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THE INFLUENCE OF CAVITATION EFFECTS ON THE PURIFICATION PROCESSES OF BEET SUGAR PRODUCTION JUICES

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ABSTRACT
The existing technology for the purification of diffusion juice and its hardware design has not fundamentally changed over the past four decades. The lack of the necessary theoretical developments and experimental data hinders the development of existing and the development of new technological processes. Therefore, the main direction of improving the purification efficiency of juices of sugar beet production is the disclosure of its unused reserves and their implementation in practice. The scientific problem of choosing the rational direction for improving the technology of juice purification, which ensures the production of consumer granulated sugar in the face of changes in a wide range of quality of raw materials, is relevant and has important economic importance, especially in the context of the transition of beet sugar factories to a market economy. One way to solve it is to make fuller use of the adsorption capacity of calcium carbonate particles while increasing the filtration properties of saturation sediments. Therefore, the study investigates the effect of cavitation effects – vapor condensation and hydrodynamic processing of diffusion juice on the processes of purification of diffusion juice, juices of preliminary defecation, first and second saturations. The analysis of the influence of various effects of cavitation processing of juices from the point of view of improving the purification efficiency, the optimal place of the purification process in the technological scheme of production is established.

Keywords: diffuse juice; preliminary defecation; saturation; intensification; cavitation

INTRODUCTION
Classical methods of intensifying the processes of calc-carbon dioxide purification of diffusion juice of sugar beet production by changing the temperature, alkalinity, or duration of individual stages do not provide an increase in the purification efficiency. In particular, analyzing the conditions of the processes at the previous defecation is found **(Ozerov and Sapronov, 1985; Johnson, Zhou and Wangersky, 1986)** that the limiting factor at this stage is the rate of delivery of reagents to the reaction zone. In this regard, the authors of **(Lee et al., 2012)** propose a method of intensifying preliminary bowel movements using hydrodynamic (HD) cavitation, which significantly accelerates the mixing of reagents due to shock-wave action during the collapse of cavitation bubbles. But under these conditions, along with positive signs, there is also a slight deterioration in the sedimentation-filtration properties of juice of I saturation **(Almohammed, et al., 2015; Palamarchuk et al., 2019)**, which can most likely be explained by cavitation destruction (grinding) of sediment particles formed during the previous defecation.

There is also information about the application of the method of blowing steam into the juice stream to intensify the purification and sedimentation processes **(Lebovka, et al., 2007; Dalfré Filho, Assis and Genovez, 2015)**, which helps to reduce the content of calcium salts and the color of the juice of II saturation **(Kim et al., 2016)**.

But in the mentioned works (especially on the injection of water vapor), the physical essence of the effects and the mechanisms of their action on the physicochemical transformations of non-curved diffusion juice is not considered, but only the positive consequences taking place, in this case, are given. In addition, the literature does not contain data comparing the effects of hydrodynamic (HD) or vapor condensation (VC) cavitation processing of juices in terms of improving the purification efficiency and research to establish the optimal place in the technological scheme of purification and has become the subject of our research.

Scientific hypothesis
The scientific hypothesis lies in the rational direction of the intensification of the technology for the purification of beet sugar juices. It is assumed that an increase in the quality and yield of sugar is possible due to the collapse of steam bubbles during the vapor condensation and

hydrodynamic cavitation. The latter accelerate the main reactions at the stages of juice purification, leading to an increase in the overall purification effect.

MATERIAL AND METHODOLOGY

The objects of research are diffuse juice, juice of preliminary defecation, juice of the first and second saturation. Diffuse juice is processed in a hydrodynamic cavitation installation under optimal conditions. Samples of diffusion juice according to standard methods **(Ozerov and Sapronov, 1985)** in laboratory conditions are processed before the juice of preliminary defecation and the first and second saturation.

For preliminary defecation juice and juice of the first saturation, the sedimentation rate and juice sedimentation volume after settling are determined after 20 minutes; for the second saturation juice, the content of calcium salts in percent by weight of the juice and its purity are determined.

It is known that the shock-wave effect of a hydrodynamic cavitation field on the medium is processed, determined by the stage of cavitation **(Sheiko et al., 2019; Sukhenko et al., 2019)**. In this case, the effective regime of cavitation mixing and dispersion corresponds to the maximum of the shock-wave action of cavitation field bubbles on the medium, it is being processed **(Matyashchuk et al., 1988)**. Therefore, the cavitation stage λ is used by us as a determining parameter for characterizing the operation mode of a hydrodynamic cavitation device and ranged from 0.62 to 4.0. This choice is because at $\lambda = 1.0$ a flow regime arises, which is characterized by a bubble form of cavitation, which can be considered transitional from turbulent to cavitation. At $\lambda = 4.0$, which is characterized by a mixed form of cavitation, a super-cavitation regime begins to form.

To determine the sedimentation rate, a 2-liter cylinder was used, which was used to determine the height of the clarified suspension and the sedimentation rate after 5 minutes. To determine the purity of the juice it is necessary: to divide the sucrose content by the dry matter content. The dry matter content was determined using a URL-1 refractometer (supplier company PrimaRia, Kiev, Ukraine), and the sucrose content was determined using a SU-4 saccharometer (supplier company PrimaRia, Kiev, Ukraine).

Processing of the medium in the working area of the hydrodynamic cavitation installation occurs under the influence of cavitation bubbles, splashing. Therefore, the number and size of the formed cavitation bubbles are the determining factors of the technological efficiency of the cavitation treatment. In turn, the structure of the field of cavitation bubbles depends on the hydrodynamic parameters of the process, the main of which are the flow rate in the gap between the cavitator and the wall of the working section of the cavitation device and the stage of cavitation λ **(Luo et al., 2019)**. Therefore, the establishment of the hydrodynamic operating conditions of the installation was first carried out on barometric water with a temperature of 50 °C, which is similar for diffusion juice (diffusion column). The compression ratio of the flow in the working area of the laboratory setup is changed by establishing cavitators of different diameters with a Reynolds number of (23.6 – 25.4) $x10^4$. The cavitation stage was also determined on the water by visual measurement of the cavitation length in its characteristic radius.

Statistic analysis

Mathematical and statistical processing of experimental data was carried out in determining the criteria of Cochran's C test, Fisher and Student's *t*-test. The accuracy of the data was determined using the Cochrane criterion, and the adequacy of the mathematical model was checked using the Fisher and Student criteria. Statistical processing was performed in Microsoft Excel 2013 values were estimated using mean and standard deviations.

RESULTS AND DISCUSSION

In **Kozelová et al. (2011)** and **Zheplinska et al. (2019)** it is found that the efficiency of processing diffusion juice in a hydrodynamic cavitation device with increasing compression ratio increases and is largest at $d_{к\text{-}ра}/d_p = 0.8$. Therefore, the effect of the cavitation stage on juice processing is determined at a given constant value of the compression ratio **(Jia-Qian, 2015)**. Figure 1 shows the technological parameters of the juice of preliminary defecation during the processing of diffusion juice in the HD cavitation device with a compression ratio of 0.8.

As can be seen from Figure 1 the best technological indicators of juice when cutting diffusion juice during the cavitation stage 2.3. This is indicated by the maximum deposition rate and the smallest amount of sediment juice pre-defecation. Therefore, the cavitation stage, equal to 2.3, is chosen for processing diffusion juice to determine the effect of cavitation effects on subsequent juice purification processes. In the work of the authors **(Somaratne et al., 2019; Shmyrin, Kanyugina and Kuznetsov, 2017)** the stage of cavitation 3.3 was chosen, which in our opinion will lead to a decrease in the yield of the main product.

Comparative characteristics of diffusion juice samples, the purifications of which are carried out according to the standard scheme and according to the scheme with preliminary processing of diffusion juice in a hydrodynamic cavitation device, are given in Table 1.

As can be seen from the experimental data, cavitation processing of diffusion juice intensifies the processes of coagulation of substances of a colloidal dispersion of diffusion juice at the previous defecation and adsorption of non-curvatures at the stages of the first and second saturation, as evidenced, in particular, by an increase in the purity of purified juice by 0.7%. The authors of **(Bhatia et al., 2016)** concluded that cavitation treatment of diffusion juice intensifies the processes and leads to an increase in the purity of purified juice by only 0.3%, and the authors of **(Verma et al., 2018)** purity of purified juices on the contrary decreases by 0.1%

To determine in the technological scheme, the most appropriate place for the hydrodynamic cavitation processing of sugar production juices, let's carry out studies in which juices: diffuse, preliminary defecation, and main defecation are cleared in the hydrodynamic cavitation installation. Samples of juices after a single treatment from the cavitation stage $\lambda = 2.3$ in laboratory conditions are brought to the juice of the first saturation and S_5 and V_{20} re determined in them. Figure 2 presents the values of these

values for each of the juices. As can be seen from the research results, the best indicators of the juice of the first saturation according to the scheme when the diffusion juice is processed in the hydrodynamic cavitation device.
In this case, the deposition rate during the processing of diffusion juice in a hydrodynamic cavitation device compared with the conventional method increases by 19.4%, and the sediment volume decreases by 14%. When processing juices of preliminary and main defecation, the technological properties of the juice of the first saturation significantly (confidence probability $p = 0.95$).

deteriorate in comparison with the usual purification method. Similar results were obtained in studies presented in the works of the following authors **(Katariya, Arya and Pandit, 2020; Krasulya et al., 2016).**

Processing in the installation of juices of preliminary and main bowel movements leads to a slight deterioration in the indicators of the juice of the first saturation – a decrease in the sedimentation rate of juice by 6 and 12.5%, respectively, and sediment volume by 7 and 20.7% compared with the usual method of juice purification. This indicates that during the processing of juices of preliminary and main defecation, the sediment particles formed at the stage of preliminary defecation are destroyed, followed by hydration of the substances of colloidal dispersion (SCD) particles that are adsorbed on it. Due to this, the deposition rate decreases, and the volume of juice sediment after settling increases. Similar data were obtained in work **(Guo et al., 2018)**, in which the juice of preliminary defecation was processed in a cavitation apparatus with a cavitator of a dynamic type before the main defecation, where the milk of lime is fed **(Dhar et al., 2015)**.

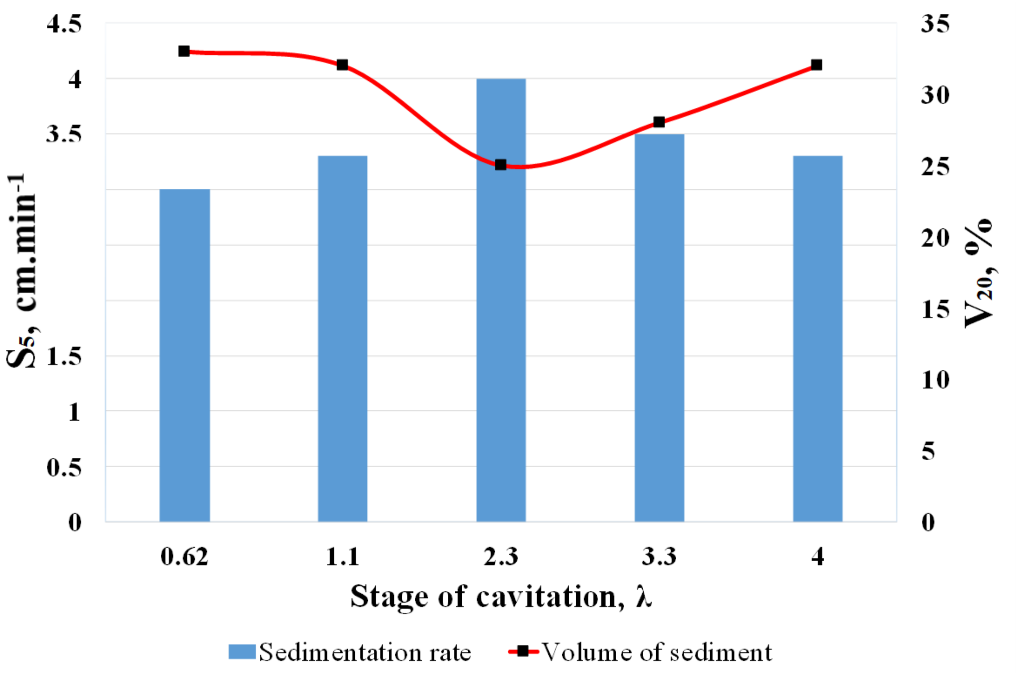

Figure 1 The effect of the cavitation stage on the technological parameters of preliminary defecation juice.

Table 1 Technological indicators of juices at diffusion juice purification according to a standard scheme and using the effects of HD cavitation.

Purification scheme	Juice						
	Diffuse	Preliminary defecation		First saturation		Second saturation	
	Purity, %	S_5, cm.min^{-1}	V_{20}, %	S_5, cm.min^{-1}	V_{20}, %	Salts Ca^{2+}, % CaO	Purity,%
Typical	86.5	3.2	33	3.3	30	0.04	90.3
	86.3	3.0	35	3.1	31	0.036	90.5
	86.7	3.3	32	3.3	31	0.04	90.6
Average	86.5	3.2	33.3	3.2	30.7	0.039	90.9
With hydrodynamic cavitation	86.5	3.7	32	3.9	25	0.021	91.3
	86.3	3.9	30	4.1	26	0.020	91.5
	86.7	4.0	30	4.1	24	0.021	91.5
Average	86.5	3.9	29.0	4.0	25.0	0.021	91.6

Note: * all studies were performed in 5 replicates, the deviation of which did not exceed 3%.

Table 2 Comparative characteristics of technological indicators of juices at diffusion juice purification according to a standard scheme and using the effects of HD and VC cavitation.

Purification scheme	Juice							
	Diffuse		Preliminary defecation		First saturation		Second saturation	
	Δt, °C	Purity, %	S_5, cm.min^{-1}	V_{20}, %	S_5, cm.min^{-1}	V_{20}, %	Salts Ca^{2+}, % CaO	Purity, %
Typical	–	86.5	3.2	33	3.3	30	0.04	90.3
	–	86.3	3.0	35	3.1	31	0.036	90.5
	–	86.7	3.3	32	3,3	31	0.04	90.6
Average	–	86.5	3.2	33.3	3.2	30.7	0.039	90.9
With processing in a VC cavitation device	4	86.5	3.5	29	3.7	26	0.025	91.1
	5	86.3	3.7	30	3.9	27	0.021	91.3
	4	86.7	3.8	28	4.1	25	0.027	91.0
Average	4.3	86.5	3.7	29.0	3.9	26.0	0.028	91.4
With processing in a HD cavitation device	–	86.5	3.7	32	3.9	25	0.021	91.3
	–	86.3	3.9	30	4.1	26	0.020	91.5
	–	86.7	4.0	30	4.1	24	0.021	91.5
Average	–	86.5	3.9	29.0	4.0	25.0	0.021	91.6

Note: *all studies were performed in 5 replicates, the deviation of which did not exceed 3%.

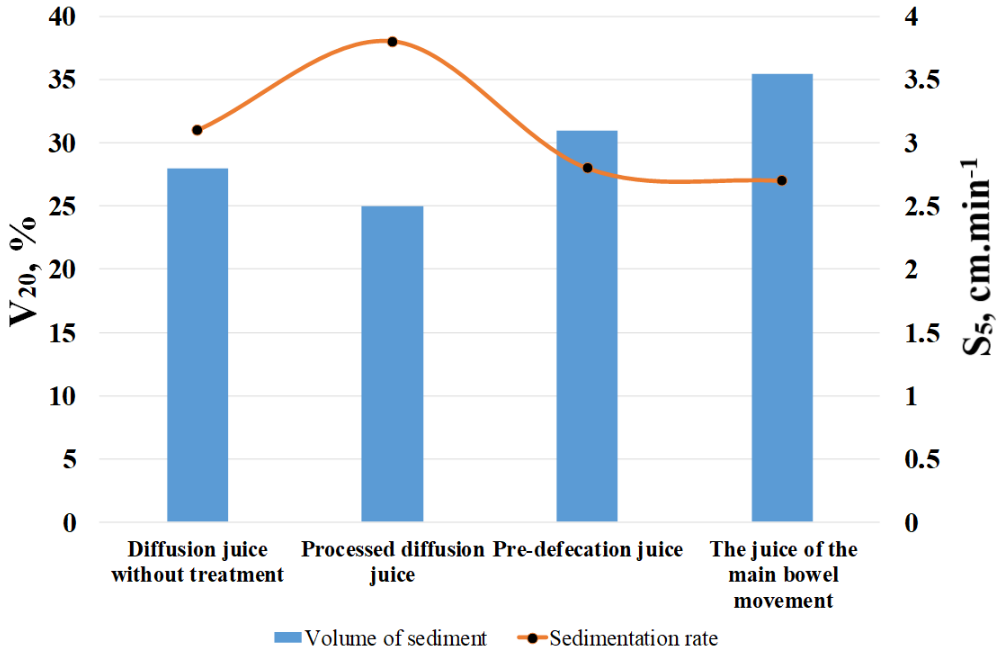

Figure 2 Technological indicators of the juice of the first saturation in the processing of juices of the main unit

The authors found improvements in the physicochemical parameters of the juices of the first and second saturation.

Such changes are explained by the fact that the activity of Ca^{2+} ions is increased, which are released from the clathrate structure of the hexo aqua complex, which interacts more fully with non-sugars juice. However, the sedimentation rate of the juice of the first saturation decreases by 10%, and the filtration coefficient increases.

From an analysis of laboratory studies, it can be assumed that the cavitation treatment of diffusion juice in a hydrodynamic cavitation device is the first step in the conversion of particles of substances of a colloidal dispersion of juice. After a certain period of time, they interact with each other, or with a chemical reagent, if any, which will contribute to the formation of a compact, low-hydrated coagulate precipitate during the previous defecation, which is resistant to peptization under conditions of basic defecation. As a result, the filtration properties of juice and carbonation will improve and the effect of the juice of I purification as a whole will increase.

To establish an analogy of the effect of the studied effects on the purification of diffusion juice in cavitation devices, parallel experiments are conducted in which the diffuse juice after treatment in hydrodynamic and vapor condensation cavitation devices is cleaned according to the following scheme: optimal previous defecation at a temperature of 55 – 65 °C, which is fed 0.25 – 0.3% CaO at pH_{20} 10.8 – 11.2, heating to a temperature of 80 – 85 °C, the main defecation with the addition of 2.5% CaO, the first saturation to pH_{20} 10.8 – 11.2, sediment separation of the juice of first second saturation by decantation followed by filtration; second saturation; filtering the juice of the second saturation.

Comparative values of juices according to the standard scheme and with cavitation processing of diffusion juice are given in Table 2.

According to research results, when processing diffusion juice in cavitation devices, the performance of juices is improved compared to the usual purification method. So, the sedimentation rate of preliminary defecation juice after processing diffusion juice in a vapor condensation cavitation device increases by 15.6%, and in a hydrodynamic cavitation device by 21.8%, the volume of juice sediment decreases in both cases by 12.9%. A similar dependence is observed in the juice of the first saturation: the sedimentation rate of the juice sediment processed in the vapor condensation cavitation device increases accordingly by 21.8%, in the hydrodynamic cavitation device - by 25%, the volume of juice sediment decreases by 15.3 and 18, 6, respectively % The same dependence remains with the content of calcium salts in the juice of the second saturation. According to calcium salts are reduced by 28.2 and 46.2%.

The authors **(Buniowska et al., 2017; Alves et al., 2017)** conducted similar studies only without the use of cavial influence and other temperature characteristics, the volume of juice precipitate decreases by only 8.3 and 9.6%.

Purification is carried out after sampling under the action of gravitational forces in production conditions, ie the process of deposition (settling). The difference in the results is that the samples were taken at the existing sugar factory directly in the production conditions in the stream, so the possibility of their variation depends on the technological parameters, which may vary slightly.

CONCLUSION

From comparisons of the technological indicators of juices, it can be concluded that upon the collapse of steam bubbles in vapor condensation and hydrodynamic cavitation devices, structural transformations of non-curved diffusion juice occur. This means that during the collapse of bubbles in vapor condensation and hydrodynamic cavitation devices, similar effects occur that positively affect the efficiency of juice purification. However, the indicators of juices processed in a hydrodynamic cavitation device are somewhat better than in the vapor condensation one. This indicates, in our opinion, that the distribution of bubbles in the hydrodynamic cavitation device is more uniform than in the vapor condensation one due to the fact that the flow velocity in the hydrodynamic cavitation device is higher, and, as a consequence, the flow turbulence is higher. It is established that the cavitation treatment of diffusion juice before liming causes a significantly (p = 0.95) acceleration of the course of the main reactions to the previous and main bowel movements and an increase in the overall purification effect. But the mechanism of the influence of cavitation phenomena on the components of diffusion juice remains unknown and will be the subject of our further research since without this it is impossible to improve or optimize the processes of sugar beet production.

The proposed purification scheme allows compared to the typical scheme to reduce the content of lime milk for the second saturation by 0.018% CaO (almost 2 times), accelerate the process of separating the solid phase from the liquid (settling), as evidenced by the volume of juice and sedimentation rate. are better by 3.4 and 2.5%, respectively, and increase the purity of the juice by 0.7 units. And this will increase the yield of sugar.

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