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The influence of the impact of electrical impulses on the juice outputting of the pulp

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Abstract. In this article was applied a comprehensive research method which made it possible to quite fully investigate the mechanism of the effect of electrical impulses on the protoplasm of cells and determine the optimal parameters of such effect on plant raw materials, ensuring high efficiency of their use to increase the juice yield. The complex research method made it possible to obtain the necessary data for the implementation of the electrical method for intensifying the process of extracting juice from plant materials. Due to the fact that the issues related to the use of electrical impulses for the processing of plant materials have been little studied and there is no sufficiently clear understanding of the mechanism of such an effect on living cells, we made an attempt to investigate the mechanism of this process. A technique has been developed for studying the dynamics of the action of electric current on plant tissue cells. We expressed the yield of juice from raw materials as a percentage of the weight of the pulp, which was processed and pressed. Thus, a comparison of the results of individual experiments showed an absolute increase in juice yield as a percentage.

1. Introduction

Several methods of electrical technology have already found apply in the production of juices. The original method of using electrolysis - electro flotation allows you to purify and clarify juice. Electro plasmolysis and electrohydraulic processing of the pulp before pressing lead to an increase in the juice yield. High-frequency sterilization and electrical contact heating can also be successfully used in juice production. Thus, now a fundamentally new direction is being born, a direction that undoubtedly has a great future the electrical technology of juices.

In the technology of press extraction of juice, a significant role is given to the operation of grinding raw materials. For each type of plant material, there is an optimal degree of grinding before pressing, which ensures the maximum yield of juice in a short time, and therefore it is very important to be able to correctly determine the size of the particles obtained after grinding. Equally important for the pressing process is the uniformity of the pulp particle composition.

The processing of plant materials with electric current allows increasing the yield of juice during pressing due to the destruction of the protoplasm of the cells. At the same time, a sufficient effect of increasing the juice yield is obtained only with a certain ratio of the parameters of the electrical effect and the duration of this effect on the raw material. At once the mechanical characteristics of the raw material, the quality of the pulp preparation, the parameters of the pressing process itself, and many other factors have a significant impact on the overall yield of juice. The use of electrical impulses for processing the pulp introduces its own, still poorly studied, features and patterns into the juice extraction process.

Some methods of electrical technology have been shown by many researchers, under electrical influences on plant tissue, the protoplasm of its cells dies and thereby loses the ability to retain vacuolar sap. However, only the effect of processing the pulp with an electric current of the 220/380 V mains voltage has been sufficiently studied, and the question of the effect of electric high-voltage pulses on the juice yield of the pulp has not yet been raised and is largely unclear. There are fundamental differences between these two types of electrical influences. For example, the electrical energy stored in a capacitor at a high potential gradient, when it is discharged to the pulp, affects the cells of plant tissue within microseconds. At the same time, a significant power develops, many times, by about 3 orders of magnitude, exceeding the power of the action of a current with a voltage of 220 V. This causes a qualitative difference between such pulse action on plant tissue from the action of currents of low potential gradients [1-5].

A study by microphotography and direct visual observation of the dynamics of the action of an electric current on plant tissue cells and a comparison of our results with the data of other authors showed that the nature of the destruction of cell protoplasm by electric impulses is somewhat different than when exposed to an electric current with a voltage of 220 V. Treatment of plant tissue with an electric current low potential gradients leads to cell death, but the protoplasm does not disintegrate, but only loses the ability to retain juice in vacuoles. When exposed to electrical impulses, the death of protoplasm is accompanied by its decay. This difference in the nature of these two types of electrical impact required special research. It was necessary to find out how the processing of the pulp with electrical impulses affects its juice yield in order to clarify the possibility and effectiveness of using such an electrical effect to intensify the juice extraction process [6-10].

2. Materials and Methods

Treatment of plant materials with electric current allows one to increase the yield of juice during pressing due to the destruction of cell protoplasm [11-16]. At the same time, a sufficient effect of increasing the juice yield is obtained only with a certain ratio of the parameters of the electrical effect and the duration of this effect on the raw material. At once the mechanical characteristics of the raw material, the quality of the pulp preparation, the parameters of the pressing process itself, and many other factors have a significant impact on the overall yield of juice. At the same time, a sufficient effect of increasing the juice yield is obtained only with a certain ratio of the parameters of the electrical effect and the duration of this effect on the raw material. At once the mechanical characteristics of the raw material, the quality of the pulp preparation, the parameters of the pressing process itself, and many other factors have a significant effect on the overall yield of juice. The use of electrical impulses for processing the pulp introduces into the process of extracting juice its own, still poorly studied, features and patterns [1, 2, 4, 7, 25, 26, 27, 28].

3. Results and Discussion

Experiments were carried out on crushed apples and grapes. For this, a weighed amount of crushed raw material was placed in a cuvette with graphite electrodes (Figure 1), flat weights were applied to the pulp, and electrical impulses were applied to the compressed pulp from a battery of high-voltage capacitors with a capacity of 2.2 μF. The juice from the cuvette ran down the trays into two measuring glasses.

The processing of the pulp with electric pulses was carried out as follows. A cable from a high-voltage installation was connected to the terminals of the cuvette with the pulp. A high-voltage rectifier unit was connected to a 220 V network. The voltage across the high-voltage transformer was gradually raised by an autotransformer. As the voltage supplying the installation increased, the voltage across the capacitors increased, and when the set value, regulated by the gap of the spark gap, was reached, a breakdown occurred. The capacitors were discharged to ground through a cuvette with pulp. The high-voltage pulse affected the pulp. The duty cycle of the pulses was controlled by the voltage in the primary circuit of the installation, by changing the strength of the charging current [17, 18, 19, 20].

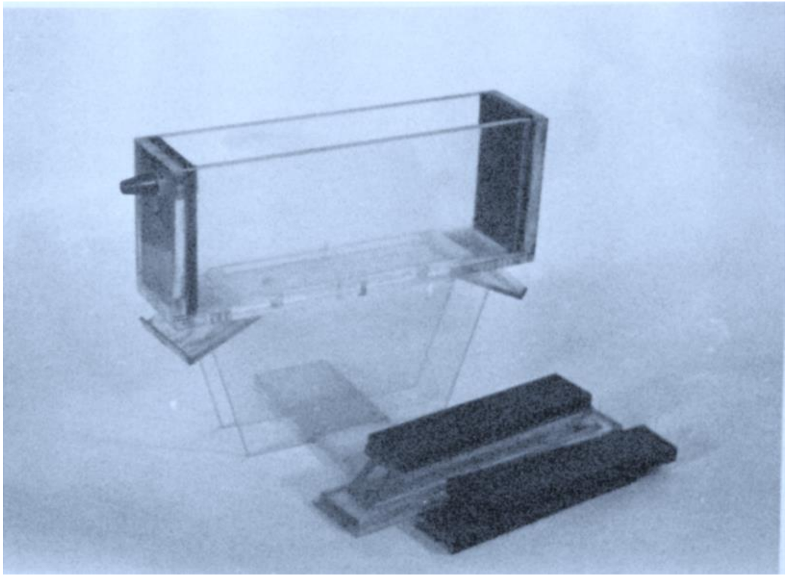

Figure 1. Bath for processing mash with electrical impulses and flat weights with a pressure board

Table 1. Influence of electrical impulses on the yield of crushed grape juice at different values of specific pressure (pulp weight - 1000 g; degree of grinding, $1/d_e = 0.222$; voltage - 4.8 kV; capacity - 2.2 μF; number of pulses - 25; pulse duty cycle - 1.4 sec.)

Time, min	Specific pressure 2.5 kgf/cm^2				Specific pressure 5 kgf/cm^2			
	without electrical processing		with electrical treatment		without electrical processing		with electrical treatment	
	juice volume, ml	juice yield, %	juice volume, ml	juice yield, %	juice volume, ml	juice yield, %	juice volume, ml	juice yield, %
2	44	4.4	70	7.0	61	6.1	91	9.1
4	115	11.5	177	17.7	160	16.0	225	22.5
8	228	22.8	314	31.4	286	28.6	380	38.0
12	290	29.0	388	38.8	345	34.5	452	45.2
16	316	31.6	434	43.4	360	36.0	504	50.4
20	325	32.5	456	45.6	371	37.1	536	53.6
24	330	33.0	469	46.9	375	37.5	550	55.0
30	334	33.4	473	47.3	378	37.8	558	55.8
35	335	33.5	475	47.5	381	38.1	560	56.0
40	336	33.6	475	47.5	381	38.1	560	56.0

In the experiments, the pressing cycle time, the total processing time of the pulp with electric pulses, the number of pulses, and the voltage at which the capacitors were discharged were recorded. The amount of juice coming out of the pressed pulp was recorded at certain time intervals separately for the anode and cathode parts of the cuvette. This was done in order to simultaneously detect the presence of electroosmotic transfer of juice to one of the electrodes under the action of electrical impulses [21, 22, 23, 24].

The experiments were carried out at different values of the specific pressures on the pulp, and the pressure remained constant throughout the experiment. The pulp of varying degrees of grinding was

treated with electrical impulses.
For comparison, as a control, similar experiments were carried out without processing the pulp with electrical impulses.
In the first series of experiments, the results of which for grapes are shown in Table 1, the processing of the pulp with electric pulses began simultaneously with the start of pressing.
From the graph in Figure 2, built on the basis of these experiments, it can be seen that, as a result of the effect of electrical impulses on the compressed pulp, the juice yield increases. This occurs due to the destruction of the protoplasm of cells that survived during grinding. With an increase in the specific pressing pressure, the effectiveness of such an effect increases. This can be explained by a better compaction of the pulp, improved contact between tissue particles and thereby an increase in the efficiency of electrical processing. Apparently, a certain role is played by a certain decrease in the elastic modulus of plant tissue, as a result of exposure to electrical impulses.
Comparison of curves 1' and 2' in this graph shows that the processing of the mash with electric pulses affects the juice yield more than a simple increase in the specific pressing pressure from 2.5 kgf/cm^2 to 5.0 kgf/cm^2. This conclusion confirms the well-known theses that it is almost impossible to obtain a high yield of juice from raw materials only by using high specific pressing pressures [4, 24].

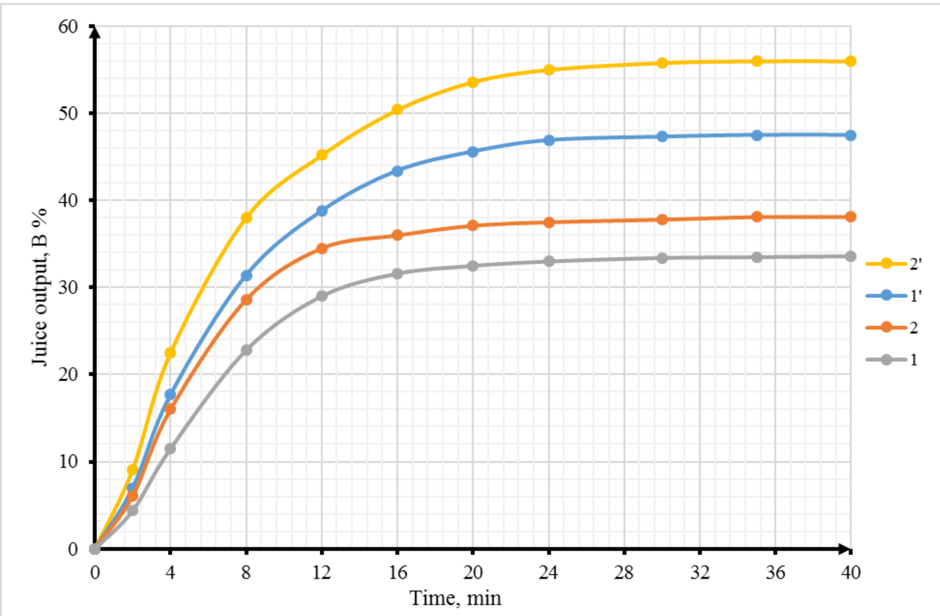

Figure 2. The influence of electrical impulses on the yield of crushed grapes under pressure: 1-2 kgf/cm^2; 2-5.0 kgf/cm^2; 1' and 2'- treatment with electrical impulses

The results of our experiments to determine the electrical conductivity of the pulp during pressing showed that, from the moment the juice separates from the pulp, an increase in the electrical resistance of the pressed pulp is observed. Therefore, it should be expected that the efficiency of processing the pulp with electric pulses can be somewhat higher if it is carried out after squeezing out the bulk of the juice contained in the pores and capillaries of the pulp body.
In order to clarify this situation, experiments were carried out in which the pulp was processed with electrical impulses not immediately after the start of pressing, but after a certain period of time. During this time, the bulk of the juice came out of the pulp and the pulp was compacted. The electrical impulses were applied to the compacted pulp, which had good contact between the particles. The results of these experiments are shown in Table 2, and are graphically shown in Figure 3. The processing of the pulp with electric impulses was carried out after 20 minutes of squeezing the juice out of it.

Table 2. Dependence of the juice yield on the processing of the pulp by electric impulses (Pulp weight - 900 g; specific pressure, p = 2.5 kgf / cm2; voltage, U = 6.5 kV; capacitance of capacitors, C = 2.2 μF; pulse duty cycle - 1.4 sec; number of pulses - 65)

Time, min	$1/d_e = 0.166$		$1/d_e = 0.222$		$1/d_e = 0.333$	
	volume ml	juice yield, %	volume ml	juice yield, %	volume ml	juice yield, %
2	76	8.4	91	10.1	114	12.7
4	143	15.7	175	18.3	197	21.9
8	225	25.0	258	28.7	308	34.2
12	265	29.4	313	34.8	360	40.0
16	274	30.5	338	37.6	383	42.6
20	279	31.0	348	38.7	395	43.9
24	398	44.2	444	49.3	477	53.0
30	463	51.4	488	54.2	515	57.2
35	475	52.8	498	55.4	519	57.7
40	477	53.0	500	55.5	522	58.0

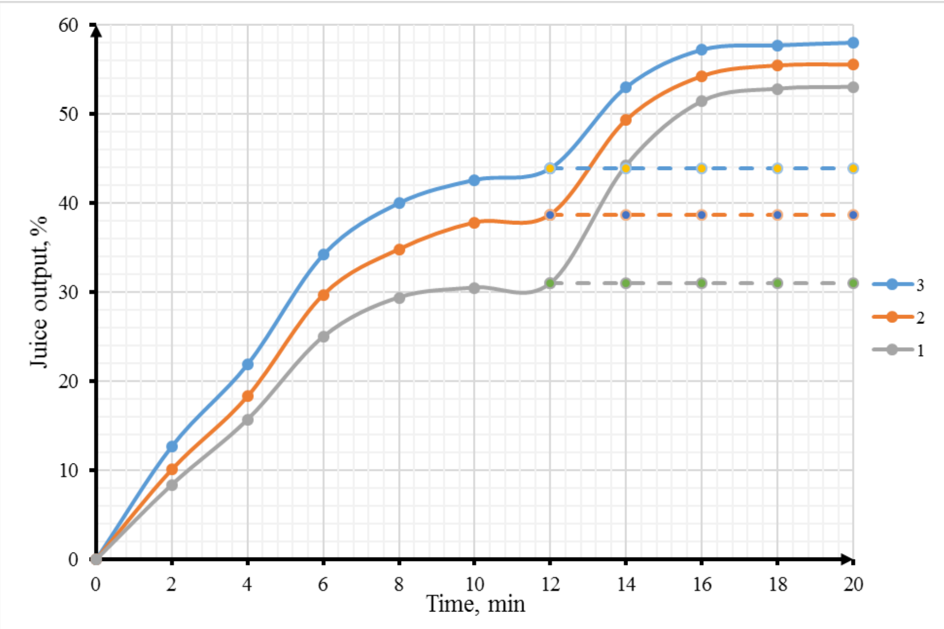

Figure 3. Influence of the processing of pulp of various degrees of crushing on the juice yield by high voltage electrical impulses. Grinding degree: 1-0.166; 2-0.222; 3-0.333

The table contains the results of experiments carried out on the pulp of three degrees of grinding. In the graph (Figure 3), the dotted line shows the extrapolation of the curves of the juice yield in time.
Analysis of the data obtained shows that juice is intensively separated from the pulp at the beginning of the pressing process, but by 10-12 minutes of the process, the juice release rate noticeably decreases and then only a slight increase in the juice yield occurs. Almost by the 20th minute, the juice output stops. An increase in the degree of grinding of raw materials leads to an increase in the yield of juice, but even in the case of pressing a pulp of a high degree of grinding, the bulk of the juice is separated in the first 20 minutes of pressing. Further management of the pressing process practically does not increase the juice yield. From this we can conclude that all the juice came out of the pulp.
However, the impact on such a squeezed pulp of electrical impulses leads to the fact that juice begins to come out of it again. This is the juice that was contained in cells that were not mechanically destroyed. Hence it follows that the applied pressure values on the pulp did not squeeze out the juice

from the whole cells that survived during the grinding of raw materials, but electrical impulses destroyed these cells.

With an increase in the degree of grinding of raw materials, such whole cells remain less and less. But even in the pulp with small particles, there are still quite a lot of whole cells, which leads to an additional yield of juice after processing the squeezed pulp with electric pulses (curve 3 in Fig. 3).

Comparison of the values of the total juice yield from the pulp of three degrees of grinding, exposed to electric pulses, shows that the parameters of the pulses used in this series of experiments are not optimal, since the total juice yield from the pulp with large particles remains somewhat lower than from the pulp with high degree of grinding. But even in this case, the juice yield is much higher than that obtained with conventional pressing.

Comparison of the results of the experiments given in Tables 1 and 2 and in Figures 2 and 3 shows that the effect of electrical impulses on the pulp, from which most of the juice is squeezed out, is somewhat more effective than in the case of processing the pulp saturated with juice. At the same time, it should be noted that the difference in the efficiency of these two cases of processing with electric pulses is not as significant as could be expected based on the dependence of the electrical conductivity of the pulp on pressure.

Perhaps this is due to the fact that at high potential gradients, the destruction of the protoplasm of plant tissue cells occurs not so much due to the thermal action of the electric current (as is the case in the case of electro plasmolysis at low voltages), but due to the force interaction of the field with the electrically charged cell system.

Thus, as a result of the studies carried out on the effect of electrical impulses on the pulp, the possibility of their use for processing raw materials with the aim of more complete extraction of juice by pressing was established. The optimal combination of specific pressing pressures, the degree of grinding of the raw material and its processing with electrical impulses should ensure a high yield of juice.

In the experiments carried out, an attempt was made to reveal the presence of movement of the juice to one of the electrodes by the forces of electro osmosis under the influence of electrical impulses. However, we did not receive a clear answer to this question. In some experiments, there was a noticeable difference in the yield of juice at the anode and cathode parts of the cuvette (the cathode has a greater yield of juice), but the repeatability of the results was poor. Therefore, for the final judgment on the presence of such an effect when electric impulses are applied to the compressed pulp, it is necessary to carry out special extensive studies.

4. Conclusions

The effect of electrical impulses on the pulp is manifested in a significant increase in the yield of juice from it during pressing. An increase in the degree of grinding of raw materials leads to an increase in the yield of juice before the processing of the mash with electrical impulses and has a very weak effect on the overall yield of juice. The high efficiency of the press extraction process can be ensured by an optimal combination of specific pressing pressures, the degree of grinding of raw materials and processing of the pulp with high voltage electrical impulses.

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