment with enzyme preparations and electrophysical methods, one of which is electroplasmolysis [1-3].

Electroplasmolysis is a technological process that is intended to intensify the press method of processing plant raw materials. After exposure of a plant cell to an electric field and heat, a state of plasmolysis is created in it - the removal of protoplasm (cytoplasm) from the membrane, which leads to an increase in cellular permeability, and consequently, juice yield. Electroplasmolysis refers to electrocontact processing processes. It is carried out on direct, alternating (industrial - 50 Hz and higher frequencies) and pulsed currents. There are high-gradient (1800-2000 V/cm or more) and low-gradient (11-130 V/cm) electroplasmolysis. And since it is an electrophysical process, it is easy to control by changing

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the electrical parameters of the circuit. When an electric current flows through the compacted pulp of plant tissue, it heats up, therefore electroplasmolysis is often called electrothermoplasmolysis [4-6].

The juice content in fruits and vegetables, as is known, reaches 90-95%, and when processed under production conditions, the juice yield is only 50-70% [7-9]. The currently used press-extraction and press-enzyme methods do not allow the juice to be extracted from crushed plant materials quickly and completely [10, 11].

The method of pulsed electroplasmolysis is that short (several microseconds) electrical pulses, the power of which can reach 50,000 kW, are passed through compacted sugar beet shavings. As a result of this effect, the plasma membrane ruptures [12].

The process of extracting juice from fruits and berries in the production of fruit and berry juices, as well as in the wine industry, differs from similar processes in beet sugar production in that the juice from fruits and berries is extracted more easily by pressing than from sugar beets [13].

Since the discovery of the electrohydraulic effect (EHE) by L.A. Yutkin in the early 50s, a large number of studies have been carried out in the field of studying the physics of the process. It has been established that the electrohydraulic effect occurs during high-voltage spark breakdown of a liquid and is accompanied by the following phenomena: a powerful shock wave, intense ultrasonic and light radiation, cavitation processes, pulsed magnetic fields, etc. [14]. It has been proven that such a complex of simultaneously acting physical phenomena can be used to intensify technological processes in more than 60 sectors of the national economy [15]. Most of the work both in our country and abroad involves the use of EGE in molding and stamping. metals, casting cleaning, pipe flaring, and grinding of various materials.

Research into the possibility of using EHE in food production processes is scarce. At this stage of work we were faced with two tasks. The first is to determine the nature of the EH effect on fruit tissue of succulent plant raw materials. We were not interested in the biological side of the impact on the life processes of the cell, but in the possibility of intensifying the technology for processing this raw material and, first of all, the process of extracting juice. In doing so, we proceeded from the well-known plasmatic theory of juice yield, according to which the yield of juice depends on the degree of damage to the protoplasmic cell membranes, which are the main obstacle to the release of juice and substances dissolved in it. The second task was to determine the optimal mode of EH processing of raw materials, which would produce the maximum yield of juice and would not deteriorate its quality. Considering that the effectiveness of the EHE depends on many factors (the inductance of the current pulse generator, the area, shape of the electrodes and the distance between them, the shape and volume of the working chamber, the type and temperature of the liquid, as well as the operating voltage, capacitance of the capacitor bank and the number of pulse discharges) , we set out to determine the influence of changes in the values of the last three factors on the processing of succulent plant raw materials under other identical conditions [16-18].

2 Materials and methods

The studies were carried out using a laboratory current pulse generator with an inductance of 3.6 μH, connected via copper busbars to the working chamber, which was a cylindrical vessel with a capacity of 2.2 liters with a spherical bottom and a hermetically sealed lid. The vessel was placed in a tank with running water. The positive electrode was made of a steel rod 8 mm in diameter with a sharpened end. The electrode had polyethylene insulation and was tightly inserted into the chamber lid. The bottom of the chamber served as the negative electrode. Distilled water was used as the working fluid (ρ = 120,000 – 196,000 Ohm/cm).

The main raw material for the study was sugar beet shavings, which can be used for a long time. Other types of raw materials were also used (apricot, plum, cherry, etc.).

3 Results and discussion

Preliminary search work made it possible to establish the following boundaries of EG processing parameters: U = 3, 5, 7 kV, C = 0.2-1 μF, the number of pulses is up to 50, the working gap between the electrodes is 30 mm. The weight ratio of chips and water is 1:2.5. For comparison, a control experiment was performed in parallel with each experiment, in which the EG treatment was replaced by mixing. The main criteria for assessing the effect of EG on succulent plant raw materials were the following: the content of dry substances in the juice extract, the percentage of damaged cells, the degree of diffusion equilibrium, an increase in juice yield and tissue microscopy.

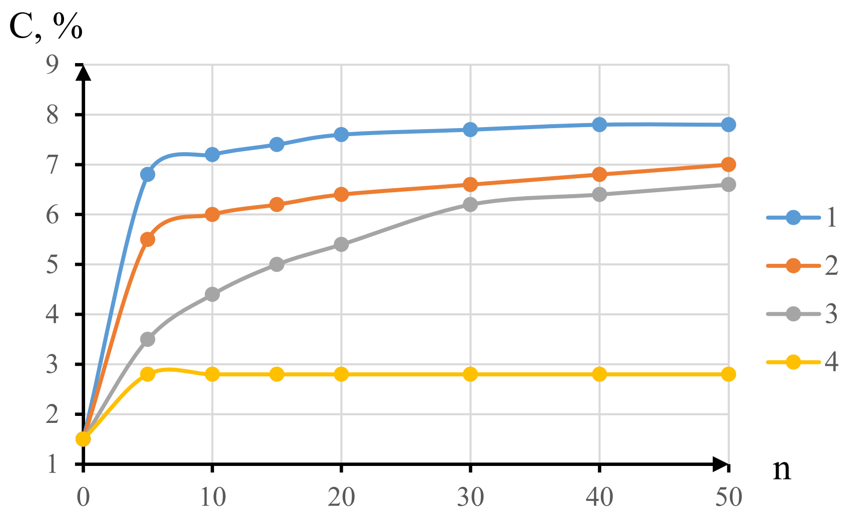

Fig. 1. The yield of dry substances from sugar beet shavings during EH processing depending on the number of pulses n at different voltages (C = 1 μF): 1 - 7 kV; 2 – 5 kV; 3 – 3 kV; 4 – control.

The relationship between the content of dry substances in the juice extract and the number of pulses when operating in mode C = 1 μF, U = 3, 5, 7 kV is shown in Figure 1. Analysis of the data obtained suggests that the transition of dry substances from sugar beets into water during EG treatment is directly dependent on the increase in voltage, capacitance of the capacitor bank and the number of pulses. The yield of dry substances at 5 and 7 kV differs little, but in the latter case there is a significant rise in temperature (up to 48 °C). Considering the above, the EG treatment mode at 7 kV and 1 μF should be considered optimal. The given dependencies indicate that the bulk of dry substances in all cases is extracted within a limit of up to 10 pulses.

To release the bulk of dry substances from sugar beet shavings, 20 pulses are required (Figure 2). Since in this case the chips are practically crushed a little, the increase in the yield of dry substances into juice can be explained by internal damage to the protoplasmic cell membranes. This is confirmed by the results of a study of the percentage of damaged cells, determined according to the method proposed in [17]. The technique is based on the fact that when plant tissue is washed with cold water, the contents of damaged cells are washed away, while whole cells retain substances soluble in cell sap. According to the data obtained, the bulk of cells are damaged within up to 20 pulses.

The indicator on which the degree of diffusion equilibrium depends is cellular permeability. The method for determining it is to infuse plant tissue with water for 30 minutes [18]. Like the previous one, this method is based on the easy washing of dry substances with cold water only from damaged cells. It has been established that the maximum value of the degree of diffusion equilibrium is in the limit of up to 20 pulses; further increase in the number of pulses does not change the result.

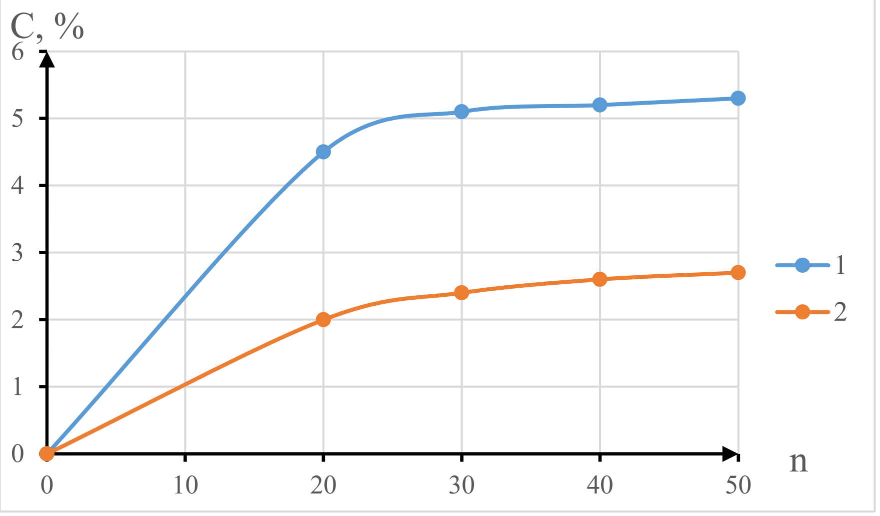

Fig. 2. The yield of dry substances from sugar beet shavings is within the limits of up to 50 pulses (C=1 μF, U=7 kV): 1 – experiment; 2 – control.

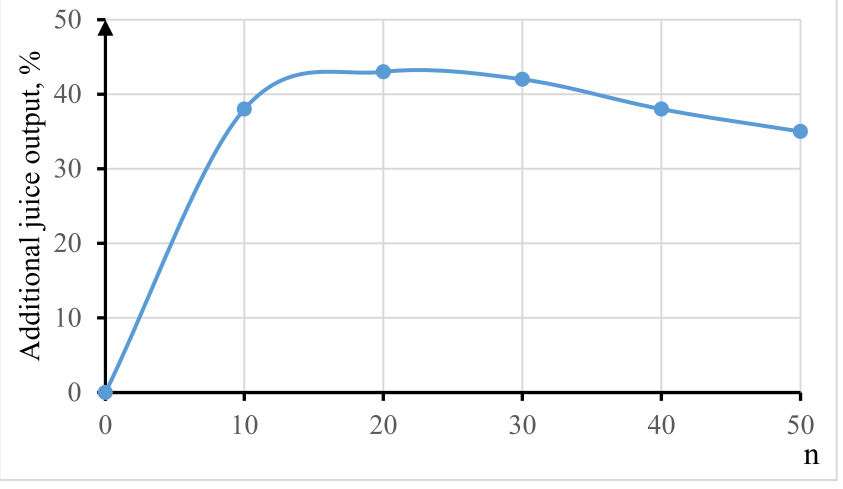

Fig. 3. Increasing the yield of juice from sugar beets treated with different numbers of pulses (C=1 μF, U=7 kV).

As would be expected, given the experimental data, the juice yield from raw materials subjected to EG exposure increased significantly. The dependence shown in Figure 3 shows that an increase in output is observed in experiments up to 10 pulses; up to 30 pulses it remains almost constant, and then decreases. This is explained by the strong grinding of the chips, and consequently, the deterioration of the juice yield during pressing.

In order to confirm the damaging effect of EHE on the cells of succulent plant raw materials, microscopy was carried out. Due to the grinding and softening of tissues during EH processing, obtaining thin sections is associated with certain difficulties. Analysis of the above, as well as other images from the tissues of sugar beets, carrots, apricots, and plums allowed us to conclude that in the process of EH processing of raw materials (such as sugar beets, carrots, quinces), a decrease in the volume of cells, a change in their shape, a violation of the internal structure and rupture are observed membranes of individual cells. In soft tissues (such as apricot, plum) there is a rupture of intercellular connections and separation of cells, a change in their shape, compression of the protoplasmic membrane and leaching of cell contents.

4 Conclusion

EH-processing of succulent plant raw materials helps to increase its juice yield.

The main reason for the increase in juice yield is the active effect of EHE on the protoplasm of cells, as a result of which its permeability increases.

Due to the transfer of dry substances into the environment, this treatment can only be recommended for pulp with a liquid consistency (like grape pulp).

The established optimal mode with minor refinements was used in the development of a pilot EH installation for processing grape pulp in a stream.

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