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The use of vapor condensation cavitation to increase the activity of milk of lime in sugar beet production

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ABSTRACT

The paper presents research on increasing the activity of milk of lime in beet sugar production using vapor condensation cavitation. The work aimed to develop a rational way of activating milk of lime using the effects of vapor condensation cavitation and its hardware design, substantiating the optimal values of the process parameters. It was established that to increase the activity of milk of lime at a steam potential of 0.18 MPa, an optimal consumption of water vapor using vapor condensation cavitation is required, which is 1 .75 – 2.0% to the weight of the suspension. This is ensured by the action of the combined CaO particles with the bulk of the steam, due to which the Their additional solution is due to the t-plot, which occurs through the boundary layer from the bubbles. As a result, a pre-saturated, water-lime suspension is created, in which the It is the number of dissolved calcium ions. It has been proven that the water vapour-treated suspension is 1.5 times lower It expands and has a volume of sediment of the solid phase in the medium that is 10% larger than that of processed suspension. Such a study is indirect evidence of the increase in the dispersal of these systems after Her husband's work. By increasing the activity of milk of lime, it is possible to increase the effect of cleaning juices at various stages of the technological process and reduce the consumption of limestone for the production of granulated sugar.

Keywords: water-lime suspension, milk of lime, lime, vapour condensation cavitation, activity.

INTRODUCTION

One of the most important processes of beet sugar production, which largely determines the efficiency of the use of raw materials, fuel-energy materials, and material resources, as well as the final results of the plant, is the purification of the diffusion juice with the use of lime and saturated gas **[1]**. The existing technology for the purification of diffusion juice and concentrated sugar-containing solutions, and its hardware design, in principle, have not changed much during the last decades **[2]**. The lack of necessary theoretical developments and experimental data inhibits the development of known and the development of new technological processes **[3]**. Therefore, the main direction of increasing the effectiveness of lime-carbonic acid cleaning of sugar-containing solutions is the disclosure of its unused reserves and their implementation in practice.

The scientific problem of choosing a rational direction for improving the technology of lime-carbonic acid purification of solutions, which ensures the production of granulated sugar in conditions of changes in the quality of raw materials, is very relevant and has an important national economic significance, especially in the conditions of a market economy. The problem of reducing limestone consumption, which is used to obtain a water-lime suspension for cleaning solutions from non-sugars, is also relevant **[4]**. One of the ways to solve it is to increase the activity of this suspension to make fuller use of the adsorption capacity of calcium carbonate particles with a simultaneous increase in the filtration properties of saturated sediments **[5]**. Therefore, the paper conducted a study and proposed a physicochemical method of increasing the reactivity of the water-lime suspension and calcium carbonate particles.

Scientific hypothesis

In work **[6]**, we presented the effects of vapour condensation and hydrodynamic cavitation on the transformation of associated and complex compounds of non-sugars of diffusion and beet juices with the formation of substances with increased reactivity. Furthermore, in work [7], the effectiveness of the simultaneous application of the effects of vapour condensation cavitation and a calcium-containing reagent for the treatment of diffusion juice before preliminary defecation was theoretically substantiated and experimentally confirmed, which contributes to the formation of sediment of preliminary defecation juice with minimal hydrophilicity and saturation sediments with high filtration capacity. Therefore, there is an assumption that the applicant applying the vapour-condensation cavitation effect to the milk of lime can lead to its activation, which affects the purification of the diffusion juice from non-sugars. Thus, by increasing the activation of milk of lime, it is possible to reduce its total amount for cleaning, which will lead to a decrease in the cost price and the cost of the finished product - granulated sugar.

MATERIAL AND METHODOLOGY

Samples

The research was carried out using limestone from the Polupaniv deposit of the Ternopil region, which was crushed in laboratory conditions and diluted with water to a density of 1.14 g/cm^3.

Chemicals

0.1 n. hydrochloric acid (HCl, hydrochloric acid, manufactured by the private enterprise "Khimreaktivy", Ivano-Frankivsk, Ukraine).

Instruments

Portions of the water-lime suspension were treated with steam on a steam condensing unit, which is shown in Figure 1.

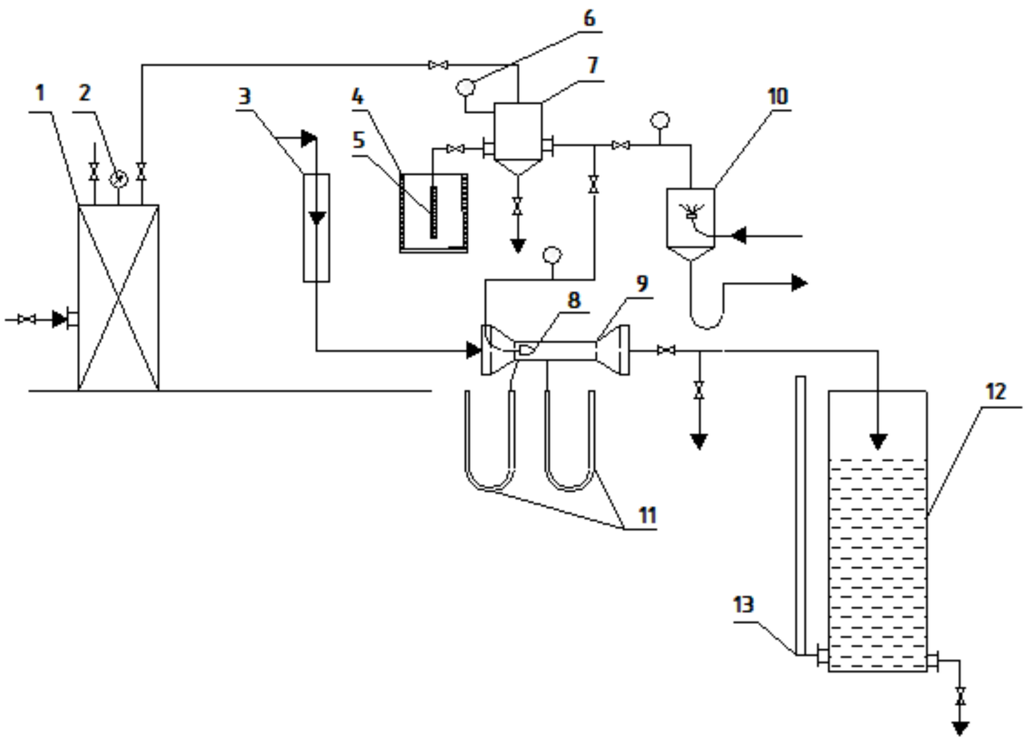

Figure 1 Diagram of a laboratory steam condensing unit. Note: 1 – steam boiler" 2, 6 – manometers; 3 – rotameter; 4 – thermostat capacity; 5 – bubbler; 7 – droplet catcher; 8 – nozzle; 9 – transparent section of the vapor condensation device; 10 – steam contact device; 11 – water diffmanometers; 12 – collection; 13 – measuring glass.

The steam-condensing cavitation device 9 consists of a working area into which a pipeline for supplying steam with a nozzle 8 attached to its end is inserted. It consists of confusion, a transparent cylindrical channel with a diameter of 25.4 mm, and a diffuser. With the help of pipelines, this device is connected to communication through the rotameter 3 with the water collector 12 and to the steam boiler 1 through the droplet separator 7. The steam pressure in front of the nozzle is controlled by the manometer 6. During the experiments, the hydrodynamics of the flow of the vapour-liquid mixture was visually observed.

The steam pressure in front of the nozzle was measured with a standard manometer MO 1 227 (manufactured by the Spetsavtomatika Ukrainy company, Kharkiv, Ukraine).

The pressure of the liquid in front of the nozzle Rs, the pressure of the vapor-water mixture, and the pressure at the exit from the working area What did you measure with the help of the DSP-160-M1 digital meter (manufactured by Spetsavtomatyka Ukrainy, Kharkiv, Ukraine).

The steam torch length was measured with a ruler's help 1 $\pm 10^{-3}$ m.

The rate of stratification of the water-lime suspension was determined using a ruler and a stopwatch.

The temperature was controlled with the help of the TLS-2 thermometer (manufactured by the Skloprylad plant, Kyiv, Ukraine).

Crushing of limestone was carried out using a DM 4x3 hammer crusher (producer LLC "Progress Industrial Equipment Plant", Cherkasy, Ukraine).

Time intervals were determined and monitored with a stopwatch with an accuracy of 1 s.

The density of the water-lime suspension was determined with an AZP-1 hydrometer (manufactured by the Skloprylad plant, Kyiv, Ukraine).

The sediment volume was measured using a measuring cylinder 1-100-1 (manufactured by the Skloprylad plant, Kyiv, Ukraine).

The specific electrical conductivity of the water-lime suspension was determined using a laboratory pH-meter/conductometer XS PC 50 VioLab Complete Kit, which consists of a pH-electrode type 201T and a conductometric cell type 2301T (manufactured by XS Instruments, Carpi, Italy).

Laboratory Methods

Determination of the activity of lime in the milk of lime was carried out by the method **[8]**, which is based on the titration of the weight of milk of lime with hydrochloric acid. To do this, it is necessary to filter milk of lime in the amount of 500 cm^3, and take a weight of milk of lime in the amount of 50 – 60 g, after which it is titrated with 0.1 n. hydrochloric acid and the activity of lime in the milk of lime are determined as a percentage ratio of the concentration of lime in the milk of lime to the solubility of lime in it.

The cost of steam at the exit from the nozzle was calculated based on the thermal balance.

The velocity of the liquid flow was calculated analytically from the dependence:

$$V = Q/S \quad (1)$$

Where:

Q – single environmental costs, determined using a meter; S – the cross-sectional area at the point of velocity determination.

Description of the Experiment

Sample preparation: the water-lime suspension was obtained by preliminary crushing of limestone with a hammer crusher followed by mixing with water until the suspension density was 1.14 g/cm^3.

Number of samples analyzed: eight samples of water-lime suspension were used to study the influence of suspension activity on the steam potential and the amount of steam for processing.

Number of repeated analyses: all the experiments were conducted three times.

Number of experiment replication: all the experiments were replicated three times.

Design of the experiment: according to the created laboratory installation (see Figure 1) with the help of the meter, the non-observable constant well, water consumption through the working transparent part of the steam-condensing cavitation device. By regulating the flow of steam with a fan, they chose the lifetime of the steam torch, which they looked at in the transparent part, and photographed the pattern of the flow of steam mixtures Next, they switched on the supply of steam to the thermostatic container 5, filled with water lime suspension, in which the bar is placed. They supplied the steam for a certain time and determined the thermal balance. spend a couple Analogously, you determined the consumption of steam for a steam-powered apparatus 10. Recorded indicators and diffmanometers, the height of the liquid column in collector 12, the temperature of the water at the entrance and exit from the transparent working area of the cavitation device, and the temperature of the juice before and after its processing in the vapor contact apparatus, into which the juice was fed under pressure through a centrifugal nozzle, were recorded.

Statistical Analysis

All data are expressed as the mean standard deviation of three parallel experiments and indicate significance at p <0.05. The data obtained during the research were subjected to statistical analysis using Excel and STATISTICA 13 programs (Dell, StatSoft).

RESULTS AND DISCUSSION

The water-lime suspension, traditionally called "lime milk" **[9]** by sugar makers, is shown in Figure 2 and is the main chemical reagent for cleaning semi-products of sugar beet production. Depending on the conditions of its production in factory conditions, such a suspension can have different quantitative and qualitative compositions **[10]**. The quantitative composition is characterized by density, which depends on the ratio of calcium hydroxide and water content. A density of 1.18 – 1.19 g/cm^3 is considered normal, but due to the high content of impurities (unslaked CaO and recalcitrant) and the low dispersion of $Ca(OH)_2$ particles, which leads to rapid delamination of the suspension factories use a lime suspension with a density of 1,12 – 1.14 g/cm^3. And this means that for the consumption of 2.5% of CaO to the mass of beets, an additional 2.6% of water, which must be evaporated, is introduced into the technological flow.

Figure 2 Water-lime suspension.

The qualitative composition of the water-lime suspension is characterized by activity. The activity of milk of lime is the ability of calcium hydroxide to quickly and completely react with non-sugars during preliminary and main defecation and with carbon dioxide at saturation. It is quantitatively evaluated as a percentage of the content of active CaO to its total content **[11]**, **[26]**. The consumption of milk or lime for cleaning the diffusion juice also depends on the amount of activity.

At temperatures close to the dissociation temperature of $CaCO_3$ (about 1000 °C), highly dispersed and highly active lime is obtained, which can be extinguished even with cold water in a few minutes. As the firing temperature increases, lime recrystallization processes take place, after which the sintering process begins. The latter interferes with the access of water to CaO particles during quenching, and lime, remaining chemically free, becomes inactive for reaction with water **[12]**, **[27]**.

At the same time as calcium recrystallization and sintering, the processes of its high-temperature process there are mods with admixtures and the formation of complex compounds: silicates, aluminates, and calcium oxide ferrites of various modifications. Films of these compounds slag the parts of the plaster, as well as prevent access to water. But if these films are destroyed by rubbing or damage, they are not active. It is transformed into action **[13]**, **[28]**.

In the 80s of the 20th centuries, VNDICP was developed and implemented in some sugar factories' methods of hydrodynamic cavitation activation of aqueous suspension **[14]**, **[29]**. The increase in its reaction capacity under these conditions is explained by the destruction of aggregates in suspension by cumulative micro streams into colloidal parts. But by using such a method in industrial conditions, significant abrasive wear of activator parts was found, which prevented their wide distribution **[15]**. We conducted a series of experiments to study the possibility of activation of water-lime suspension by using the effects of vapor condensation cavitation.

To compare the influence of the steam temperature on the effectiveness of the activation of the water-lime suspension With such processing, the temperature difference before and after processing was the same in all cases, which is composed of 5 °C and according to the method described above, the content of active calcium and its activity were determined. The obtained data are presented in Figure 3, which testify that the activity of calcium carbonate increases with the increase in temperature of the steam, but after the temperature of the steam is higher than 0.18 MPa, the increase in lime activity decreases.

Dependence of the activity of calcium carbonate milk on different consumption of steam with a pressure of 0.18 MPa gives the possibility to create, that for effective processing you have optimized the loss of water vapor is 1.7 – 2.0% of the mass of the suspension.

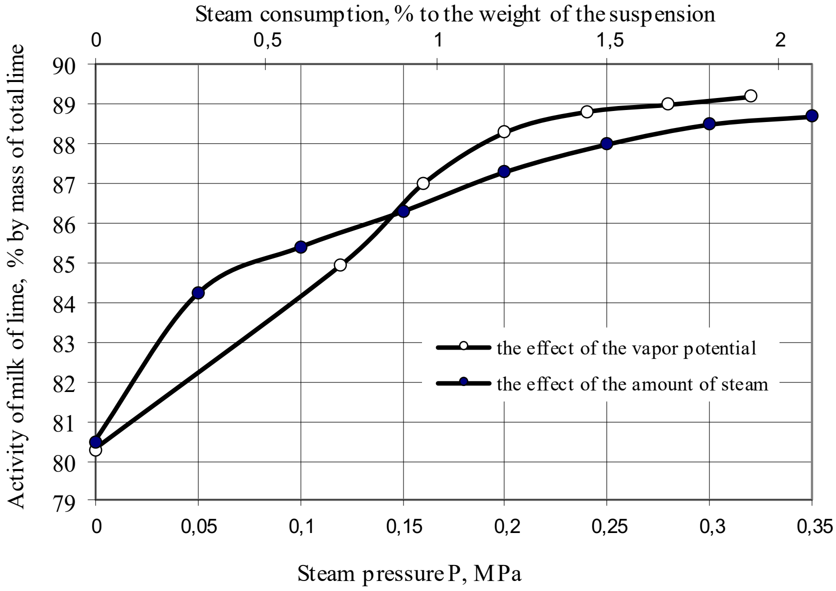

Figure 3 Change in the activity of milk of lime during its treatment with steam.

The obtained results can be explained, taking into account such assumptions. First of all, milky milk is a single suspension that appears with Both of them are the alkaline solution of calcium hydrogen oxide **[16]**. It also contains inorganic $Ca(OH)_2$ in the form of agglomerates that form over time in mixers for "ripening" milk of lime as a result of coagulation of soluble colloidal particles and the so-called hexaquark complexes of calcium hydroxide **[17]**. As a result of the collapse of the left bubbles in the water-lime suspension, part of the bubbles coalesce with the formation of cumulant streams, which destroy aggregates and complexes of $Ca(OH)_2$ **[18]**, **[30]**. When crushed particles come into contact with bubbles, which burst while maintaining symmetry, their additional dissolution occurs due to the heat perceived through the boundary layer from the bubbles. As a result, we get a supersaturated hydro line suspension, in which the amount of dissolved calcium ions increases **[19]**, **[31]**. The destruction of the constituent parts of the solid phase of the aqueous suspension is subject to increasing the dispersion and increasing the volume of the solid phase after processing Not a couple. The rate of dissolution and the volume of sedimentation of the solid phase of the aqueous suspension to We followed the method **[20]**, **[32]**. Data for the study of the rate of expansion and the volume of sediment of the solid phase of the suspension before and after steam processing is shown in the Table. 1.

Table 1 Comparative data of the speed of stratification and the volume of sediment of water-lime suspension before and after treatment with vapor condensation cavitation.

№	Before processing		After processing		
	delamination speed, mm/min	**sediment volume, %**	**the amount of steam, % to the mass of the suspension**	**delamination speed, mm/min**	**sediment volume, %**
1	2.5 ±0.05	72 ±0.7	1.7	1.7 ±0.04	81 ±0.8
2	2.5 ±0.05	75 ±0.7	1.8	1.6 ±0.04	80 ±0.8
3	2.5 ±0.05	71 ±0.7	1.9	1.4 ±0.04	82 ±0.8
Average	2.5 ±0.05	73 ±0.7	1.8	1.6 ±0.04	81 ±0.8

Table 1 testifies that the suspension is 1.5 times more processed with water vapor It expands more slowly and has a volume of sediment of the solid phase in the medium by 10% white better than unprocessed suspension. Such a phenomenon is indirect evidence of an increase in the dispersibility of the system after its steam treatment.

Secondly, in the aqueous suspension, there are parts of undissolved CaO, which are externally covered with a layer of insoluble $Ca(OH)_2$ particles. At the contact of such a part with a cumulative current, there is its destruction and further dissolution by calcium hydroxide. Liberation from the protective layer of CaO particles is accompanied by their extinguishing, which increases calcium ions' content in an aqueous suspension **[21]**, **[35]**. This was confirmed by measuring the electrical conductivity of the various numbers before steam suspension treatment was 7.9×10^{-3} sim/sm, and after treatment – 8.1×10^{-3} sim/sm.

At this stage of research, it is difficult to conclude whether the increase in specific electrical conductivity depends only on the increase in the solubility of lime in lime water, or whether it is the sum of the increase in the solubility of lime and the increase in the degree of electrolytic dissociation of hydroxy calcium ($CaOH^+$) with the formation of an additional amount of Ca^{2+} ions in the solution. In any case, increased solubility will positively affect the coagulation of substances of colloidal dispersion and the degree of decomposition of non-sugars in the diffusion juice **[22]**, **[33]**.

In addition to the expected decrease in the consumption of active milk and water- calcium suspension on the previous defecation will contribute to complete coagulation of substances of colloidal dispersity with the formation of poorly hydrated sediment and, as a result, an increase in the sedimentation and filtration properties of the juice and saturation **[23]**, **[34]**. An increase in the dispersion of calcium hydroxide particles contributes to the formation of highly dispersed calcium carbonate particles during the first saturation, which will increase the overall cleaning effect **[24]**.

At the same time, in work **[25]** it was established that the duration of the relaxation of the hydrodynamic cavity activated by applying the effects of It takes 20 – 30 minutes to prepare the milk. Therefore, we also studied the influence of the lime milk storage duration lime milk storage activated by vapour condensation cavitation on the change in its activity. The experiments showed that after the initial activity of the milk, after the activity of 89.4% CaO, the latter does not change for almost 15 minutes, and after 30 minutes it becomes smaller by 3 – 4% CaO. This means that it is advisable to carry out such activation before dosing milk of lime for preliminary and main defecation.

In this way, we can state that under the influence of the effects of vapour condensation cavitation, the activity of the vapour increases. of fresh milk up to 10% due to the destruction of calcium hydroxide particles and hexoaquacomplexes and the "advance" of parts of CaO, which contributes to an increase in the solution of active calcium ions (+2), necessary for interaction with the non-sugars of the diffusion juice during its lime-carbon dioxide purification.

CONCLUSION

It was established that to increase the activity of milk of lime at a steam potential of 0.18 MPa, an optimal consumption of water vapor with the use of vapor condensation cavitation in the amount of 1.75 – 2 is required. 0% to the weight of the suspension. This is ensured by the action of suspended CaO particles with steam bubbles, due to which their additional dissolution occurs due to the heat that the second is due to the boundary layer from the bubbles. As a result of this, a re-saturated single-calcium suspension is formed, in which the It is the number of dissolved calcium ions. It has been proven that the water vapour-treated suspension is 1.5 times lower It expands and has a volume of sediment of the solid phase in the medium that is 10% larger than that of processed suspension. Such a study is indirect evidence of an increase in the dispersity of the system after its steam treatment. As a result of the experiments, it was proved that due to the application of the effects of steam condensation cavitation, the activity of lime milk increases by 8 – 10%, which contributes to the temporary increase in the solution of active Ca^{2+} ions, which are necessary for interaction with the non-sugars of the diffusion juice during its lime-carbonation purification and simultaneously increasing the dispersion of calcium hydroxide particles. By increasing the activity of milk of lime, it is possible to increase the effect of juice purification at various stages of the technological process and reduce the consumption of limestone for the production of granulated sugar.

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