Research into application of zeolite for purification of diffusion juice in sugar production

1. Introduction

The modern development of food technologies is aimed at obtaining high-quality and safe products. The development and implementation of innovative technologies aimed at improvement of sugar quality is currently relevant. Dealing with these problems requires a comprehensive solution of the problem of ensuring high technological quality of sugar beet and enhancement of effectiveness of processing [1]. At the same time, the production receives raw materials that do not always meet the requirements of quality and are characterized by high content of mechanically damaged and microbiologically affected roots [2]. This leads to a significant decrease in technological indices of juices and finished products of sugar manufacturing [3].

One of the main stages of the technological process, which determines the yield and the quality of the finished product, is the process of extracting sucrose from beet chips. The aim of the extraction process is to ensure maximum extraction of sucrose on condition of the minimum transition of other chemical compounds to the composition of diffusion juice. High-molecular compounds, mainly proteins, pectin substances, araban, galactan and saponin make up a significant portion of non-sugars of diffusion juice [4]. As a result of the development of mucous bacteriosis, the juice can accumulate polysaccharide dextran [5], which negatively affects the technological process [6] and the quality of the obtained sugar [7, 8].

Thus, the search for alternative methods for application of additional reagents for purification of sugar juices in sugar production is relevant, primarily, due to the need to ensure the quality of white sugar that meets the requirements of EU [9].

2. Literature review and problem statement

Effectiveness of extraction and the purity of obtained diffusion juice depend on a number of factors, including the quality of the feed water and keeping to optimal parameters of the process. The most common way of preparing feed water is sulfitation in order to bring pH to 5.8–6.2. Paper [10] considers a number of ways of deammonization of condensates and preparation of pulp press water, however, these methods did not get widely used as a result of various factors, including high power consumption of the process, lack of effectiveness, etc.

A number of ways to intensify the extraction process using the influence of chemical reagents on beet chips were developed. In particular, the attempts of using calcium hydroxide for chemical processing have been made repeatedly. Thus, paper [11] shows that the intensification of the extraction process is achieved by the treatment of beet chips with calcium-containing solution for 3.5 min. After the separation of juice, chips are washed with diffusion juice, taken from the plant in order to remove alkaline sugar-containing solution. However, the proposed method was not introduced into production due to its complexity. In addition, such treatment is unacceptable in the case of processing beet, affected by mucous bacteriosis [12, 13].

A series of studies were conducted and high efficiency of application of aluminum salts, namely, aluminum sulfate for treatment of feed water and beet chips was established [14]. According to the research findings, it was found that a change is observed in the conformation of the pectin macromolecule at the interaction of pectins with aquahydroxocomplexes of aluminum. In this case, pectin substances are deposited inside the beet tissue, which contributes to an increase in its elasticity and reduces the transition of high-molecular compounds into diffusion juice. The ways of the application of polyhexamethyleneguanidine hydrochloride to decrease the sucrose consumption by suppressing the development of microbiological processes and improving the quality of diffusion and purified juice were studied and developed [15]. Along with this, it should be noted that the main tendency of the modern development of technologies is making the production ecologically friendly by reducing the use of chemical reagents. The use of sorbents should be emphasized among the modern methods. Such adsorbents as activated carbon, silica gel (gel of silica acid), alumogels (aluminum hydrate), zeolites, clays and other natural adsorbents are widely used in food production [16]. Thus, the effectiveness of aluminum hydroxide in the nano-dimension condition for sugar beet production was experimentally established in article [17]. Adsorbents, which are in direct contact with food, must be biologically safe, that is, without showing toxicity and without leading to the introduction of additional substances into the product. Among the natural mineral formations of different origin (sedimentation, volcanic, etc.), disperse silica, clay minerals (layered and layered-tape alumo-iron-magnesium silicates) and zeolites are most widely used in practice [18].

More than 100 deposits of clay minerals of different genetic types with the total reserve of 100 million tons are known on the territory of Ukraine. From the position of the environmental protection, zeolites are ecologically clean, affordable and cheap raw materials, potentially suitable for using in the manufacture of food products. Zeolites are known to be used in the food industry [19] for bleaching vegetable oils and animal fats [20], as well as for clearing drinking water from toxic elements [21] and xenobiotics [22, 23], water for food production [24], and juices [18]. In particular, the authors present the research results [25] of the application of zeolite in different branches of food industry. Zeolites were shown to have found practical use in the production of soft drinks (clearing of carbon dioxide for using in carbonated drinks) in the processes of water treatment (water de-mineralization and softening, de-alkalization, removal of nitrate, arsenic, silica, and iron), and in packaging food products. Along with this, the properties of zeolites for application with the view to improving the quality of diffusion juice in sugar production were not explored.

Clinoptilolite is a high silica zeolite with the ration of the silica and alumina from 3.5 to 10.5, which contains on average 60 % of silicon dioxide. The properties of zeolites, which contain 60–75 % of SiO_2, are in many ways similar to the properties of silica [25]. The feature of natural zeolites is the existence of a system of voids and channels in the structure, the volume of which can be up to 50 % of the total volume of the mineral, which determines the value of the zeolite as a sorbent. In clinoptilolite, the diameter of the inlet windows in the cavity is equal to 0.4 nm [26]. Depending on the deposit, one can observe a change in the ratio of Si/Al and composition of exchange cations, such as low-silica varieties, enriched with calcium. Clinoptilolite is characterized by the monoclinic syngony with the following parameters of the elementary cell: *a*=0.741 nm, *b*=1.789 nm, *c*=1.585 nm. The idealized composition of the elementary cell is (Na, K)$_4$ Ca Al$_6$ Si$_{30}$O$_{12}$ x 24 H_2O, cations – K^+, Na^{2+}, Ca^{2+}, Mg^{2+}. Ions of Cu^{2+}, Zn^{2+}, Pl^{2+}, Co^{2+}, Mn^{2+}, Ni^{2+}, Fe^2 are successfully absorbed on clinoptilolite. Sorption of NH_4^+ ions flows with different selectivity all over the range of concentrations, even more actively than sorption of K^+, Ca^{2+}, Fe^{3+}, AI^{3+}, Mg^{2+} [24]. High ion exchange activity of clinoptilolite is associated with the content of Al^{3+}, which is characterized by constant electron crisis. Cations, adsorbed by zeolite, compensate excessive negative stress and neutralize the negative charge. That is, such adsorption activity is caused by the lack of cations in the structure of the sorbent itself and tendency of systems "zeolite-environment" to balance [27].

The widespread use of the mineral in different areas is also determined by such properties as excess technical strength of clinoptilolite, resistance to high temperatures, corrosive environments and ionization radiations. In this case, the low costs of natural zeolites determine the possibility of their use in sorption processes which do not imply ionite regeneration.

Thus, in spite of the above merits, the properties of the zeolite-clinoptilolite were not investigated enough in terms of purification of juices and products in sugar production. Thus, paper [10] shows the effectiveness of zeolite-clinoptilolite for decalcination of juice of the II carbonation. In this case, the authors studied ion-exchange properties of zeolite.

Along with this, the sorption properties of zeolite with the view to increasing the effect of purification of juices in the production almost were not explored. According to the generally accepted technological scheme, diffusion juice is subject to lime-carbonization purification, during which much of the high-molecular non-sugars, including protein, pectin compounds, saponin, are removed. However, if juices contain polysaccharide dextran, the quality of purified juice decreases and the filtration-sedimentation properties of precipitate deteriorate. Eventually, this leads to slowing down the process of crystallization, the increase in duration of massecuite boiling, deterioration in the quality of white sugar [8, 12].

Dextran is a polyglucan, the properties of which vary depending on dimensions of the macromolecule from low-molecule – soluble, to high-molecule – insoluble. Additionally, the solubility of dextran depends on the structural composition of a macromolecule: the higher the content of α-(1→6) bonds, the greater the solubility. Conversely, the higher the percentage of α-(1→3) bonds in the polymer, the lower solubility in water [8]. The deterioration of the sedimentation-filtration properties of the precipitate of juice of the I carbonation is explained by blocking the surface of calcium carbonate by molecules of polysaccharide. In this case, finely dispersed amorphous precipitate is formed [15, 28]. Thus, mitigation of the impact of high-molecular compounds, including, dextran, will contribute to the intensification of technological processes and an increase in sugar quality.

Thus, solution of the problem of enhancement of the quality of juices and products in sugar production requires subsequent research, in particular aimed at the use of natural sorbents that have sorption and ion exchange properties.

3. The aim and objectives of the study

The aim of this research is to establish the patterns of removing high-molecular compounds during the application of natural zeolite for the purification of diffusion juice. This will make it possible to increase the effectiveness of purification of diffusion juice and to ensure high technological performance.

To accomplish the set aim, the following tasks were set:

– to establish the effectiveness of purification of feed water by the adsorbent zeolite and to identify the ways of application of zeolite at the stage of receiving diffusion juice during processing sugar beets of various technological quality;

– to establish rational consumption of sorbent zeolite for the process of extracting sucrose from beet chips in order to improve the technological quality of diffusion and purified juices;

– to explore the degree of removal of high-molecular compounds from diffusion juice with the help of zeolite.

4. Materials and methods of research into the influence of natural zeolite on improvement of the technological quality of diffusion juice

4. 1. Research materials that were used in the experiment

For the research, we used natural zeolite by fractions of <0.3 (powdered), 0.2...0.5 mm and 1...3 mm, made by SE "Transcarpathian zeolite plant", village of Sokyrnitsa of Khust district, Zakarpatska Oblast, Ukraine, TU–U 15.7–31251965–001:2009.

4. 2. Procedure for preparing feed water for the process of sucrose extraction from beet chips with the use of zeolite

Barometric water and condensates of secondary juice vapors were used for the research. Processing was carried out by passing the feed water through the contact column, filled with zeolite with the fraction of 1–3 mm. Duration of contact of water with zeolite was 4–6 min. Coloration, dry residue, permanganate oxidation, the content of ammonium, sulfates, total iron (Fe^{2+}; Fe^{3+}) were determined in barometric water before and after the treatment with zeolite. Ammonium content was determined in the condensates of secondary vapor juices.

4. 3. Procedure for obtaining diffusion juice with the use of feed water, treated with zeolite

For the research, we used the conditioned raw material with beet juice purity of 86.8 %, as well as sugar beet containing up to 15 % of roots, affected by mucous bacteriosis (beet juice purity of 72.2 %). To extract sucrose from beet chips, we used feed water, previously treated at 70 °C. The process of extraction was carried out at the temperature of 68–72 °C h zeolite faction of <0.3 mm at consumption of 0.1...0.4, pH 6.2–6.25 and the temperature for 60–80 min. Purification of diffusion juice was carried out by common lime-carbonization scheme: juice was treated with CaO to conduct preliminary liming at the consumption of lime of 0.25 %; 1.8 % CaO was added to the weight of juice and heated up to 85 °C to conduct the process of main liming. The first carbonation was sequentially carried out to the alkalinity of 0.1 % CaO, filtered, treated with CaO in the amount of 0.5 % to the weight of juice and with carbon dioxide to the alkalinity of 0.03% of CaO, which meets the requirements for the juice of second carbonation, filtered and analyzed. In diffusion juice, the content of dextran, pectin substances (PS), high-molecular compounds (HMC) was determined and juice purity was calculated. In the juice of the first carbonation, the average rate of precipitate sedimentation was determined. In the purified juice, the content of Ca^{2+} salts and coloration were determined.

4. 4. Procedure for determining the basic technological parameters of quality of juices

During the studies, we used the standard methods for determining the basic technological parameters of quality of diffusion and the cleared juice [29].

5. Results of studying the application of zeolite to increase the technological quality of diffusion and purified juices

To increase the effectiveness of technological processes of obtaining diffusion juice and subsequent lime-carbonization purification, it is advisable to use additional reagents or other physical and chemical methods of the intensification of processes. Based on the set tasks of the research, the following ways of using zeolite sorbent were selected:

1) purification of feed water that is used for sucrose extraction from beet chips;

2) introduction of powdered zeolite to feed water for the purpose of processing beet chips in the extraction process and enhancement of the quality of diffusion juice.

5. 1. Results of research into effectiveness of feed water treatment with the use of zeolite

Because the quality of feed water depends on the content of pollutants, we studied the influence of feed water treatment with natural zeolite on the chemical composition of water and condensates of secondary juice vapors that are the part of the extragent on the quality of diffusion juice.

Thus, Table 1 shows the results of research into the quality of barometric water and condensates of secondary juice vapors before and after the treatment.

Table 1

Description of barometric of water before and after treatment with zeolite

No. by order	Indicator	Measurement unit	Research outcome	
			before treatment	after treatment
	Barometric water			
1	Coloration	degrees	26	20
2	Content of ammonium	mg/dm^3	31.5	5.4
3	Content of sulfates	mg/dm^3	52.9	50.2
4	Dry residue	mg/dm^3	426.0	419.0
5	Content of total iron (Fe^{2+}; Fe^{3+})	mg/dm^3	0.86	0.43
6	Permanganate oxidation	mg O_2/dm^3	48	10
Condensates of secondary juice vapors				
7	Content of ammonium	mg/dm^3	126	35

The results of the studies reseal that due to water treatment with zeolite, content of total iron and ammonium in the samples decreases. Thus, in the case of treatment of condensates with zeolite, the content of ammonium in the water samples decreased by 70–80 %. There is also a significant decrease in the indicator of permanganate oxidation of water, which testifies to a significant decrease in the content of organic and inorganic compounds that are capable of chemical oxidation. Obtained results indicate the effectiveness of feed water treatment for the process of extraction with the help of zeolite.

It was also found that in the case of feed water treatment, the microbial seeding of feed water and diffusion juice decrease by 30 and 23 %, respectively (Table 2).

Table 2

Total content of microorganisms in feed water

Content of feed water	NMAFAnM*, CFU / cm^3	
	Without treatment	After treatment
Condensates of secondary juice vapors	sterile	sterile
Barometric water	5.6×10^4	3.8×10^4
Pulp press water	1.8×10^6	1.3×10^6
Diffusion juice	0.96×10^6	0.74×10^6

*Note: * – NMAOAnM – Number of Mesophilic Aerobic and Facultative Anaerobic Microorganisms*

Thus, the use of water, purified with zeolite helps to reduce microbiological contamination of the obtained diffusion juice that is relevant from the point of view of reducing sucrose losses as a result of microbiological decay.

5. 2. Results of studying a technique for sucrose extraction from beet chips using zeolite for feed water treatment

To establish rational consumption of zeolite in terms of enhancing the technological quality of diffusion and purified juices, the study in the system zeolite – juice–chip mixture was conducted. The results of the experimental studies of the effectiveness of introduction of crashed zeolite (the fraction is less than 0.3 mm) to feed water to enhance the quality of diffusion juice are shown in Fig. 1–5 and Table 3.

An important objective of the study was to explore the degree of removal of high-molecular compounds from diffusion juice by natural zeolite. It should be noted that in case of the zeolite introduction, it is sorbed on the surface of beet chips, which contributes to an increase in elasticity and lower transition of high-molecular compounds in the extract. Thus, according to the experiment, at the consumption of zeolite of 0.1...0.4 % by the weight of beets, the content of high-molecular compounds and pectins in diffusion juice decreases by 30–40 %, respectively (Fig. 1).

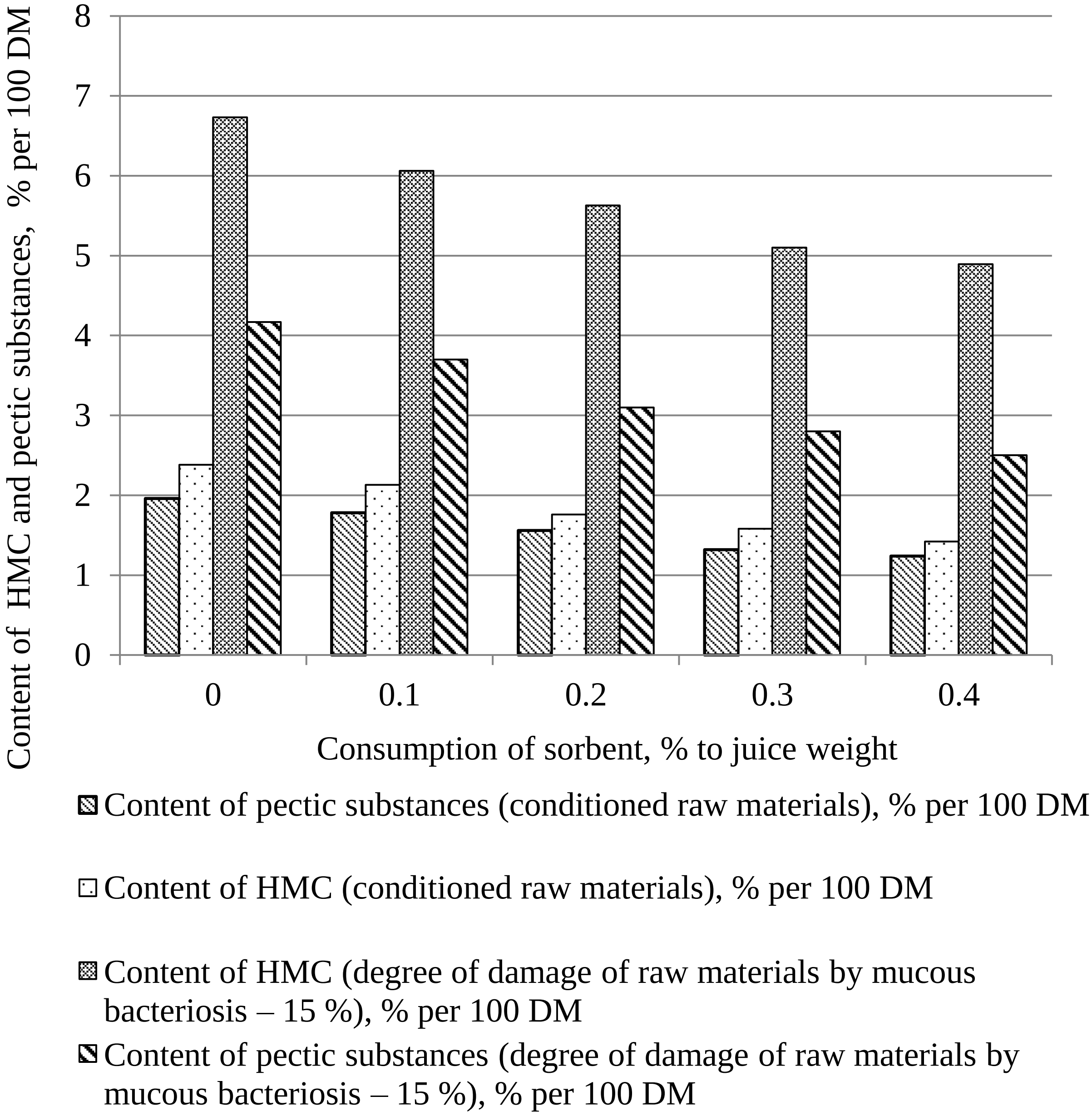

Fig. 1. Dependence of the content of high-molecular compounds (HMC), including pectins, in diffusion juice on zeolite consumption

The results of the conducted studies revealed that in the case of treatment of feed water and beet chips with zeolite, the content of dextran polysaccharide in diffusion juices decreases (Fig. 2).

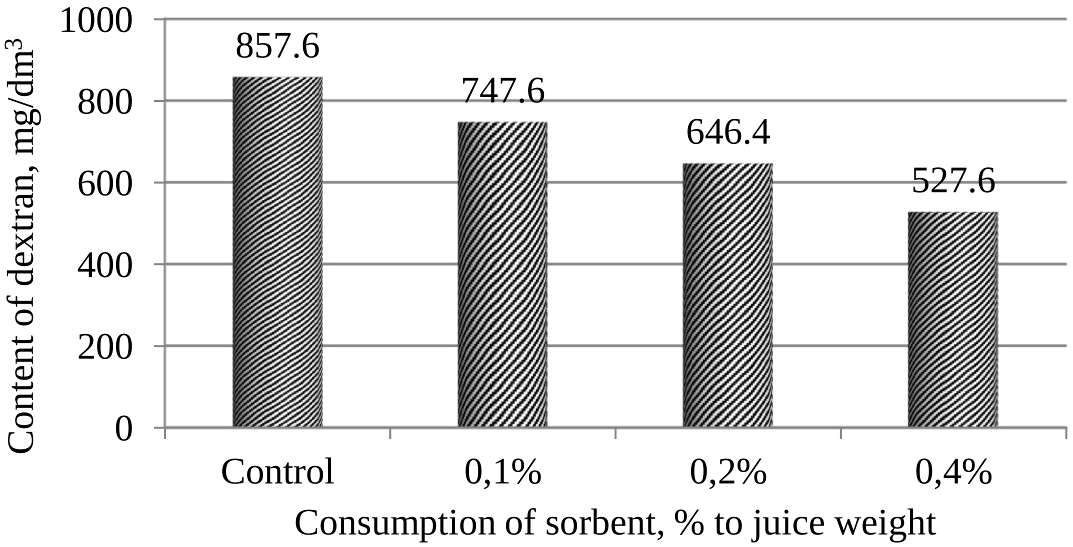

Fig. 2. Dependence of the content of dextran in diffusion juice, obtained from the raw materials, affected by mucous bacteriosis, on zeolite consumption

Thus, if in beet raw material there are roots, affected by mucous bacteriosis by 13–18 %, a significant increase in the content of dextran in diffusion juice, by 800–820 mg/dm^3 is observed. At the same time, in case of using feed water with the zeoline content of 0.2–0.4 % for treatment of beet chips, the content of dextran in diffusion juice decreases up to 500–640 mg/dm^3.

A decrease in the transition of high-molecular compounds from beet chips into diffusion juice contributes to enhancement of its quality, including purity (Table 3).

Table 3

Increase in technological indicators of diffusion juice quality

Technological indicators	Zeolite consumption, % by weight of water			
	0	0.1	0.2	0.4
Conditioned raw materials				
Diffusion juice purity (by direct polarization method), %	87.7	88.4	88.9	89.2
Juice purification effect during extraction, %	7.8	13.7	17.9	20.4
Purity of cleared juice, %	91.3	92.1	92.4	92.6
Purification effect during lime-carbonization, %	32.1	34.6	34.1	34
15 % – degree of the damage by mucous bacteriosis				
Purity of diffusion juice (by direct polarization method), %	73.4	74.9	76.4	77.2
Juice purification effect during extraction, %	5.9	13.0	19.8	23.3
Purity of diffusion juice (by the method of inverse polarization), %	72.3	74.5	75.4	77.2
Purity of cleared juice, %	80.1	81.5	82.8	83.5
Purification effect during lime-carbonization, %	31.4	32.3	32.7	33.1

Thus, at zeolite consumption of 0.1...0.4 %, it is possible to observe an increase in purity of diffusion and purified juice, obtained during processing of conditioned raw materials by 0.7…1.5 and 0.8…1.3, respectively.

It should be noted that in the case of the zeolite introduction to feed water, the effect of diffusion juice purification during extraction increases on average by 8–15 units during processing beets of different technological quality. In this case, a slightly higher effectiveness is observed in the case of processing beet, affected by mucous bacteriosis.

Analysis of technological indicators of purified juice (Table 3) showed that at an increase in zeolite consumption, the purity of juice and the effect of its purification increase. It also should be noted that there is the improvement of filtration-sedimentation properties of lime-carbonization composition of the precipitate (Fig. 3).

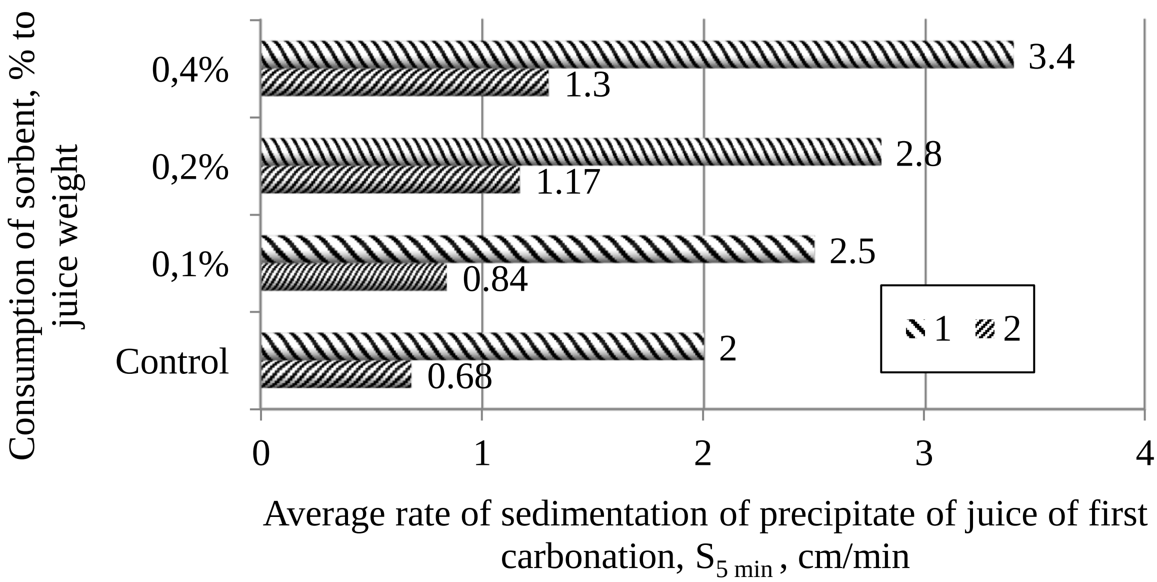

Fig. 3. Influence of zeolite on filtration-sedimentation properties of lime-carbonization precipitate at processing beets of different technological quality: 1 – conditioned raw materials (86.6 % purity of beet juice); 2 – raw materials, affected by mucous bacteriosis (72.2 % purity of beet juice)

It was proven that the use of zeolite enables improvement of filtration-sedimentation properties of the precipitate of juice of I carbonation. Thus, the average rate of sedimentation of precipitate of juice of I carbonation S_{5m}, obtained with the use of feed water, treated with zeolite, increased by 8–32 % and made up 3.4 cm/min at the consumption rate of 0.4 % when processing conditioned raw materials. During processing raw materials, affected by mucous bacteriosis by 15 %, this indicator increased by 20–50 %.

Comparative data of quality indicators of purified juices during addition of zeolite at the extraction stage at various consumption are shown in Fig. 4, 5.

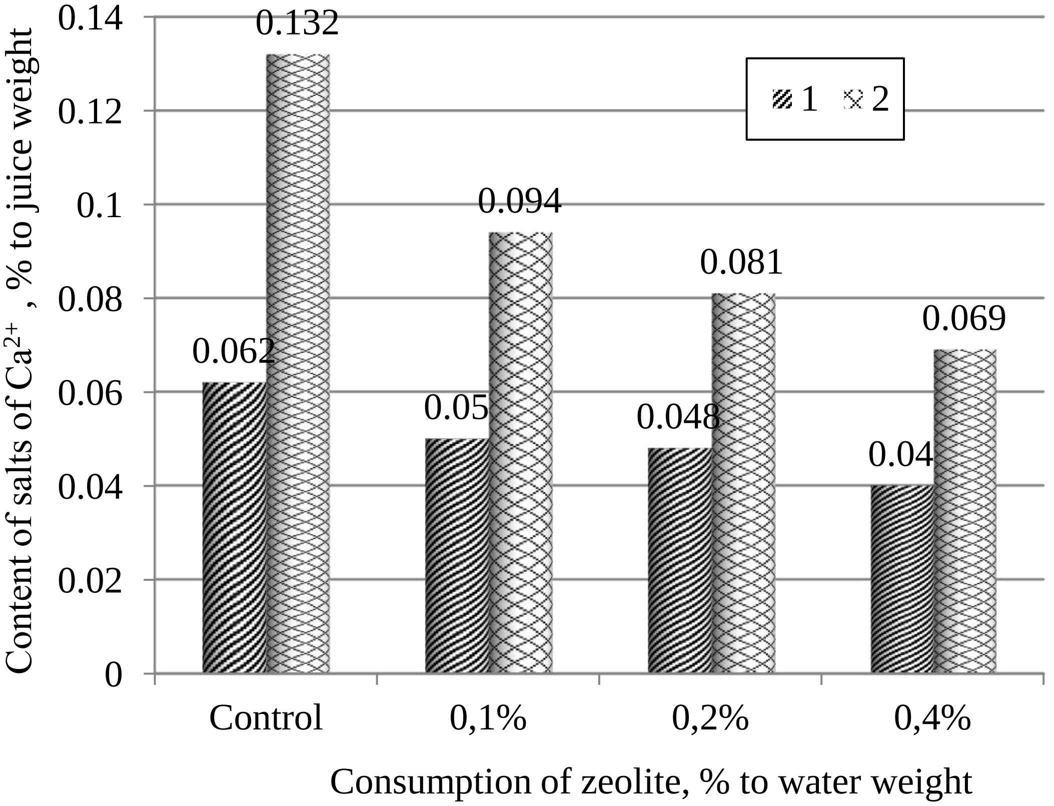

Fig. 4. Dependence of content of salts Ca^{2+} in purified juice on zeolite consumption in processing beets of different technological quality: 1 – conditioned raw materials (86.8 % purity of beet juice); 2 – raw material, affected by mucous bacteriosis (72.2 % purity of beet juice)

In purified juices (Fig. 4), obtained at various consumption of zeolite, there is a decrease in the content of calcium in comparison to the control juice, which is especially observed in the case of deterioration of the technological quality of raw materials.

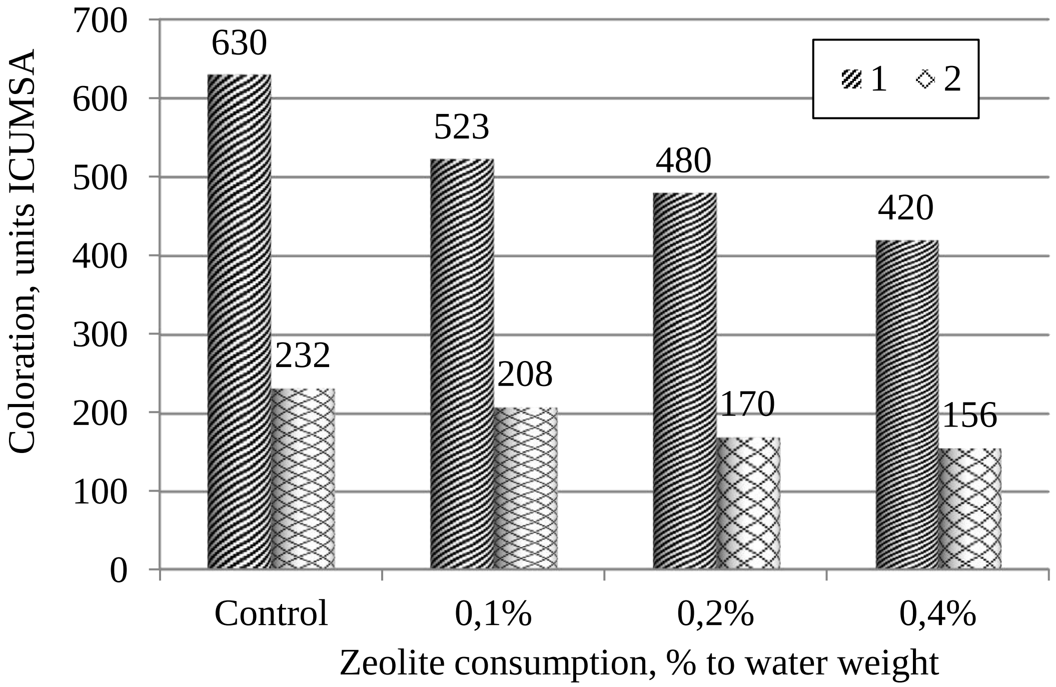

Fig. 5. Dependence of coloration in purified juice on zeolite consumption in processing beets of different technological quality: 1 – raw material, affected by mucous bacteriosis (72.2 % purity of beet juice); 2 – conditioned raw materials (86.8 % purity of beet juice)

Thus, the conducted studies indicated the effectiveness of the application of powdered zeolite in the amount of 0.1...0.4 % for treatment of feed water and beet chips in the process of sucrose extraction.

It is advisable to regulate zeolite consumption depending on the quality of sugar beets, arriving for processing. Dependence of the rational consumption of zeolite on the purity of beet juice is shown in Fig. 6.

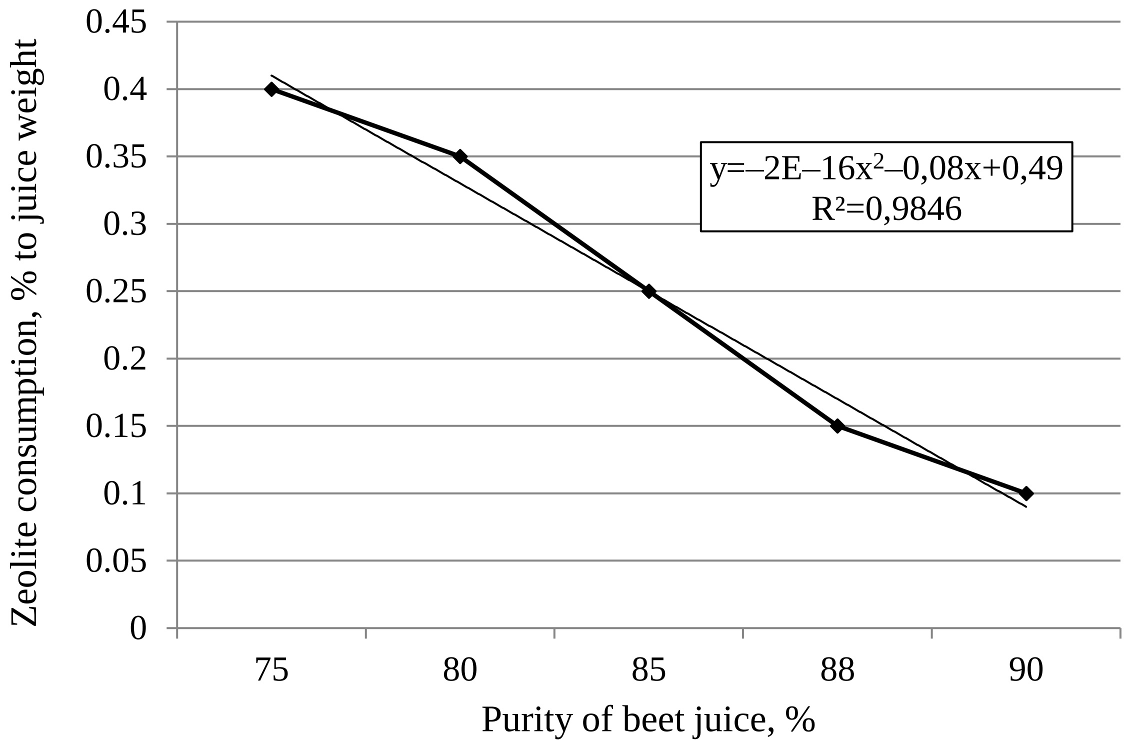

Fig. 6. Dependence of rational consumption of zeolite on purity of beet juice

Thus, taking into consideration the quality of raw materials, consumption of zeolite of fraction of < 0.3 mm changes within 0.1...0.4 % by the weight of beets.

6. Discussion of results of studying the influence of zeolite application for improving technological quality of diffusion and purified juice

As it follows from the obtained experimental data (Table 3), an increase in the effect of juice purification at an increase in consumption of a sorbent is common during the application of zeolite for treatment of feed water and diffusion juice. This is due to the flow of ion exchange and sorption processes in the system zeolite: feed water – beet juice. In this case, the part of non-sugars precipitate inside the beet root tissue, while some amount of them is adsorbed on the zeolite surface. This is proved by the decrease by 30–40 % of the content of high-molecular compounds in diffusion juice (Fig. 1). Therefore, the quality of both the obtained and the purified juice is enhanced in case of zeolite application for the treatment of feed water.

As a result of the progress of microbiological processes and accumulation of the products of microbial metabolism, specifically, polysaccharide dextran, the technological quality of products worsens considerably, which is proved by the obtained experimental data (Table 4). In case of an increase in the content of dextran, the quality of the purified juice and sedimentation-filtration properties of the precipitate worsens. Obtained results are consistent with the findings of other studies [27]. In the case of application of zeolite at the consumption of 0.1–0.4 % for the treatment of diffusion juice, the content of dextran decreases (Fig. 2), which contributes to improvement of the technological quality of juices and an increase in the sedimentation-filtration properties of the precipitate.

Comparison of the effectiveness of diffusion juice purification during the introduction of zeolite at various consumptions testifies to the appropriateness of their increase at the deterioration of the quality of raw materials (Fig. 6). This is consistent with the findings of studies [28] concerning the need to clarify the consumption of additional reagents depending on the content of non-sugars in the original juice.

The obtained data on the influence of zeolite on the process of obtaining diffusion juice make it possible to assert the following:

– an effective way to enhance the quality of juices and products in sugar production from beets is the application of the additional reagent – zeolite, which has the ion exchange and sorption properties;

– it is advisable to use the zeolite with the fraction of <0,3 in the amount of 0.1…0.4 % to the juice weight for feed water preparation (Table 3);

– the use of zeolite for feed water treatment helps to reduce the content of high-molecular compounds in diffusion juice on average by 30–40 %, specifically, dextran by 15...40 % (Fig. 2, Table 4);

– in the case of zeolite introduction at the stage of sucrose extraction from beet chips, we achieve a decrease in coloration and an increase in purity of the cleared juice due to increasing stability of the precipitate of non-sugars under conditions of the main defecation (Table 4) and ensure the improvement of filtration-sedimentation properties of the precipitate (Fig. 3).

The obtained conclusions can be considered feasible from the practical point of view, because it enables us to approach reasonably determining the necessary consumption and the place of the sorbent introduction, with the aim of improving the quality of diffusion juice. However, we cannot but note that the results of this study indicate a subsequent slight increase in the purification effect in the case of increasing zeolite consumption. At the same time, an increase in consumption is economically unreasonable.

From the theoretical point of view, we substantiated the progress of the physical and chemical processes and sorption of non-sugars of diffusion juice, specifically, high-molecular compounds, on the zeolite surface. Along with this, it should be noted that the sorption properties of zeolites depend on a number of factors that are not addressed in the framework of this study. This causes the development of potentially interesting scientific and practical direction for subsequent research. In particular, the research can be focused on the study of the influence of dimensions of macromolecules of polysaccharides on effectiveness of sorption on the zeolite surface. Such studies will make it possible to explore the microstructural conversion in the system zeolite – beet juice and to determine the input variables of the process that significantly influence the effectiveness of non-sugars removal.

7. Conclusions

1. It was determined that it is appropriate to apply the treatment with zeolite for:

– feed water treatment for the purpose of iron removal, de-ammonization and removal of organic compounds;

– a decrease in microbial seeding of feed water for sucrose extraction from beet chips;

– additional purification of diffusion juice in the process of sucrose extraction from beet chips and enhancement of the technological quality products in sugar production.

2. The conducted research revealed the effectiveness of applying natural zeolite as an additional reagent sorbent for enhancing the quality of diffusion juice in processing sugar beets of various technological quality. Due to the use of zeolite at the consumption of 0.1...0.4 %, we observed the increase in the purity of diffusion and cleared juice, obtained as a result of processing conditioned raw materials by 0.7…1.5 and 0.8…1.3 units, respectively. The effect of juice purification during defeco-carbonation in processing the beets, affected by mucous bacteriosis, increases by 1…2 units. The addition of zeolite significantly affects a decrease in coloration of purified juice, which can be caused by the processes of sorption of coloring substances on its surface.

3. It was experimentally determined that the use of zeolite for feed water treatment contributes to a decrease in the content of high-molecular compounds in diffusion juice on average by 30–40 %. In particular, dextran content in diffusion juice at zeolite consumption of 0.1...0.4% decreases by 15…40 % at processing raw materials, affected by mucous bacteriosis.

References

1. Husiatynska, N. A. (2014). Aktualni pytannia mikrobiolohichnoho kontroliu u vyrobnytstvi tsukru. Tsukor Ukrainy, 7, 19–24.
2. Noori, S., Naghavi, N. S., Mohammadi Sichani, M., Gol Gol Jam, M., Zia, M. A. (2014). Identification and biological control of microbial agents causing corruption of stored sugar beets in sugar production industry. Journal of Sugar Beet, 29 (2), 79–85.
3. Wojtczak, M., Antczak-Chrobot, A., Chmal-Fudali, E., Papiewska, A. (2013). Determination of microbiological activity during the processing of frost damaged sugar beets. Sugar Industry, 12, 1–4.
4. Reva, L. P., Shulha, S. A. (2015). Optymizatsiya zahalnykh vytrat vapna na ochyshchennia dyfuziynoho soku pry dodatkovomu vykorystanni aktyvovanoi kremniievoi kysloty ta filtroperlitu. Tsukor Ukrainy, 10 (118), 14–18.
5. Abraham, K., Flëter, E. (2018). New approaches for the determination of dextran in the sugar production process. Sugar Industry, 143, 1–9.
6. Bukhari, M. M., Salem El, Kh., Osman, A., Hegazi, S. E. F. (2015). Investigations of the influence of dextran on sugar cane quality and sugar cane processing in Kenana sugar factory. Journal of Chemical and Pharmaceutical Research, 7 (4), 381–392.
7. Abraham, K., Hagen, S., Schlumbach, K., Rohde, A., Flöter, E. (2016). Dextranase application in sucrose solutions – towards a better understanding. International Sugar Journal, 118, 582–588.
8. Soliman El-Sayed Ali Abdel-Rahman (2007). Investigations on the influence of dextran during beet sugar production with special focus on crystal growth and morphology. Berlin, 109.
9. Borysiuk, P. H., Halatsan, L. A. (2018). Harmonizatsiya ukrainskykh standartiv z mizhnarodnymy i yevropeiskymy. Tsukor Ukrainy, 1, 23–29.
10. Lipiets, A. A., Malyshev, V. O. (2011). Vykorystannia pryrodnoho tseolitu-klinoptylolitu dlia deamonizatsiyi kondensativ sokovykh pariv. Naukovi pratsi NUKhT, 37, 57–61.
11. Daishev, M. I., Reshetova, R. S., Molotilin, Yu. I. (1994). Podgotovka sveklovichnoy struzhki k ekstrakcii. Saharnaya promyshlennost’, 4, 15–17.
12. Husiatynska, N. A., Bratiuk, D. M., Lipiets, A. A., Muravska, K. V. (2010). Udoskonalennia tekhnolohiyi ochyshchennia dyfuziinoho soku pry pereroblenni buriakiv, urazhenykh slyzystym bakteriozom. Visnyk Cherkaskoho derzhavnoho tekhnolohichnoho universytetu. Seriya: tekhnichni nauky, 2, 132–135.
13. Reva, L. P. (2012). Fizyko-khimichni osnovy tekhnolohichnykh protsesiv ochyshchennia dyfuziynoho soku u vyrobnytstvi tsukru. Kyiv, 371.

14. Husiatynska, N. A., Lipiets, A. A. (2015). Suchasni sposoby intensyfikatsiyi protsesu ekstrahuvannia sakharozy z buriakovoi struzhky. Tsukor Ukrainy, 1, 13–18.

15. Husiatynska, N. A., Nyzhnyk, V. V., Bohdanov, Ye. S., Chorna, T. M. (2009). Vykorystannia polimernoho reahentu PHMHKh pry ekstrahuvanni sakharozy z buriakovoi struzhky. Naukovi zapysky NAUKMA. Khimichni nauky, 92, 65–68.

16. Stetsenko, N. O., Miroshnykov, O. M., Mank, V. V., Podobiy, O. V. (2008). Perspektyvy vykorystannia pryrodnykh adsorbentiv Ukrainy v tekhnolohiiakh harchovykh produktiv. Veda a technologie: krokdobudoucnosti – 2008: IV mezinarodni vedeckoprakticka konference: materialy. Praha, 87–89.

17. Tkachenko, S. V., Khomichak, L. M., Vierchenko, L. M., Lopatko, K. S., Sheiko, T. M. (2017). Zastosuvannia hidroksydu aliuminiu v nanorozmirnomu stani dlia pidvyshchennia efektu ochyshchennia dyfuziynoho souk. Tsukor Ukrainy, 1 (133), 37–45.

18. Matko, S., Kostenko, Ye., Melnyk,L. (2008). Sorbenty riznykh typiv. Kharchova i pererobna promyslovist, 8-9, 16–17.

19. Prytulska, N. V., Bondarenko, Ye. V. (2015). Research of prospects for using zeolites in the food industry. Eastern-European Journal of Enterprise Technologies, 5 (11 (77)), 4–9. doi: https://doi.org/10.15587/1729-4061.2015.51067.

20. Ishchenko, V. M., Kolotusha, T. P., olumbryk, O. M. (2013). Vykorystannia bentonitiv u kharchoviy promyslovosti. Kharchova promyslovist, 14, 34–36.

21. Tkachuk, N. A., Melnyk, L. M., Mank, V. V., Melnyk, Z. P. (2008). Pidvyshchennia yakosti ta bezpeky pytnoi vody shliakhom yii ochyshchennia vitchyznianymy pryrodnymy mineralamy. Obladnannia ta tekhnolohiyi kharchovykh vyrobnytstv, 18, 3–8.

22. Petrus, R., Malovanyi, M., Sakalova, H., Bunko, V. (2012). Zastosuvannia pryrodnykh sorbentiv u pyrodookhoronnykh tsiliakh. Naukovyi visnyk Natsionalnoho universytetu bioresursiv ryrodokorystuvannia Ukrainy. Ser.: Lisivnytstvo ta dekoratyvne sadivnytstvo, 171 (1), 139–144.

23. Eroglu, N., Emekci, M., Athanassiou, C. G. (2017). Applications of natural zeolites on agriculture and food production. Journal of the Science of Food and Agriculture, 97 (11), 3487–3499. doi: https://doi.org/10.1002/jsfa.8312.

24. Wang, S., Peng, Y. (2010). Natural zeolites as effective adsorbents in water and wastewater treatment. Chemical Engineering Journal, 156 (1), 11–24. doi: https://doi.org/10.1016/j.cej.2009.10.029.

25. Tzia, C., Zorpas, A. A. (Eds.) (2012). Zeolites in Food Processing Industries. Handbook of Natural Zeolites, 601–651. doi:
https://doi.org/10.2174/978160805261511201010601.

26. Zahrai, Ya. M., Rebreniuk, A. V. (2014). Vykorystannia pryrodnykh mineraliv (tseolitu) yak etapiv kompleksnoi tekhnolohiyi korehuvannia skladu vod-nykh

rozbavlenykh rozchyniv do pryrodno sformovanoi yakosti. Ekolohichni nauky: naukovo-praktychnyi zhurnal, 6, 82–87.

27. Lipiets, A. A., Malyshev, V. O. (2009). Vykorystannia pryrodnykh tse-olitiv typu klynoptylolit dlia dekaltsynatsiyi ochyshchenoho soku pered vyparnoiu ustanovkoiu. Naukovi pratsi NUKhT, 28, 41–43.

28. Husiatynska, N. A., Lipiets, A. A., Bratiuk, D. V. (2012). Zastosuvannia dodatkovykh reahentiv pid chas vapnokarbonizatsiynoho ochyshchennia dyfuziynoho soku. Tsukor Ukrainy, 11, 31–36.

29. Kupchyk, M. P., Reva, L. P., Shtanhieieva, N. I. et. al. (2007). Tekhnolohiya tsukrystykh rechovyn. Kyiv, 393.

// EASTERN- EUROPEN JOURNAL OF ENTERPRISE TECHNOLOGIES. Східно-Європейський журнал передових технологій. 5/11(95) 2018. P. 6–13.