Identification of influential patterns of chemical treatment of sugar production thick juice and remelt syrups on the beet sugar quality

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Abstract. Laboratory studies have been carried out on the effect of chemical treatment with the use of various sulfite-containing reagents of sugar production concentrated intermediates - thick juice and remelt syrups on the beet sugar quality. It has been established that the chemical treatment of concentrated intermediates with the use of sulfur dioxide provides a greater reduction in their color compared to sodium bisulfite – from 996,7 to 830,30 and 857,30 ICUMSA units, respectively. It has been established that chemical treatment with the use of sulfite-containing reagents improves the quality of the resulting sugar. It has been established that during long-term storage (up to 100 days) of concentrated sugar-containing intermediates, their color increases, however, preliminary chemical treatment with the use of sulfur dioxide provides the least increase in color during storage, compared with treatment with sodium bisulfite. The increase in color after 100 days of storage relative to the initial values was 18,46 and 36,26%, respectively.

1 Introduction

The color of sugar production intermediates is an important technological indicator, since it determines the color of the resulting product - crystalline sugar. According to the current GOST 33222-2015, highly colored crystalline sugar has lower quality categories (TS2 and TS3) and, as a result, a lower selling price.

Taking this into account, by establishing technological regimes in production aimed at increasing the yield of finished products without focusing on its consumer properties, the risk of producing sugar of low-quality categories (TS2 and TS3) ultimately increases, as a result of which the company's revenue will be lower than it would be with less production of sugar of high-quality categories (Extra and TS1).

The problem of color reduction is especially relevant in relation to concentrated sugar-containing intermediates of beet sugar processing - thick juice, standard liquor and remelt syrups B and C, since these intermediates directly determine the color of the resulting

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crystalline sugar [1]. In case of non-compliance with technological regimes and obtaining concentrated sugar-containing intermediates with increased color, the production of crystalline sugar of high categories becomes almost impossible [2, 3].

It should be noted that a single increase in the color of thick juice and standard liquor under production conditions will contribute to the deterioration of the technological performance of the crystallization station in the medium term - up to 3-5 days, since in this case, in addition to increasing the color of crystalline sugar, the color of the outflows of the A massecuite also increases, from which the massecuites B and C are boiled down within 8 and 24 hours respectively [4]. This, in turn, leads to an increase in the color of sugars B and C and the remelt syrups obtained from them, which are returned back to the standard syrup preparation stage [5-8]. Thus, the deterioration in the color of thick juice and standard syrup has a cyclical character [9, 10].

In this regard, in order to obtain crystalline sugar of a high-quality category, it is necessary to ensure the production of concentrated sugar-containing intermediates with the lowest possible color.

2 Materials and methods

Under laboratory conditions, studies were carried out to identify the effect of chemical treatment with the use of various sulfite-containing reagents of sugar production thick juice and remelt syrup on the beet sugar quality.

As research objects were selected thick juice and remelt syrup B+C obtained under production conditions and provided by Sugar Factory Kurganinsky.

At the first stage of the research, the quality of the provided intermediates was assessed in order to select the most suitable one as the object of further research.

At the second stage, a study was made of the effect of chemical treatment with the use of various sulfite-containing reagents of concentrated sugar-containing intermediates on their quality and color of the resulting sugar. Taking into account that the research object (at the first stage, the remelt syrup B+C was selected) had a low initial pH value of 7,08, it was alkalized with 1N NaOH solution to pH 9,0-9,5. Next, the remelt syrup B+C was divided into 4 equal parts. The first part was left untreated as a control (Control), the second part was treated with sulfur dioxide until pH 8.5-9.0 was reached (Sample 1), the third part was treated with sulfur dioxide until pH value of 8,5-9,0 was reached, after which it was adjusted until the initial pH value of 9,0-9,5 was reached with 1N NaOH solution (Sample 2), and the fourth - with a solution of sodium bisulfite Grade A with a mass fraction of the active substance of 25,5% until pH value of 8,5-9,0 was reached (Sample 3). Further, in laboratory conditions, sugars were obtained from the obtained samples and their color was analyzed. The studies were carried out in triplicate, the obtained data were averaged.

At the third stage, a study was made of the effect of chemical treatment using various sulfite-containing reagents on the quality of thick juice withdrawing for long-term storage. At this stage, the higher dry substances content in the remelt syrup B+C, as well as the lower reducing substances content, made it more promising for use as the research object.

It should be noted that in industrial practice for boiling massecuite, this method is not used, since the optimal pH range for boiling massecuite is pH equal to 8,5-9,0, and failure to comply with this range leads to an increase in the boiling duration [11-15].

Storage of concentrated intermediates was carried out for 100 days under a layer of vegetable oil. After that, the quality indicators were determined in the samples. The studies were carried out in triplicate, the obtained data were averaged.

3 Results and Discussions

Table 1 shows quality indicators of the remelt syrup B+C and thick juice.

Table 1. Quality indicators of the remelt syrup B+C and thick juice

Indicator name	Indicator value	
	Remelt syrup B+C	Thick juice
Dry substances content, %	67,30±1,0	50,10±0,8
Sucrose content, %	64,10±0,9	45,55±0,7
Purity, %	95,20	90,90
Reducing substances content, % by product weight	0,242	0,486
pH value, unit	7,08	7,37
Color, ICUMSA unit	996,7	1246,9

It should be noted that the pH values of the provided intermediates were not in the optimal required pH values range of 8,5-9,5. Analyzing the data obtained, at first glance, it is obvious that in order to obtain more visual data on the effect of chemical treatment with the use of various sulfite-containing reagents of thick juice and remelt syrup on the beet sugar quality, it was necessary to select an intermediate product with a higher color. However, the remelt syrup B+C had a higher dry substances content and purity, as well as a lower reducing substances content, leading to autocatalytic decomposition of sucrose. Due to that for further studies the remelt syrup B+C was selected.

Table 2 shows data characterizing the effect of chemical treatment of concentrated sugar-containing intermediates on their quality.

Table 2. The effect of chemical treatment of concentrated sugar-containing intermediates on their quality

Indicator name	Indicator value			
	Control	Sample 1	Sample 2	Sample 3
Dry substances content, %	67,0±1,0	67,5±1,0	66,8±1,0	67,4±1,0
Sucrose content, %	64,00±0,8	64,25±0,8	63,60±0,8	64,15±0,8
Purity, %	95,20	95,20	95,20	95,20
pH value, unit	9,16	8,76	9,15	8,74
Color, ICUMSA unit	891,70	830,30	824,80	857,30
Color change, %	–	– 6,89	– 7,50	– 3,86

From the presented data it follows that the chemical treatment of concentrated intermediates with the use of sulfur dioxide provides a greater reduction in their color compared to sodium bisulfite. The greatest decrease in color was achieved by chemical treatment with sulfur dioxide, followed by a return to the initial pH value. In our opinion, this was achieved by the fact that the sodium hydroxide introduced for alkalization, being more active, replaced a certain amount of calcium, as a result of which a decrease in color occurred. The same effect was also observed when the initial sample was alkalized to the control one - the color decreased from 996,70 to 891,70 ICUMSA units.

Table 3 shows the data characterizing the effect of chemical treatment using various sulfite-containing reagents on the resulting sugar color.

Table 3. The effect of chemical treatment using various sulfite-containing reagents on the resulting sugar color

Indicator name	Indicator value			
	Control	Sample 1	Sample 2	Sample 3
Color, ICUMSA unit	63,0	56,0	55,0	58,0
Color change, %	–	– 11,11	– 12,70	– 7,94

From the presented data it follows that chemical treatment with the use of various sulfite-containing reagents of concentrated intermediates provides a greater reduction in the sugar color. It should be noted that according to the color index, sugar obtained in laboratory conditions from samples obtained using chemical processing, according to the requirements of GOST 33222-2015, corresponds to the TS1 category, and obtained from an untreated sample, to the TS2 category. However, it should be noted that the intermediates used initially had a high color. Nevertheless, it can be concluded that chemical treatment using various sulfite-containing reagents improves the quality of the resulting sugar and, in a critical situation, can provide sugar of a high-quality category.

Figure 1 shows data characterizing the effect of chemical treatment using various sulfite-containing reagents on the color of concentrated sugar-containing intermediates during long-term storage.

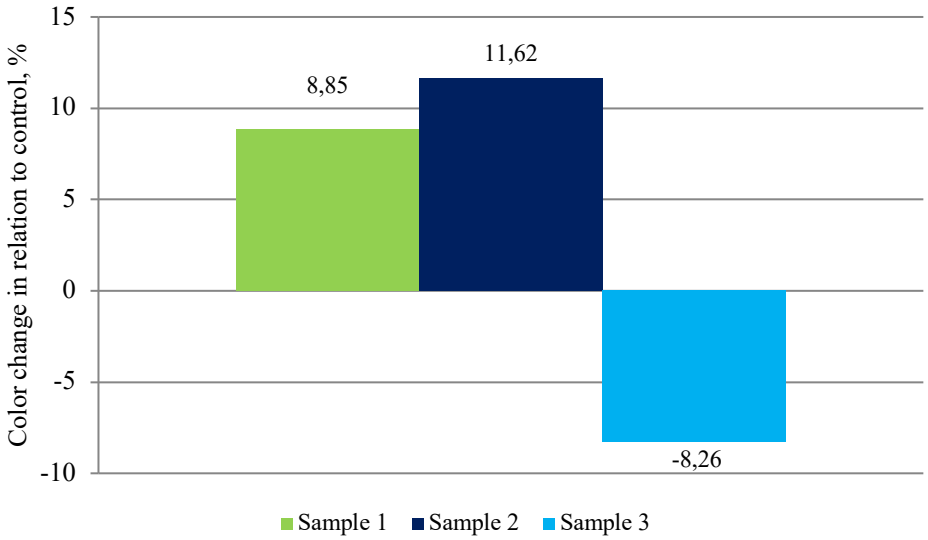

Fig. 1. The effect of chemical treatment using various sulfite-containing reagents on the color of concentrated sugar-containing intermediates during long-term storage

From the data presented in Figure 1, it follows that during long-term storage of concentrated sugar-containing intermediates, their color increases, however, preliminary chemical treatment with the use of sulfur dioxide provides the least increase in color during storage, especially when using alkalization before storage. At the same time, the increase in the color of the sample treated with sodium bisulfite was the highest, which indicates its ineffective effect on inhibiting the increase in the color of the thick juice during storage.

In our opinion, this is due to the fact that the blocking of the aldehyde and ketone groups of reducing substances when using sulfurous dioxide occurs due to the divalent anion SO32-

, and when treated with bisulfite, the monovalent HSO_3^-, which forms unstable compounds that decompose during storage.

As a result, the color value of Samples 1 and 2 was lower than the color value of the control sample by 8,85% and 11,62%, while the color value of Sample 3 was higher by 8,26%.

4 Conclusion

It was found that chemical treatment using sulfur dioxide is more effective than using sodium bisulfite. The use of sodium bisulfite for chemical treatment is advisable only for the continuous processing of concentrated intermediates, however, such treatment is less effective than the use of sulfur dioxide.

Regardless of the sulfite-containing reagent used, chemical treatment improves the quality of the resulting sugar and, in a critical situation, can provide sugar with a higher quality category.

When using the technological method of withdrawing thick juice for storage, it is advisable to carry out its preliminary chemical treatment with the use of sulfur dioxide, as well as subsequent alkalization. This will provide an opportunity for further processing of such thick juice to obtain crystalline sugar of a high-quality category.

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