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THE LIME PURIFICATION OF SUGAR-CONTAINING SOLUTION USING HIGH VISCOSITY COLLOIDAL SOLUTIONS

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Aim of the work was to determine the efficiency of combined application of lime and high-viscous suspensions, containing the aluminium nanoparticles as a precursor in treatment of sugar-containing solutions.

At the first stage the aluminium nanopowder, encapsulated into a salt matrix, was produced by the combined precipitation from a gas phase of metal and halogenide of alkali metal (NaCl). For the long-term stabilization of aluminum nanoparticles the method, developed by the authors, for dispersing these powders in the composition of polyethylene glycols was used, providing the colloidal solution of high viscosity (gel).

At the second stage, as an object of investigation a juice of sugar beet, produced in the laboratory conditions by water extracting from the beet chips, was applied. In the produced juice the main characteristics of its quality were determined: the content of solids, sucrose, its purity was calculated (ratio of sucrose to solids content, in%). The content of protein and pectin components was also determined (as the main components of the colloidal fraction of the diffusion juice). Conventionally, as a basic reagent for the process of a lime pretreatment a lime milk of 1.18 g/cm^3 density, prepared by liming the burned lime using hot water, was used.

During the experiments the effectiveness of reagents, containing aluminum in nanoform, their influence on the degree of removal of the colloidal dispersion substances in the process of juice purification in sugar beet production and improvement of its quality, is shown. However, the obtained results show that, depending on the method of producing, the additional reagents with aluminium nanoparticles have different effect on change of diffusion juice purity in the process of its treatment by the lime milk.

Key words: nanopowders, defecosaturation treatment, sugar-containing solutions.

Today, to attain the required quality of sugar, it is necessary to have the high quality of semi-products, it concerns, in particular, juices after the defecosaturation treatment by using a lime milk and saturation gas. Due to the fact that the beet of a low technological quality is supplied often into processing, the diffusion juice has a high content of different compounds (so-called non-sugars), which reduce greatly its purity [1]. To purify this juice it is necessary either to increase the consumption of the lime milk and saturation gas or to apply additionally in the technology such reagents which could improve sufficiently the effectiveness of the carried out processes of the juice purification, and also reduce the consumption of conventional reagents. The use of the additional reagents in the technology of treatment of the sugar-containing solutions is the rather urgent problem for the sugar complex of Ukraine, as this is the most simple and economic way for the improvement of characteristics of the ready products. This problem was studied in many works, in particular in [2–8]. However, the variety of processes, proceeding under conditions of a diffusion juice treatment, does not give an opportunity to evaluate precisely the mechanism of interaction of added additional chemical reagents with non-sugars of the diffusion juice. First of all, it concerns the process of coagulation of colloids. On the other hand, the adding of additional reagents to the processes of the juice treatment should be in compliance with a number of conditions, in particular these are a minimum dose of reagent at high efficiency, the absence of interaction with the sucrose, removal in the process of production together with other wastes [9–13].

On the basis of investigations of properties of colloidal high-viscosity solutions, produced by encapsulation of metallic aluminium particles into a salt coat, the present work deals with their effect on the quality of semi-products at applying the nanoreagents for an additional treatment of the sugar-containing solutions in the beet sugar production. The work considered the possibility of applying the additional reagents on the base of aluminium nanoparticles in the process of lime pretreatment of the diffusion juice.

Materials and Methods

The nanopowders of biogenic metals were produced by the combined precipitation of metals and halogenide of alkali metals from the gas phase [14, 15]. Encapsulation of metallic particles into a chemically inert matrix limits them by sizes on the one hand and on the other hand it provides formation of a protective coat on their surface (Fig. 1). This does not only prevent the processes of consolidation of particles during storage, but also protects them from their interaction with environment.

Statistic processing of results of measurement using the computer program Image Pro Plus is given in Table 1, that allowed plotting a diagram of distribution of nanoparticles by sizes, given in Fig. 2. It is seen from the diagram that the sizes of these particles are 6–7 nm.

Such composite structure allows the encapsulated nanoparticles to be stored for a long time in ordinary atmosphere and then to be used by dissolution of the salt coat for producing the colloidal solution [16–18].

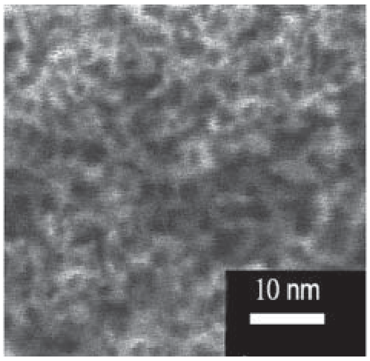

Fig. 1. **Electron-microscopic image of condensate: light background**

To provide a long-time stabilization of the nanopowders in the form of a colloidal solution, a method of dispersion of these powders into compositions of PEG (PEG 1500–8000 in the volume of 4–7 parts and PEG 400–600 in the volume of 3–6 parts) was developed. The initial powder, placed into fluid, was subjected to dispersion for 60 min, accompanied by heating up to 60–80 °C. However, the same as any colloid, this system will tend to agglomeration under the action of external factors. Therefore, to prevent this phenomenon, the rapid cooling of the colloidal solution is used at the last stage of producing. Such an approach makes it possible to store the produced gel for a long time in a compact form. The appearance of high-viscosity colloidal solution (gel) is shown in Fig. 3.

To reduce the viscosity of this gel is possible by introducing into the water suspension. The properties of this produced suspension were

Table 1. **Statistic processing of the nanoparticles observation using the computer program Image Pro Plus**

Diameter of particles, nm	Frequency, %	Number of investigated particles
4	15	298
5	16	325
6	21	421
7	12	236
8	15	292
9	9	185
10	6	124
11	6	128

Hereinafter: * — $P < 0.05$.

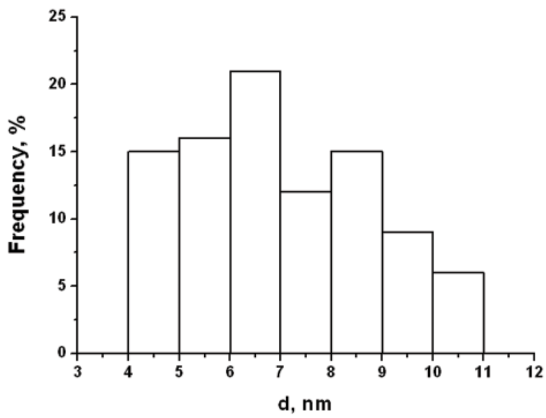

Fig. 2. **Distribution of particles by sizes**

investigated by using the device Malvern Zetasizer Ver. 7.11. From Fig. 4, at which the distribution of particles by sizes is presented, it is seen that such reducing of viscosity does not cause an aggregation process. The size of particles remains within the nanorange [19].

By comparing Fig. 2 and 4, it is possible to conclude that the average size of particles in the solution is smaller than in a precursor. It can be assumed that the particles in the precursor are more agglomerated, and in the process of solution producing the division of agglomerated particles is occurred, in particular, under the ultrasound effect.

Effectiveness of reagents for additional treatment of sugar-containing solutions

During investigations a diffusion juice was used, produced in the laboratory conditions by water extraction from beet chips. In the produced juice the main its quality characteristics were determined, namely: content of solids, sucrose, its purity was calculated (ratio of sucrose content to solids content, in %). Content of protein and pectin components (as main components of

Fig. 3. **Appearance of high-viscosity colloidal solution (gel)**

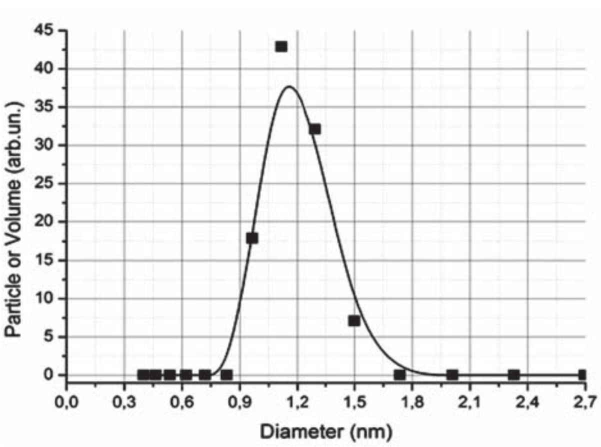

Fig. 4. **Distribution of aluminium particles by sizes**

colloidal fraction of diffusion juice) was also determined, which makes the proceeding of treatment processes difficult to the greatest extent. As a main reagent for carrying out the process of lime treatment, a lime milk of 1.18 g/cm^3 density was used, prepared by liming of burned lime by hot water [20].

As the main aim of the lime pretreatment of the diffusion juice consists in maximum precipitation of components of colloidal dispersity (protein and pectin components) by the lime milk and producing a well-structured precipitate [20], then at the first stage of the investigations the task was put for determination of effect of additional reagents, containing aluminium in a nanoform, on colloidal component of the diffusion juice proper. Two modifications of reagents were used: DAl4 (No.807) and DAl5(No.805). Characteristic of these reagents is given in Table 2.

Experiment was made according to the following procedure. Six test samples of diffusion juice of 100 cm^3 volume were heated up to 60 °C temperature (typical temperature of carrying out the process of lime pretreatment of juice). The preliminary calculated value of reagent in the range of 0.25...1.5 g (with content of Al nanoparticles in the limits of 0.0013...0.0078 g) was added to the preheated samples at continuous stirring. The obtained samples were stirred for 10 min at constant temperature and then at stirring during 15 min the lime milk was added up to producing of value pH of mixture of 11.2...11.3 (final point of lime pretreatment). Then, precipitate was separated in the obtained samples by a filtering and in the filtrates the purity, content of protein and pectin components were determined. The obtained results are given in Tables 1 and 2. For comparison, the treatment of the diffusion juice was also made by the lime milk without adding of Al nanoparticles (reference sample). In this case the quality of initial diffusion juice was the following: purity — 83.3%, content of protein components — 0.887 g/100 g of juice; pectin components — 0.29 g/100 g of juice.

The obtained results show that the additional reagents have a different effect on value of changing in purity of the diffusion juice in the process of its treatment. Thus, when adding the reagent DAl4(No.807) in the amount of 0.0052...0.0078 g/100 g of juice the improvement of its quality characteristics is observed (purity, content of protein and pectin

Table 2. **Characteristic of colloidal solutions of high viscosity (gels)**

No. of reagent	Characteristic of reagent		
	Volume fraction of nanoparticles in precursor	Concentration of nanoparticles of Al in colloid high-viscosity solution	Dav, nm
DAl4 (No.807)	25%	52 mg/10 g	1.2–1.5
DAl5 (No.805)	30%	51 mg/10 g	1.2–1.5

Table 3. **Results of interaction of reagent DAl4(No.807) in the process of diffusion juice treatment with a lime milk**

No. of test sample	Quantity of DAl4(No.807), g/100 g of juice	Purity,%	Content in test sample	
			Protein components, g/100 g of juice	Pectin components, g/100 g of juice
0 Control	0	84.3	0.414	0.212
1	0.0013	84.55	0.406	0.210
2	0.0026*	84.84	0.368	0.206
3	0.0039	85.20	0.350	0.200*
4	0.0052	85.36	0.344	0.198*
5	0.0065	85.40	0.346*	0.192*
6	0.0078	85.39	0.350	0.201

Hereinafter: * — $P < 0,05$ compared with control

Table 4. **Results of interaction of reagent DAl5(No.805) in the process of diffusion juice treatment with a lime milk**

No. of test sample	Quantity of DAl5(No.805), g/100 g of juice	Purity, %	Content in test sample	
			Protein components, g/100 g of juice	Pectin components, g/100 g of juice
0 Control	0	84.3	0.414	0.212
1	0.0013	84.25	0.226*	0.110*
2	0.0026	84.10	0.210*	0.100*
3	0.0039	82.12	0.115*	0.094*
4	0.0052	80.29*	0.112*	0.086*
5	0.0065	77.34*	0.100*	0.080*
6	0.0078	77.39*	0.098*	0.079*

components) as compared with a control sample without the reagent addition. The visual inspection for the formation and quality of the precipitate showed that at such consumptions the active formation and quick precipitation of the precipitate particles is observed. This gives an opportunity to separate this precipitate and avoid its effect on proceeding of further processes of the diffusion juice treatment (for example, main lime pretreatment, carried out under the conditions of high alkalinity and temperature, which destroy the earlier formed precipitate).

For the reagent DAl5(No.805) the results of experiments showed its negative effect on the result of treatment of the juice samples. Though the effect of removal of protein and pectin components is rather higher than that in reagent DAl4(No.807), but the purity of this juice is occurred to be very low, that proves about the additional removal of sucrose from the juice. The decrease in content of sucrose for treatment of the diffusion juice can be, probably, explained by the formation by an aluminium saccharate, which is precipitated into the precipitate together with other colloidal particles in system [$Al(OH)_3$ +

$C_{12}H_{24}O_{12} \rightarrow C_{12}H_{21}O_{12}Al + 3H_2O$]. For the technology of sugar production from the beet this effect is not admissible. The visual inspection for the formation of the precipitate showed the similar results. Therefore, this reagent has, possibly, the higher purifying effect on other semi-products of the beet sugar production, which do not contain sucrose, for example, feed water for proceeding the process of sugar extraction from the beet.

Thus, during experiments the effect of the reagents, containing aluminium in the nanoform, on degree of removal of components of the colloidal dispersity in the process of the diffusion juice purification in the beet sugar production, is shown. In future these investigations will be continued for determination of an optimum time of interaction and effect of applying the additional reagents on the efficiency of the processes.

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ВАПНЯКОВЕ ОЧИЩЕННЯ ЦУКРОВМІСНОГО РОЗЧИНУ КОЛОЇДНИМИ РОЗЧИНАМИ ВИСОКОЇ В'ЯЗКОСТІ

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Метою роботи було визначити ефективність сумісного використання вапняку та суспензій високої в'язкості, що містять як прекурсор наночастинки алюмінію, під час очищення цукровмісних розчинів.

На першому етапі отримували інкапсульований у сольову матрицю нанопорошок алюмінію спільним осадженням із парової фази металу та галогеніду лужного металу NaCl. Для тривалої стабілізації наночастинок алюмінію застосовували розроблений авторами спосіб диспергування цих порошків у композиції поліетиленгліколей, одержуючи колоїдний розчин високої в'язкості — гель. На другому етапі як об'єкт дослідження використовували дифузійний сік, отриманий в лабораторних умовах екстрагуванням водою бурякової стружки. Визначали основні показники якості соку: вміст сухих речовин, сахарози, протеїнових і пектинових речовин (як основних складових колоїдної фракції дифузійного соку), а також його чистоту — співвідношення вмісту сахарози і сухих речовин (у %). Як основний реагент для проведення процесу попереднього вапнування використовували вапняне молоко зі щільністю 1,18 г/см^3, приготоване шляхом гасіння обпаленого вапна гарячою водою.

У ході експериментів показано ефективність препаратів, що містять алюміній у наноформі, їх вплив на ступінь видалення речовин колоїдної дисперсності у процесі очищення дифузійного соку в цукробуряковому виробництві та підвищення його якості. Одержані результати свідчать про те, що залежно від способу отримання досліджувані додаткові реагенти з наночастинками алюмінію справляють різний ефект на зміну чистоти дифузійного соку в процесі його оброблення вапняним молоком.

Ключові слова: нанопорошок алюмінію, вапнякове очищення цукровмісного розчину.

ИЗВЕСТКОВАЯ ОЧИСТКА САХАРОСОДЕРЖАЩЕГО РАСТВОРА КОЛЛОИДНЫМИ РАСТВОРАМИ ВЫСОКОЙ ВЯЗКОСТИ

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Целью работы было определение эффективности совместного использования извести и высоковязких суспензий с содержанием в качестве прекурсора наночастиц алюминия при очистке сахаросодержащих растворов.

На первом этапе получали инкапсулированный в соляную матрицу нанопорошок алюминия совместным осаждением из паровой фазы металла и галогенида щелочного металла NaCl. Для длительной стабилизации наночастиц алюминия применяли разработанный авторами способ диспергирования этих порошков в композиции полиэтиленгликолей, получая коллоидный раствор высокой вязкости — гель. На втором этапе в качестве объекта исследования использовали сок сахарной свеклы, полученный в лабораторных условиях экстрагированием водой свекловичной стружки. Определяли основные показатели качества сока: содержание сухих веществ, сахарозы, протеиновых и пектиновых веществ (как основных составляющих коллоидной фракции диффузионного сока), а также его чистоту — соотношение содержания сахарозы и сухих веществ (в %). В качестве основного реагента для проведения процесса предварительного известкования использовали известковое молоко с плотностью 1,18 г/см^3, приготовленное путем гашения обожженной извести горячей водой.

В ходе экспериментов показана эффективность препаратов, содержащих алюминий в наноформе, их влияние на степень удаления веществ коллоидной дисперсности в процессе очистки диффузионного сока в свеклосахарном производстве и повышение его качества. Полученные результаты свидетельствуют, что в зависимости от способа получения исследуемые дополнительные реагенты с наночастицами алюминия оказывают различный эффект на изменение чистоты диффузионного сока в процессе его обработки известковым молоком.

Ключевые слова: нанопорошок алюминия, известковая очистка сахаросодержащего раствора.