Inorganic sorbent application in the food industry

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Abstract. Data on the effect of inorganic aluminum-containing sorbent obtained from the etching product of aluminum tape, reprecipitated and treated with a surfactant on the quality indicators of saturation juices, are presented. Diffusion juice purification was carried out with the introduction of a sorbent for predefecation. Studies have shown that the addition of a small amount of aluminum-containing sorbent (0.10 ... 0.20%) can increase the purity of saturation juice II by 2.71%, and the cleaning efficiency by 18.22% compared to the typical scheme. There is a decrease in the color of the purified juice by 8.89 conv. units.

1. Introduction
The world market makes rather stringent demands on the quality of granulated sugar and refined sugar [1-5]. For the competitiveness of domestic products of the sugar industry in Russia with the manufacturers of Western and Central Europe, it is necessary to pay special attention to the problem of reducing the color and ash content of sugar [6-8]. The color of sugar can be reduced by improving the storage of beets, as well as the application of methods such as cleaning sugar-containing solutions with inorganic adsorbents [9,10]. The uses of silica gel and aluminum gel are currently expensive methods. Therefore, cheap, affordable and effective sorbents are needed. A modified adsorbent from aluminum-containing raw materials with a fluorine-containing surfactant, with a developed surface, thermal stability, increased mechanical strength and a special mechanical lattice structure, can be used as a sorbent, catalyst, and catalyst carrier for various purposes, including for the purification of sugar solutions [11,12].

In this paper, in order to study the effect of an aluminum-containing sorbent on the quality indicators of saturation juices, we purified the diffusion juice to saturation II juice according to the scheme with the introduction of a sorbent for pre-defecation. For comparison, the diffusion juice was purified to saturation juice II according to a typical scheme.

2. Materials and methods
An aluminum-containing sorbent modified by a fluorine-containing surfactant obtained from the etched products of aluminum alloys was used as a material for research. The adsorbent consists of 95-98% α-Al₂O₃. The use of a surfactant solution with a concentration of 0.021% as a modifier with subsequent heat treatment of 450 °C is the most effective, because at the same time, a bleaching effect of 78.40% is observed. When conducting research, we used diffusion juice with a purity of 84.22%. A typical cleaning scheme consisted of the following stages: warm progressive
pre-defecation, hot main defecation, I saturation, filtration, defecation before II saturation, II saturation and filtration.

The difference between the scheme with the introduction of aluminum-containing sorbent at pre-defecation from the standard scheme was that during progressive pre-defecation into the metastable zone (III section of the pre-defecator), the sorbent content was 0.10; 0.15 and 0.20% wt., pH input 9.2-9.5.

The suspensions dispersion was determined by the sedimentation method based on the determination of the particles deposition rate in a gravitational field depending on the size, density and physico-chemical characteristics of the medium.

3. Results and Discussion
The use of an aluminum-containing sorbent introduced during pre-defecation increases the purity of saturation juice II by 2.71%, and the cleaning effect - by 18.22% compared to the typical scheme. Moreover there is a decrease in the purified juice color by 8.89 conv. units (Table 1).

| Table 1. Technological indicators of purified juice |
|-----------------------------------------------|
| Indicators of saturation II juice | Traditional scheme | Sorbent introduction scheme |
| pH  | 9.31 | 9.38 |
| P, % | 88.36 | 91.07 |
| ΔP, % | — | +2.71 |
| Purification effect, % | 26.39 | 45.21 |
| Colour, conv. units | 20.39 | 11.50 |

The suspensions dispersion of saturation I juice obtained by the standard and developed schemes was determined to evaluate the effectiveness of the method of purification of diffusion juice using an aluminum-containing sorbent for pre-defecation.

![Figure 1](image.png)

**Figure 1.** Differential curves of the distribution of saturation I juice particles: 1 - typical scheme; 2 - scheme with the sorbent introduction

The analysis of the graphical dependencies shows that when using an aluminum-containing sorbent for pre-defecation, the suspension becomes more homogeneous compared to the suspension obtained according to the standard scheme.

This is confirmed by the nature of curve 2 in Figure 1, which is characterized by a narrower range of radii and a higher maximum value of the particle distribution function ($f_{max} = 60.7 \cdot 10^3 \text{m}^{-1}$) than
on curve 1 ($f_{\text{max}} = 36.7 \times 10^5 \text{m}^{-1}$). In the suspension of saturation juice I obtained by the sorbent introduction in pre-defecation, small particles of 0.009 - 0.011 mm in size prevail, and the proportion of larger particles more than 0.014 mm is significantly reduced compared to the suspension of saturation juice I obtained by the standard scheme. That is, alumina leads to an increase in the dispersion of the sediment of saturation juice I which improves its adsorption properties. In saturation juices I obtained according to the traditional (I) and proposed (II) purification schemes, sedimentation properties (Table 2) were studied and the filtration coefficient was determined (Table 3).

### Table 2. Sedimentation indicators of saturation juice I depending on the purification scheme

| Purification scheme | Sedimentation time, min | Sedimentation layer height, cm | $S_5$ cm/min | $V_{25}$ % |
|---------------------|-------------------------|-------------------------------|--------------|------------|
|                     | 1 2 3 4 5 7 10 15 25    |                               |              |            |
| I                   | 14.5 11.0 10.3 9.3 8.0 7.4 6.8 5.7 5.0 | 1.6 | 18.2 |
| II                  | 15.5 12.8 11.4 10.7 9.6 8.2 7.4 6.3 5.5 | 1.98 | 20    |

The sedimentation properties of saturation juice I obtained according to the scheme with the sorbent introduction for pre-defecation slightly differ from the sedimentation properties of saturation juice I obtained according to the traditional scheme. This can be explained by the fact that the sediment of the saturation juice I obtained according to the proposed scheme is more dispersed.

### Table 3. The filtration coefficient of saturation juice I depending on the purification scheme

| Variant of purification scheme | $\tau_1$ | $\tau_2$ | $F_k$ | $F_{k\text{average}}$ |
|-------------------------------|----------|----------|------|---------------------|
| I                             | 19.93    | 30.46    | 5.27 |                     |
|                               | 21.02    | 30.84    | 4.91 | 4.96                |
|                               | 22.50    | 31.91    | 4.71 |                     |
|                               | 13.94    | 19.75    | 2.91 |                     |
| II                            | 15.60    | 21.95    | 3.18 | 2.95                |
|                               | 14.49    | 20.02    | 2.77 |                     |

According to the table, saturation juice I obtained with the introduction of an aluminum-containing sorbent in the process of pre-defecation has the best filtration coefficient. This can be explained by a higher degree of uniformity of sediment particles of saturation juice I. The smaller the particle size, the larger the sediment surface and more complete removal of non-sugars of the purified juice takes place. This allows us to conclude that the aluminum-containing sorbent does not impair the sedimentation rate of unfiltered saturation juice I, despite the increased dispersion of the suspension particles.

Thus, the conducted studies show that the introduction of an aluminum-containing sorbent for pre-defecation affects the removal of non-sugars positively.

The problem of sucrose stability is one of the central issues in sugar production technology. The main cause of sugar losses in production, as it was found out by researchers S.Z. Ivanov, S.E. Harin, A.R. Sapronov et al. [13-15] are the autocatalytic and consecutive reactions of sucrose decomposition in aqueous solutions when being heated.

Non-sugars affect the rate of sucrose decomposition in different ways. Sodium chloride and potassium, potassium sulfate, glucose and caramel accelerate the reaction. Melanoids, alkaline decomposition products of invert sugar, amino acids and calcium acetate slow the sucrose auto-inversion reaction, increasing the induction period.
The thermal stability of saturation juice I depends on its purity. Therefore, the sorption process can affect the decrease in the heat resistance of the juice.

The thermal stability of saturation juice I obtained according to the scheme with the introduction of an aluminum-containing sorbent at the stage of pre-defecation was studied in comparison with the saturation juice II obtained with the traditional scheme.

Research results are presented in Figure 2.

Figure 2. The influence of the heating duration on the purity (curves 1 and 2) and color (curves 3 and 4) of the saturation juice II: 2, 3 - the traditional scheme; 1, 4 - scheme with the sorbent use

The analysis of the graphical dependences presented in Figure 2 indicates that the color increase of the saturation juice II occurs with an increase in the heating time at the boiling point, and the saturation juice II obtained according to the scheme with the introduction of the sorbent for pre-defecation has a lower color than the saturation juice II obtained according to the traditional scheme, but the difference is insignificant.

Comparing the purity values of juices during heating, we can conclude that the decrease in the purity of saturation juice II obtained by the scheme with the introduction of the aluminum-containing sorbent is significantly lower than in saturation juice II obtained according to the traditional scheme. Therefore, the juice obtained by the proposed scheme has greater thermal stability, since it contains fewer non-sugars. And from literary sources it is known that the rate of decomposition reaction depends on the content of non-sugars.

Table 4. The change in the reducing substances content in the saturation juice II during heating

| The scheme for saturation juice II obtaining | Heating time, h | 0    | 3    | 7    |
|--------------------------------------------|----------------|------|------|------|
| Traditional                                |                | 0.0479 | 0.1203 | 0.0644 |
| With the sorbent introduction during the process |                | 0.0159 | 0.0321 | 0.0103 |

According to the table, the reducing substances (RS) content in the saturation juice II obtained by the proposed scheme is significantly lower than in the saturation juice II obtained by the traditional
scheme. This will positively affect the subsequent stages of sand sugar obtaining since a smaller increase in color increases the yield of sugar and reduces the loss of sucrose in molasses.

Food safety is one of the main factors determining the health of the country’s population and characterizing the quality of products [16]. Technical regulations demand the necessary requirements to ensure the safety of food products for the content of toxic elements. The analysis of the samples was carried out in an accredited independent testing laboratory of building materials, products and structures (ITLBM). The test results are presented in table. 5

Table 5. Results of atomic adsorption analysis of samples

| №  | Sample                  | Cu   | Zn   | Ni   | Co   | Fe   | Mn   | Cd   | Pb   |
|----|-------------------------|------|------|------|------|------|------|------|------|
| 1  | Sorbent not washed     | 2.597| 4.423| 0.27 | 1.683| 5.073| 1.666| 1.393| 3.656|
| 2  | Washed sorbent          | 1.417| 3.466| 0.19 | 0.970| 4.820| 1.450| 0.743| 2.703|
| 3  | Diffusion juice         | 0.031| 0.091| 0.085| 0.052| 0.072| 0.002| 0.010| 0.029|
| 4  | Saturation juice II     | 0.028| 0.024| 0.019| 0.021| 0.051| Traces| Traces| 0.018|
| 5  | Saturation juice II (with sorbent not washed) | 0.015| 0.012| 0.011| 0.019| 0.049| Traces| Traces| 0.017|
| 6  | Saturation juice II (with washed sorbent) | 0.008| 0.006| 0.010| 0.015| 0.025| Traces| Traces| 0.016|
| 7  | Syrup (traditional scheme) | 0.082| 0.080| 0.065| 0.063| 0.163| Traces| Traces| 0.058|
| 8  | Syrup (with sorbent not washed ) | 0.042| 0.038| 0.031| 0.060| 0.076| Traces| Traces| 0.023|
| 9  | Syrup (with washed sorbent) | 0.026| 0.017| 0.028| 0.045| 0.074| Traces| Traces| 0.018|

After analyzing the data obtained, it was found that the content of heavy metals in the aluminum-containing sorbent, diffusion juice, saturation juice II and syrup purified with their help does not reach amounts that are hazardous to health. As a result of washing of the aluminum-containing sorbent, the content of heavy metals in it somewhat decreases, which indicates the advisability of this stage of preparation of the sorbent for use in the technological process of sugar production. Sorbents washed and not washed effectively sort heavy metals from solutions.

Table 6 shows data on the composition of low molecular weight carbohydrates in beet juice before and after saturation with and without the use of the aluminum-containing sorbent, washed and not
washed. The data were obtained using a high-performance liquid chromatograph LP (Czech Republic) with a refractometric detector on the Separon NH2 amine-phase column; the composition of the eluent was acetonitrile-water (80:20).

### Table 6. The carbohydrate content in the samples, % by weight of juice

| Sample                        | Sucrose  | Glucose | Fructose | Xylose | Raffinose |
|-------------------------------|----------|---------|----------|--------|-----------|
| Sugar beet juice              | 9.90     | Traces  | Traces   | Traces | -         |
| Saturation juice II (traditional scheme) | 10.35   | Traces  | Traces   | Traces | 0.3       |
| Saturation juice II (with sorbent not washed) | 10.45   | Traces  | Traces   | Traces | -         |
| Saturation juice II (with washed sorbent) | 10.50   | Traces  | Traces   | Traces | -         |
| According to technological instruction |        |         |          |        |           |

Traces: from 0.01 to 0.07% by weight of juice.

Based on the data obtained, it can be seen that the aluminum-containing sorbent does not negatively affect the content and ratio of sucrose and monosaccharides in the sample, but it most likely sorts oligo- and polysaccharides, in particular, in juices obtained using an aluminum-containing sorbent, there is no raffinose trisaccharide found in the juice obtained by traditional technology.

Thus, the aluminum-containing sorbent is applicable for sugar-containing solutions bleaching.

### 4. Conclusion

The use of the modified aluminum-containing sorbent obtained by aluminum alloys etching as an additive for pre-defecation leads to an increase in the purity of the saturation juice II, and a decrease in the colloid content by 0.0026% by weight of the juice. Studies carried out demonstrated that aluminum-containing sorbent positively affects the quality indicators of juices at further stages of purification.

According to the results of the research, a method of progressive pre-defecation using aluminum-containing raw materials was developed. This method was tested on a pilot apparatus in the federal state budget scientific institution "RUSSIAN RESEARCH INSTITUTE OF SUGAR BEET AND SUGAR" and confirmed its effectiveness.

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