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AVALIAÇÃO CIENTÍFICA DO RISCO DE SEGURANÇA DOS PRODUTOS BRUTOS DE AÇÚCAR

SCIENTIFIC SECURITY ASSESSMENT OF SAFETY RISK OF RAW SUGAR PRODUCTS

НАУЧНОЕ ОБЕСПЕЧЕНИЕ ОЦЕНКА РИСКА БЕЗОПАСНОСТИ СЫРЬЯ САХАРНОЙ ПРОДУКЦИИ

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RESUMO

A organização adequada do armazenamento de produtos de açúcar bruto permite manter a qualidade do produto e minimizar a perda de massa por muito tempo. As dificuldades estão associadas ao alto conteúdo de água livre nos produtos. Foi estudado o efeito do tratamento com ozônio no armazenamento de longo prazo dos produtos do açúcar bruto, incluindo beterraba sacarina. Amostras de beterraba sacarina foram colhidas na usina de açúcar Koksu, na vila de Balpyk bi, região de Almaty, na República do Cazaquistão. O planejamento dos experimentos fatorial tipo 2^3, oito protótipos foram elaborados e cada um deles foi processado com diferentes combinações (máx e mín) dos seguintes fatores: x_1 - concentração de ozônio (g/m^3), x_2 - tempo de processamento (min), x_3 - sobrepressão (ati) (o valor da pressão pode ser contado a partir de 0 (pressão absoluta) ou atmosférica (pressão excessiva). Se a pressão é medida em atmosferas técnicas, a pressão absoluta é indicada como ata e a pressão excessiva é indicada como ati). Propriedades físico-bioquímicas, microbiológicas e indicadores de segurança foram determinados para cada amostra de beterraba sacarina: fração mássica de umidade, matéria seca, acidez, pectina, fibra, sacarose, nitrito, metais pesados, pesticidas, micotoxinas, presença de mofo e levedura. Como resultado do estudo, verificou-se que o tratamento com ozônio reduziu significativamente o crescimento de fungos e leveduras, contribui para um aumento no conteúdo de pectina, fibra e sacarose, e uma avaliação de segurança da segurança de produtos de açúcar em bruto foi fornecida cientificamente.

Palavras-chave: *ozônio, tratamento, infecção, microbiologia, doença*.

ABSTRACT

Proper organization of storage of raw sugar products allows for a long time to maintain product quality and minimize loss of its mass. Difficulties are associated with the high content of free water in them. We have studied the effect of ozone treatment on long-term storage of raw sugar products, including sugar beets. Sugar beet samples were taken from the Koksu sugar factory in the village of Balpyk bi, Almaty region of the Republic of Kazakhstan. The plans for full-factor experiments of the type — 2^3 out of eight prototypes — were drawn up and each of them was processed with different combinations (max and min) of the following factors: x_1 - ozone concentration (g/m^3), x_2 - processing time (min), x_3 - overpressure (ati) (the pressure value can be counted from 0 (absolute pressure) or from atmospheric (overpressure). If the pressure is measured in technical atmospheres, then absolute pressure is denoted as ata, and excess pressure is denoted as ati). Physico-biochemical, microbiological properties, and safety indicators were determined for each sample of sugar beet: mass fraction of moisture, dry matter, acidity, pectin, fiber, sucrose, nitrite, heavy metals, pesticides, mycotoxins, the presence of mold and yeast. As a result of the study, it was found that ozone treatment significantly reduces the growth of mold and yeast, contributes to an increase in the content of pectin, fiber and sucrose, and a safety risk assessment of raw sugar products was scientifically provided.

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Keywords: ozone, treatment, infection, microbiology, disease.

АННОТАЦИЯ

Правильная организация хранения сырья сахарной продукции позволяет длительное время сохранить качество продукции и свести к минимуму потери ее массы. Трудности связаны с большим содержанием в них воды в свободном состоянии. Нами исследовано влияние озонной обработки на длительные хранения сырья сахарной продукции, в том числе сахарной свеклы. Был проведен отбор проб сахарной свеклы из Коксуского сахарного завода, села Балпык би Алматинской области Республики Казахстан. Составлены планы полнофакторных экспериментов типа – 2^3 из восьми опытных образцов и каждые из них обрабатывались с разными сочетаниями (max и min) следующих факторов: x_1 – концентрация озона (г/м^3), x_2 – время обработки (мин), x_3 – избыточное давление (ати) (значение давления может отсчитываться от 0 (абсолютное давление) или от атмосферного (избыточное давление). Если давление измеряется в технических атмосферах, то абсолютное давление обозначается как ата, а избыточное - как ати). По обработанному каждому образцу сахарной свеклы были определены физико-биохимические, микробиологические свойства и показатели безопасности: массовые доли влаги, сухого вещества, кислотности, пектиновых веществ, клетчатки, сахарозы, нитрита, тяжелых металлов, пестицидов, микотоксинов, наличие плесени и дрожжей. В результате исследования были установлены, что озонная обработка заметно снижает рост плесени и дрожжей, способствует к увеличению содержания пектиновых веществ, клетчатки и сахарозы, научно была обеспечена оценка риска безопасности сырья сахарной продукции.

Ключевые слова: озон, обработка, зараженность, микробиология, болезнь.

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1. INTRODUCTION

Sugar production is a complex technological process consisting of various stages, which requires the use of special equipment aimed at obtaining high-quality sugar from the corresponding raw materials. It foresees the presence of 3 branches at a sugar factory:

– beet processing (peeling, grinding of beets, diffuse removal of juice from chips);

– juice purification (creating syrup from pure juice + its purification and evaporation);

– food compartment (transformation of syrup into massecuite with further crystallization, jointing, and whitening, drying, and packaging of finished sugar).

In our country, the basis of the raw material base for sugar-producing enterprises is sugar beet. It must be closely monitored for the presence / absence of microorganisms. If the microbiological activity of beets is systematically controlled in the manufacture of sugar, it is possible to establish infectious sources and foci in a timely manner, then take measures to eliminate them, and also correct deviations that occurred in the technological process during the life of organisms (Sapronov *et al.*, 2011; Apasov *et al.*, 2011; Podporinova *et al.*, 2010; Weststrat, 2002).

If there is a microbial defeat of sugar beets, the biological masses of all kinds of microorganisms accumulate in it during storage and processing. As a result, sugar production has many problems. Saprophyte molds have a destructive effect on the root structure, thereby creating a good environment for the development of bacteria, which, in turn, completes the spoilage process, beets lose their suitability for processing. Bacteria of different groups and species has a decisive influence on the composition of the final metabolic products. Heterofermentative lactic acid bacteria produce dextran polysaccharide. Putrefactive destroy the protein components of the root and therefore contribute to the appearance of hydrogen nitride, dimethyl ketone, and methyl formaldehyde. In the spectrum of the functional activity of butyric acid bacteria - the effect on starch, pectins and sugars with the formation of dimethylketone, alcohol, gas and acidic environments (in particular, butanoic and ethanoic acids). By the way, significant accumulation of gases is a dangerous explosion of a diffusion plant (Stognienko *et al.*, 2012; Sapronov, 2007; Loel *et al., 2014;* Martindale, *2013*).

Determination of the microbiological activity of sugar beet: importance for sugar enterprises. In order to ensure the sanitary and hygienic state of production in such a way that all aspects comply with the regulatory documentation SanERandR 2.3.2.1078-01, it is important to monitor the active microflora and suppress it even at the beginning of processing activities. If this is not done, not only the beets will be unsuitable for work, but also the development of microorganisms in the beet processing department of the plant, as well as their subsequent accumulation on equipment, will be implemented (Islamgulov *et al., 2013;* Sapronov *et al*., 2014; Luterbacher *et al., 2005*).

When stored at elevated temperatures, this causes intensive respiration of cells and tissues, activates the maturation and aging processes, enhances the evaporation and development of phytopathogenic microflora, which leads to significant losses in mass and product quality. Therefore, during storage, they strive to create conditions that slow down the vital processes of stored products and microorganisms (Manzhesov *et al*., 2009; Vertush, 2002; Karpov, 2007). The initial control of raw materials in the kagat (or burt - simplified storage of vegetables, root crops in the form of a shaft or foundation pit, covered with straw or tarpaulin) and entering the enterprise looks like a visual inspection. If spoilage is present, determining the nature of microflora becomes relevant (Krylov, 2006; Erkmen, 2001; Lichko *et al*., 2000).

Most attention should be paid to active fungi that destroy roots. Their standard location is the inside of beets. It is clear that to establish whether there is a problem visually or not will fail. In this case, it is necessary to sow from the inner part of the affected root crop into a nutrient medium with agar and immediately after that, if possible, establish the type of fungus. If a lot of roots with active semi-parasitic fungi are found in the kagat, all beets should be processed out of turn. Plus, measures should be taken to strengthen the fight against infectious damage in the production process, since a number of related microorganisms are a companion of such beets (Shpaar *et al*., 2000; Ober *et al*., 2010; Bugaenko, 2002).

Microbiological analysis - the most important segment of sugar production. It allows the timely detection of bacterial microflora, which is dangerous not only for the sugar-producing enterprise but also for various areas of the food industry that use sugar. Sugar contaminated with microorganisms is dangerous for soft drinks, confectionery industry, canning production, and others. Therefore, it is very important to know and use methods for determining microbiological activity and effective control of it (Trisvyatsky *et al., 1991; Gagkaeva et al., 2005*).

Microorganisms are introduced into it during the bleaching, drying, packaging, and storage of sugar beets. When sugar is washed by centrifugation, the microbes in it are minimized. Shakes and silos are areas where microflora increases. Microbes come from air masses along with sugar dust. Their control is to take about 300 g of crystalline sugar from every fifth bag. To determine how many microorganisms are present in one gram of sugar, a certain list of dilutions on selective media from the samples is sown (one warmed up for five minutes, the second unheated). Studies of granulated sugar are aimed at determining the following microflora:

– thermophiles (acid-forming aerobes, forming and non-forming hydrogen sulfide anaerobes);

– mesophiles (mucus-forming bacteria, osmotolerant yeast, mycelial fungi).

To protect sugar from negative influences as much as possible, it is important to observe the correct storage conditions. It must be kept in dry rooms with a relative humidity of 50-65% and a temperature of 15-20 °C. The surfaces of silos and premises should be treated with a disinfection agent using a 0.8% solution of the chemical combination cresol + sulfuric acid. To disinfect air and equipment by means of UV radiation (Shkalikov, 2010; Stevanato *et al*., 2019; Kim *et al*., 2003; Richardson, 2002).

2. MATERIALS AND METHODS

The following methods were used to determine the physicochemical parameters: the mass fraction of moisture and dry was determined according to GOST 28561-90, acidity according to GOST ISO 750-2013, mass fraction of pectin substances according to GOST 29059-91, mass fraction of sucrose according to GOST 28562-90, mass fraction of nitrite according to GOST 29270-95 and mass fraction fiber according to the Wende method (Timoshenko N.V. *et al*., 2006). The content of toxic elements in sugar beets was determined: lead and cadmium, according to GOST 30178-96. The content of mycotoxins, including aflatoxin M, was determined according to GOST 30711-2001. The following interstate standards were used to determine microbiological indicators, that is, the content of mold and yeast: GOST 26669-85 Food and taste products. Sample preparation for microbiological analysis; GOST 26670-91 Food Products. Methods for the cultivation of microorganisms; GOST 10444.12-2013 Microbiology of food and animal feeding stuffs. Methods for the detection and colony count of yeasts and molds

A universal ion-ozonation plant has been developed that produces ozone, molecular ions, or an ion-ozone mixture in metered concentrations of certain components of the IOM (ion-ozone mixture). The efficiency of the ion-ozonator installation was obtained by improving and combining the electrical circuits of the ozonator and ionizer installations, the selection of materials, the estimated geometric dimensions and proportions. According to calculations and experimental research, the optimal modes of IOM synthesis were established, the necessary parameters for the impact on the processed product. All this universality is united not only by the similarity and stages of the synthesis of IOM, ionization of water and their interconnected quantum-physical processes that occur in the biological environment during their processing but also in design. Moreover, the synthesis of ozone is accompanied by the formation of ions of different signs of electrical polarity. The factor of the presence of atomic ions, nitrogen oxides, and carbon during the synthesis of ozone has a great influence on the process of negative influence during the processing of products of biological origin (Iztaev, Kulazhanov *et al*., 2018; Yakiyayeva *et al*., 2016).

Therefore, there was a need to combine ozone and ion technology to neutralize side effects, harmful impurities of atomic ions, nitrogen and carbon oxides in the synthesis of ozone and in the synthesis of molecular ions with the exception of a high-frequency electromagnetic field or a constant pulsating field with a wavelength that has a harmful effect on the body ; radioactive radiation, alpha, beta and especially gamma rays, at least even in the most necessary quantities; emanations of radium - radon, exceeding in content its usual concentration in the external atmosphere; ultraviolet radiation, atomic ozone and nitrogen compounds that accompany the passage of ultraviolet light through the air; metal dust of any dispersion or carbon particles. An important component of the ionosphere is the dielectric pad of the IOM generator, which smoothes the plasma in the discharge gap and is a filter for metal combustion gases (electrodes). The technical effect of increasing ozone concentration, reducing electricity and cost, reducing the size and weight of the structure, as well as obtaining environmentally friendly ozone, molecular, atomic ions, as well as their mixtures is achieved through design solutions that have no analogs in the world (Iztayev, Urazaliev *et al*., 2018; Iztayev, Yakiyayeva *et al*., 2018).

Ion-ozonator installation (Figure 1) is necessary for the food and processing industry, microbiological industry, agribusiness, healthcare, medicine, pharmacy, environmental ecology, human ecology, as well as in other areas of national and industrial management since electrically charged particles are synthesized without cumulative harmful substances.

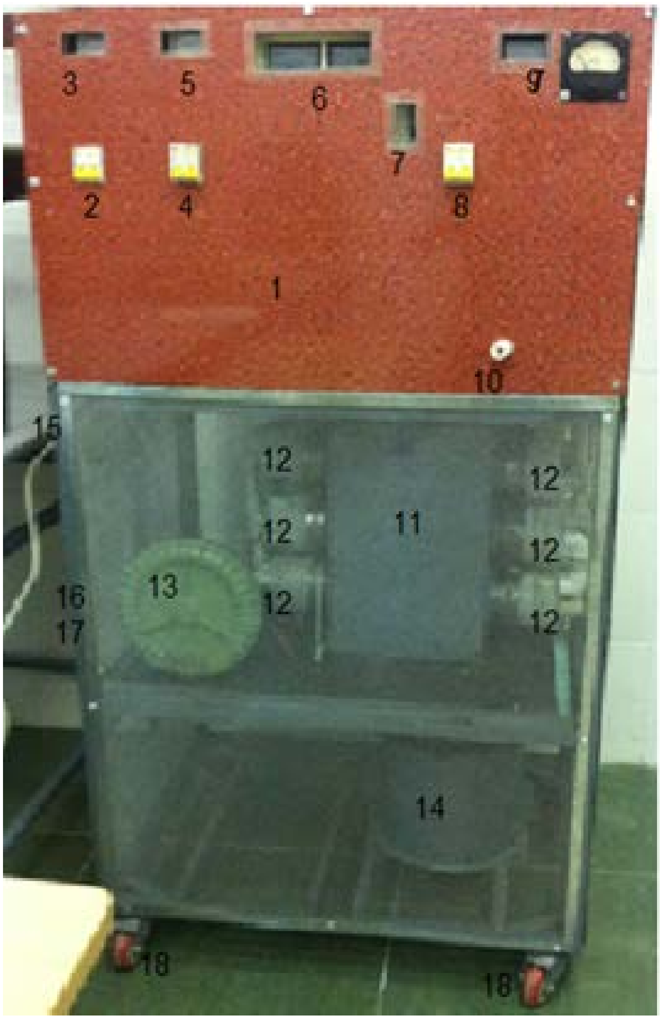

Figure 1. Ion-ozonator installation

The process control panel of the ionosphere 1 consists of:

- control panel for air compression processes (fuse switch 2, voltmeter 3, laboratory autotransformer (latr) not shown);

- ionizer synthesis control panel (fuse switch 4, voltmeter 5, laboratory autotransformer (latr) not shown);

- ozone synthesis control panel (fuse switch 8, voltmeter 9, laboratory autotransformer (latr) not shown);

- pipe for the extraction of ozone, atomic or molecular oxygen ions 10;

- water jacket cooling ozone generators 11;

- ozone generators 12;

- fan 13;

- transformer 14;

- pipe 15 for pouring water into the cooling jacket of ozone generators 12;

- a pipe 16 for taking water from the cooling jacket of ozone generators 12;

- air duct 17 with fan tap 13.

The main node, i.e., the heart of the ion-ozonator installation, is a block of generators of the ion-ozone mixture, and these are ozone generators and a generator of ions of positive or negative polarity, which are performed depending on the quantity, quality and oxidative ability of the processed product. Therefore, in the creation of an ion-ozonized installation, it is necessary to provide - what concentration, what amount of ozone and ions is necessary for the successful processing of products. It is very important to determine the technological process of product processing, to know the structure, humidity, oxidizing ability, temperature, and a very important thing. Also, for the processing of a particular product, it is necessary to control these processes, in connection with this it is necessary to provide a control panel, adjust the concentration of ozone, its amount, how many ions of positive or negative polarity of the electric current, and at what speed electrically charged particles are supplied. This requires a fan, and when processing products under excessive pressure, a compressor of the corresponding capacity.

3. RESULTS AND DISCUSSION

We have studied the effects of ozone treatment on long-term storage of sugar beets. A 2018 sugar beet crop was sampled from the Koksu Sugar Factory. Samples of sugar beets from the 1st degree of infection with bacteria and pests were selected. Sugar beet samples were treated with ozone stream. Plans were made for full-factor experiments of the type - 2^3 out of eight prototypes and each of them was processed with different combinations (max and min) of the following factors: x_1 - ozone concentration (g/m^3), x_2 - processing time (min), x_3 - overpressure (ati). Physico-biochemical, microbiological properties, and safety indicators were determined for each sample of sugar beet: mass fraction of moisture, dry matter, acidity, pectin, fiber, sucrose, nitrite, heavy metals, pesticides, mycotoxins, the presence of mold and yeast. Studies have been conducted to establish technological processing regimes for the destruction of pathogens.

To obtain a mathematical model of the technological process, which is a regression equation, we used a second-order rotatable plan (Box plan), when the number of factors is K = 3, the number of experiments of plan 8.

Based on the experimental studies of the process, the following factors are established: x_1, x_2, x_3 influencing optimization criteria - acidity, sucrose content, mold content. Next, we performed the coding of the intervals and levels of variation of the input parameters, which are presented in table 1.According to the compiled plan of full-factor experiments, samples of sugar beet from the Koksu sugar factory of the first degree of infection were investigated. The results of the study are shown in table 2.

The planning matrix is presented in table 3.

The coefficient of the regression equation is significant if its absolute value is greater than the confidence interval. Otherwise, it is considered insignificant and can be excluded from further consideration of the mathematical model.

The adequacy of the obtained mathematical regression models was evaluated by the Fisher criterion F_p. The calculated values of F_p are shown in Table 4.

Here:

b - coefficients of regression equations at coded values;

B - coefficients of regression equations at natural factors;

F_p – Fisher's criterion

Comparing the values of confidence intervals from table 3 with the corresponding regression coefficients in table 4, it can be concluded that the effects of the interaction of input factors minor, and they can be neglected.

Next, a search was made for the optimum response functions with the greatest possible accuracy (solution of a compromise problem), while insignificant coefficients were taken into account for constructing a mathematical model, which would be a regression, Equation 1:

$$y= b_0+b_1x_1+b_2x_2+b_3x_3+b_{12}x_1x_2+ b_{13}x_1x_3+ b_{23}x_2x_2+b_{11}x_1^2+b_{22}x_2^2+b_{33}x_3^2 \quad \text{(Eq. 1)}$$

Thus, the regression equations for coded values will accept the following equations (Eq. 2-13):

1. Equations for moisture sugar beet first degree of infection:

$$y_1 = 78{,}145 – 0{,}4825x_1 – 1{,}3425x_2 + 0{,}29x_3 – 1{,}535x_1x_2 – 0{,}0375x_1x_3 + 0{,}0625x_2x_3 – 0{,}03x_1x_2x_3 \quad \text{(Eq. 2)}$$

2. Equations for dry matter of sugar beet of the first degree of infection:

$$y_2 = 21{,}8175 + 0{,}445x_1 + 1{,}305x_2 - 0{,}2525x_3 + 1{,}4975x_1x_2 + 0{,}075x_1x_3 - 0{,}025x_2x_3 + 0{,}0675x_1x_2x_3 \quad \text{(Eq. 3)}$$

3. Equations for the acidity of sugar beets of the first degree of infection:

$$y_3 = 3{,}625 + 1{,}275x_1 – 1{,}375x_2 - 0{,}025x_3 – 0{,}175x_1x_2 + 0{,}025x_1x_3 + 0{,}025x_2x_3 + 0{,}025x_1x_2x_3 \quad \text{(Eq. 4)}$$

4. Equations for the content of pectin substances of sugar beet of the first degree of infection:

$$y_4 = 5{,}89375 + 1{,}29625x_1 – 1{,}21375x_2 - 0{,}02875x_3 – 1{,}41625x_1x_2 - 0{,}00625x_1x_3 - 0{,}00125x_2x_3 - 0{,}00375x_1x_2x_3 \quad \text{(Eq. 5)}$$

5. Equations for the content of sugar beet fiber of the first degree of infection:

$$y_5 = 6{,}11375 + 0{,}69375x_1 – 1{,}41875x_2 - 0{,}03375x_3 – 1{,}65375x_1x_2 + 0{,}00625x_1x_3 + 0{,}00875x_2x_3 + 0{,}00375x_1x_2x_3 \quad \text{(Eq. 6)}$$

6. Equations for sucrose content of sugar beet of the first degree of infection:

$$y_6 = 2{,}36 + 0{,}0025x_1 – 0{,}35x_2 + 0{,}015x_3 + 0{,}5225x_1x_2 - 0{,}0025x_1x_3 + 0{,}0025x_1x_2x_3 \quad \text{(Eq. 7)}$$

7. Equations for the content of nitrite sugar beet first degree of infection:

$$y_7 = 550{,}4125 + 11{,}7125x_1 – 8{,}8375x_2 + 0{,}1375x_3 + 9{,}0625x_1x_2 + 0{,}0375x_1x_3 + 0{,}1875x_2x_3 - 0{,}2125x_1x_2x_3 \quad \text{(Eq. 8)}$$

8. Equations for lead content of sugar beet of the first degree of infection:

$$y_8 = 0{,}060387 + 0{,}0062875x_1 – 0{,}0036375x_2 + 0{,}0001375x_3 + 0{,}0014125x_1x_2 + 0{,}0000625x_1x_3 + 0{,}0000125x_2x_3 + 0{,}0000625x_1x_2x_3 \quad \text{(Eq. 9)}$$

9. Equations for cadmium content of sugar beet of the first degree of infection:

$$y_9 = 0{,}0026875 - 0{,}0006625x_1 – 0{,}0002125x_2 + 0{,}0000875x_3 – 0{,}0003625x_1x_2 - 0{,}0000125x_1x_3 + 0{,}0000125x_2x_3 + 0{,}00000125x_1x_2x_3 \quad \text{(Eq. 10)}$$

10. Equations for the content of aflotoxin sugar beet first degree of infection:

$$y_{10} = 0{,}012625 - 0{,}000625x_1 – 0{,}0001125x_2 - 0{,}000875x_3 + 0{,}000125x_1x_2 - 0{,}000125x_1x_3 - 0{,}000125x_2x_3 + 0{,}000125x_1x_2x_3 \quad \text{(Eq. 11)}$$

11. Equations for the content of sugar beet mold of the first degree of infection:

$$y_{11} = 16{,}625 - 0{,}875x_1 – 3{,}375x_2 + 1{,}625x_3 – 4{,}375x_1x_2 - 1{,}875x_1x_3 + 3{,}125x_2x_3 - 1{,}875x_1x_2x_3 \quad \text{(Eq. 12)}$$

12. The equations for the content of sugar beet yeast of the first degree of infection:

$$y_{12} = 14{,}875 - 2{,}875x_1 – 0{,}625x_2 + 1{,}125x_3 + 0{,}625x_1x_2 - 0{,}125x_1x_3 + 0{,}125x_2x_3 + 2{,}875x_1x_2x_3 \quad \text{(Eq. 13)}$$

here:

b – regression equation coefficient

x_1 – ozone concentration, g/m^3

x_2 - ozone treatment time, min

x_3 – overpressure (cavitation), ati

y_1 - moisture, %

y_2 - dry matter, %

y_3 - acidity, %

y_4 - pectin substance, %

y_5 - cellulose, %

y_6 - sucrose, %

y_7 - nitrates, mg/kg

y_8 - Pb– mg/kg

y_9 - Cd – mg/kg

y_{10} - aflatoxin, mg/kg

y_{11} - mold, CFU/g

y_{12}- yeast, CFU/g

After decoding the independent variables in the equations, regression equations are obtained for natural factors (Eq. 14-16):

1. To determine the acidity of sugar beets of the Koksu sugar factory of the first degree of infection:

$$y_3=3{,}39742947+0{,}2471232x_1+0{,}671098x_2-0{,}05036x_3+0{,}025x_1x_2-0{,}225x_1x_3+0{,}075x_2x_3-0{,}09673x_1^2+0{,}150235x_2^2-0{,}09673x_3^2 \quad \text{(Eq. 14)}$$

2. To determine the sucrose content of sugar beets of the Koksu sugar factory of the first degree of infection:

$$y_6=2{,}42959795+0{,}2878224x_1+0{,}247416x_2+0{,}264398x_3-0{,}2125x_1x_2+0{,}1875x_1x_3-0{,}1125x_2x_3-0{,}0213x_1^2+0{,}031623x_2^2+0{,}119823x_3^2 \quad \text{(Eq. 15)}$$

3. To determine the mold content of sugar beet of the Koksu sugar factory of the first degree of infection:

$$y_{11}=18{,}9442368+0{,}02928x_1-0{,}22253x_2-0{,}46848x_3+0{,}25x_1x_2-0{,}25x_1x_3-1{,}5x_2x_3+1{,}057466x_1^2-0{,}35373x_2^2+1{,}410266x_3^2 \quad \text{(Eq. 16)}$$

here:

x_1 – ozone concentration, g/m^3

x_2 – ozone treatment time, min

x_3 – overpressure (cavitation), ati

y_3 - acidity, %

y_6 - sucrose, %

y_{11} - mold, CFU/g

Thus, given that $F_p<F_{table}$ The model of technological process efficiency can be considered adequate with a 95% confidence probability.

4. CONCLUSIONS

After the canonical transformation of second-order models, canonical regression equations were obtained, values of optimization parameters were calculated on a Microsoft Excel word processor computer, on the basis of which a model was constructed in three-dimensional space, which is a plane that characterizes the dependence of ozone concentration (g/m^3), overpressure (ati), processing time, which affect optimization criteria - acidity (degrees), sucrose content (%) and mold content (CFU/g) at 20 °C.

Rotatable planning of the second-order sugar beets of the Koksu sugar factory of the first degree of infection are shown in Table 5.

Based on second-order rotatable planning, a regression equation is obtained for coded, natural factors. The regimes of ozone processing of sugar beet have been optimized in terms of acidity, sugar content, and mold of the first degree of sugar beet infection in the Koksu sugar factory. The results of the study are shown in Figures 2-10.

The analysis of three-dimensional spatial models shows, which are presented in Figures 2-10, that the necessary values of the optimization criterion ‘’y’’ are achieved in the search area under consideration. This means that the levels of variation of input factors in the design of experiments are accepted quite correctly.

An analysis of the behavior of the obtained three-dimensional surface showed that the following parameters are optimal zones for processing sugar beets:

- when processing with an ozone concentration of 6-8 g/m^3, an overpressure of 6-8 ati for 15-20 minutes, the acid content ranges from 0 to 3 degrees;
- when processing with an ozone

concentration of 6-8 g/m^3 and an excess pressure of 4-6 ati for 10-15 minutes, the sucrose content is 3-10%;

- when processed with an ozone concentration of 6-8 g/m^3 for 15-20 minutes, the mold content ranges from 0 to 5 CFU/g.

The analysis of the presented graphs showed that in the three-dimensional model in space there are optimal regions of variable values of ozone concentration (g/m^3), overpressure (at), processing time — the values at which sugar beet is processed with optimal acidity (degrees), content sucrose (%) and mold content (CFU/g).

Based on the analysis and comparison of the values, it is possible to recommend generalizing operating parameters of ozone treatment time 15 min, pressure 4 ati, ozone concentration of 6 g/m^3, which leads to the death of sugar beet microorganisms of the first degree of infection.

The above dependences on the variable parameters of sugar beet processing by ozone flow in the cavitation zone (overpressure) make it possible to predict with sufficient accuracy the change in the values of the optimization criteria in the studied range of factors – acidity (deg), sucrose content (%) and mold content (CFU/g. At the same time, it is possible to establish the dominant influence of each studied factor on the optimization criterion of the process, which allows us to describe with sufficient approximation the optimal processing conditions for sugar beet of the first degree of infection. The results obtained will allow us to optimize the process under study by applying the developed mathematical model.

As a result of the study, it was found that for the storage of raw sugar production, it is necessary to use ozone treatment in the cavitation zone (overpressure). It has been scientifically proven that ozone treatment significantly reduces the growth of mold and yeast, contributes to an increase in the content of pectin, fiber and sucrose while ensuring the safe storage of raw sugar products.

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Table 1. *Coding of intervals and levels of variation of input factors*

Indicators	**Coded value**	**Factors and their dimension**		
		x_1 – ozone concentration, g/m^3	**x_2 – ozone processing time (min)**	**x_3 – overpressure, ati**
Upper level	+	6	20	4
Zero level	0	4,5	15	3
Lower level	-	3	10	2
Range of variation		1,5	5,0	1

Table 2. *The results of full-factor experiments of type 2^3 – sugar beet Koksu sugar factory of the first degree of infection*

Experience number	Planning				Indicators											
	x_0	x_1 – ozone concentration, g/m^3	x_2 - ozone treatment time (min)	x_3 – Overpressure, ati	y_1 - Moisture, %	y_2 - dry matter, %	y_3 - Acidity, %	y_4 - Pectin substance, %	y_5 - cellulose, %	y_6 - Sucrose, %	y_7 - Nitrates, mg/kg	y_8 - Pb– mg/kg	y_9 - Cd – mg/kg	y_{10} - Aflatoxin, mg/kg	y_{11} - Mold, CFU g	y_{12}- Yeast, CFU/g
1	+	6	15	4	75,07	24,93	3,4	4,52	3,72	2,55	562,5	0,0646	0,0015	0,010	9	16
2	+	3	15	4	79,24	20,76	1,1	4,78	5,62	1,5	521,3	0,0492	0,0036	0,011	27	15
3	+	6	5	4	80,76	19,24	6,4	9,79	9,84	2,2	562,1	0,0689	0,0027	0,012	22	10
4	+	3	5	4	78,67	21,33	3,5	4,37	5,14	3,25	556,3	0,0594	0,0033	0,014	15	23
5	+	6	15	2	74,5	25,2	3,3	4,6	3,75	2,52	562,2	0,0643	0,0014	0,012	7	8
6	+	3	15	2	78,4	21,6	1,2	4,82	5,69	1,47	520,3	0,0489	0,0034	0,013	10	18
7	+	6	5	2	80,32	19,68	6,5	9,85	9,92	2,18	561,7	0,0689	0,0025	0,014	25	14
8	+	3	5	2	78,2	21,8	3,6	4,42	5,23	3,21	556,9	0,0589	0,0031	0,015	18	15

$y_1 = f_1 (x_1, x_2, x_3)$, $y_2 = f_2 (x_1, x_2, x_3)$, $y_3 = f_3 (x_1, x_2, x_3)$, ……………., $y_{12} = f_{12} (x_1, x_2, x_3)$

Table 3. *The matrix of rotatable planning experimental studies of processed sugar beets*

Coefficients	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}	y_{11}	y_{12}
b_0	78,145	21,8175	3,625	5,89375	6,11375	2,36	550,4125	0,0603875	0,0026875	0,012625	16,625	14,875
b_1	-0,4825	0,445	1,275	1,29625	0,69375	0,0025	11,7125	0,0062875	-0,0006625	-0,000625	-0,875	-2,875
b_2	-1,3425	1,305	-1,375	-1,21375	-1,41875	-0,35	-8,8375	-0,0036375	-0,0002125	-0,001125	-3,375	-0,625
b_3	0,29	-0,2525	-0,025	-0,02875	-0,03375	0,015	0,1375	0,0001375	0,0000875	-0,000875	1,625	1,125
b_{12}	-1,535	1,4975	-0,175	-1,41625	-1,65375	0,5225	9,0625	0,0014125	-0,0003625	0,000125	-4,375	0,625
b_{13}	-0,0375	0,075	0,025	-0,00625	0,00625	-0,0025	0,0375	-6,25E-05	-0,0000125	-0,000125	-1,875	-0,125
b_{23}	0,0625	-0,025	0,025	-0,00125	0,00875	0	0,1875	1,25E-05	-0,0000125	-0,000125	3,125	0,125
b_{123}	-0,03	0,0675	0,025	-0,00375	0,00375	0,0025	-0,2125	6,25E-05	-1,25E-05	0,000125	-1,875	2,875

Table 4. *The coefficients of the regression equations of the output parameters*

Optimization criterion	**Coefficients**	**Process**
Acidity	With coded factor values	
	b_0	3,397429472
	b_1	0,2471232
	b_2	0,6710976
	b_3	-0,0503616
	b_{12}	0,025
	b_{13}	-0,225
	b_{23}	0,075
	b_{11}	-0,09672538
	b_{22}	0,150234624
	b_{33}	-0,09672538
	With natural factors	
	B_0	-1,7968
	B_1	0,826237728
	B_2	-0,12106203
	B_3	1,173441408
	B_{12}	0,0025
	B_{13}	-0,1125
	B_{23}	0,01500
	B_{11}	-0,02418134
	B_{22}	0,006009385
	B_{33}	-0,09672538
	F_p	4,739616678
Sucrose content	With coded factor values	
	b_0	2,429597952
	b_1	0,2878224

	b_2	0,247416
	b_3	0,2643984
	b_{12}	-0,2125
	b_{13}	0,1875
	b_{23}	-0,1125
	b_{11}	-0,02129722
	b_{22}	0,031622784
	b_{33}	0,119822784
	With natural factors	
	B_0	0,7639
	B_1	0,151552848
	B_2	0,229035859
	B_3	-0,91918387
	B_{12}	-0,02125
	B_{13}	0,09375
	B_{23}	-0,02250
	B_{11}	-0,0053243
	B_{22}	0,001264911
	B_{33}	0,119822784
	F_p	1,927073998
Mold content	With coded factor values	
	b_0	18,9442368
	b_1	0,02928
	b_2	-0,222528
	b_3	-0,46848
	b_{12}	0,25
	b_{13}	-0,25
	b_{23}	-1,5
	b_{11}	1,0574656
	b_{22}	-0,3537344
	b_{33}	1,4102656
	With natural factors	
	B_0	31,5457
	B_1	-3,0327568
	B_2	1,42997568
	B_3	-6,5006048
	B_{12}	0,025
	B_{13}	-0,125
	B_{23}	-0,30000
	B_{11}	0,2643664
	B_{22}	-0,01414938
	B_{33}	1,4102656
	F_p	0,962853903

Table 5. *Rotatable planning of the second order acidity of sugar beets of the Koksu sugar factory of the first degree of infection*

Name of indicators		**x_1**	**x_2**	**x_3**
Lower levels of factors	(-1)	*4*	*10*	*3*
Upper Factor Levels	(+1)	*8*	*20*	*5*
Main factor levels	(0)	6	15	4
Factor Variation Levels		2	5	1
Relationship		3	3	4

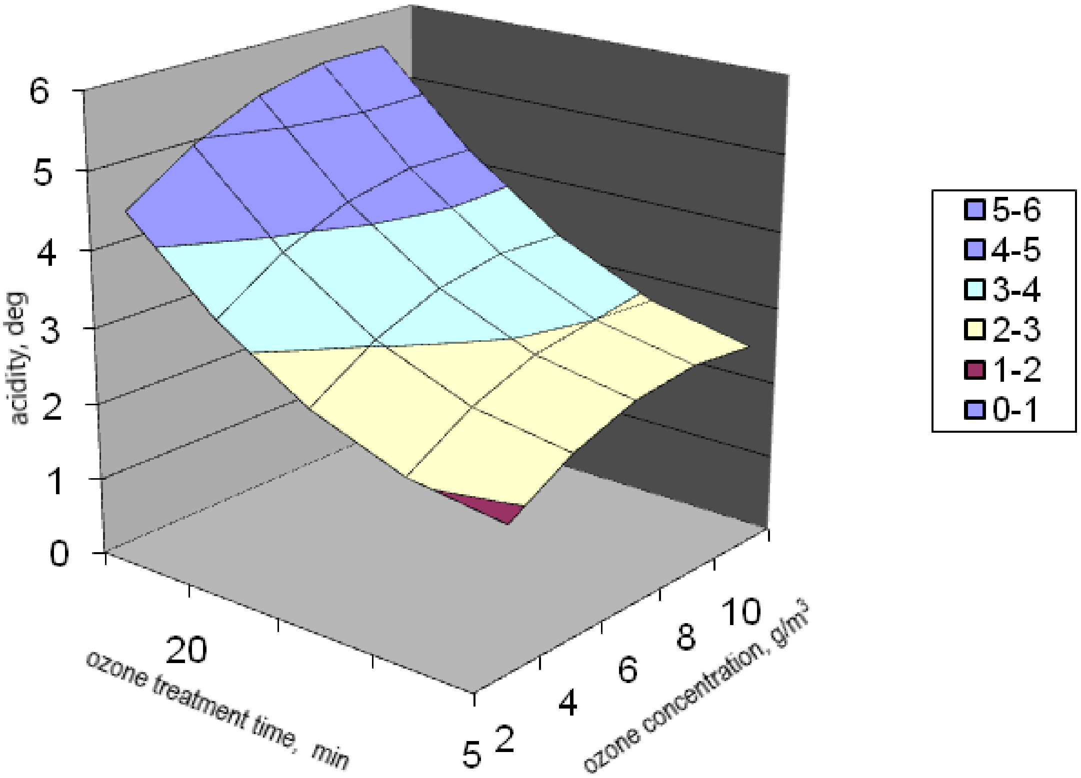

Figure 2. *Changes in the acidity content of sugar beets of the Koksu sugar factory of the first degree of infection, depending on the ozone concentration and processing time*

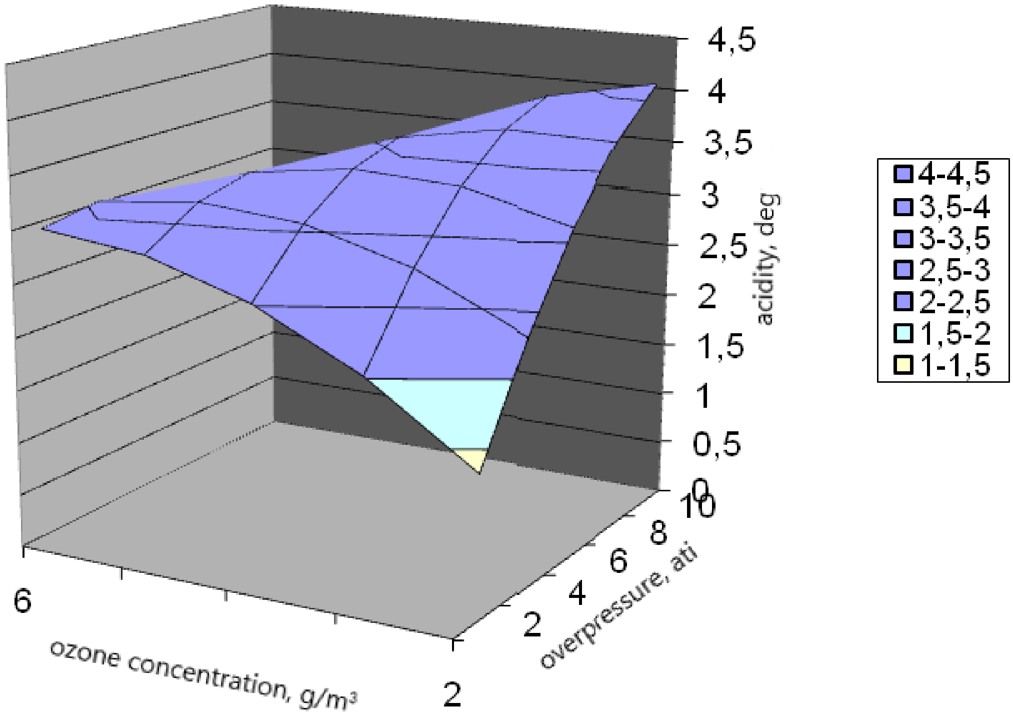

Figure 3. *Changes in the acidity content of sugar beets of the Koksu sugar factory of the first degree of infection, depending on the concentration of ozone and pressure concentration*

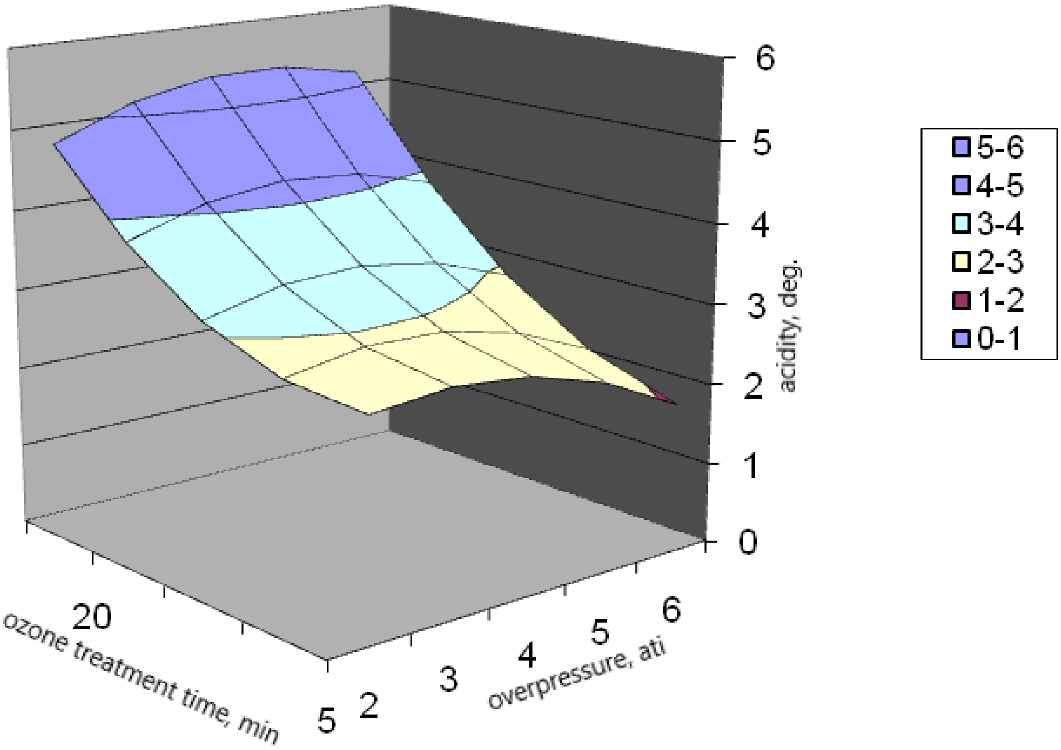

Figure 4. *Changes in the acidity content of sugar beets of the Koksu sugar factory of the first degree of infection, depending on the concentration of pressure and processing time*

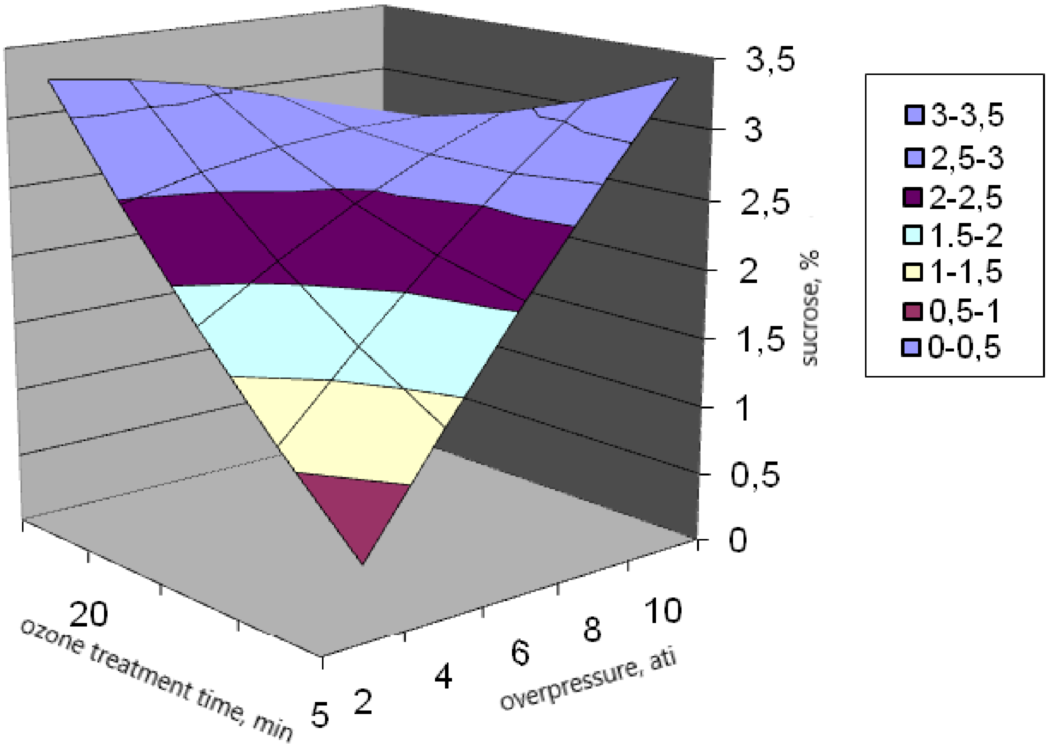

Figure 5. *Changes in the sucrose content of sugar beets of the Koksu sugar factory of the first degree of infection, depending on the concentration of pressure and processing time*

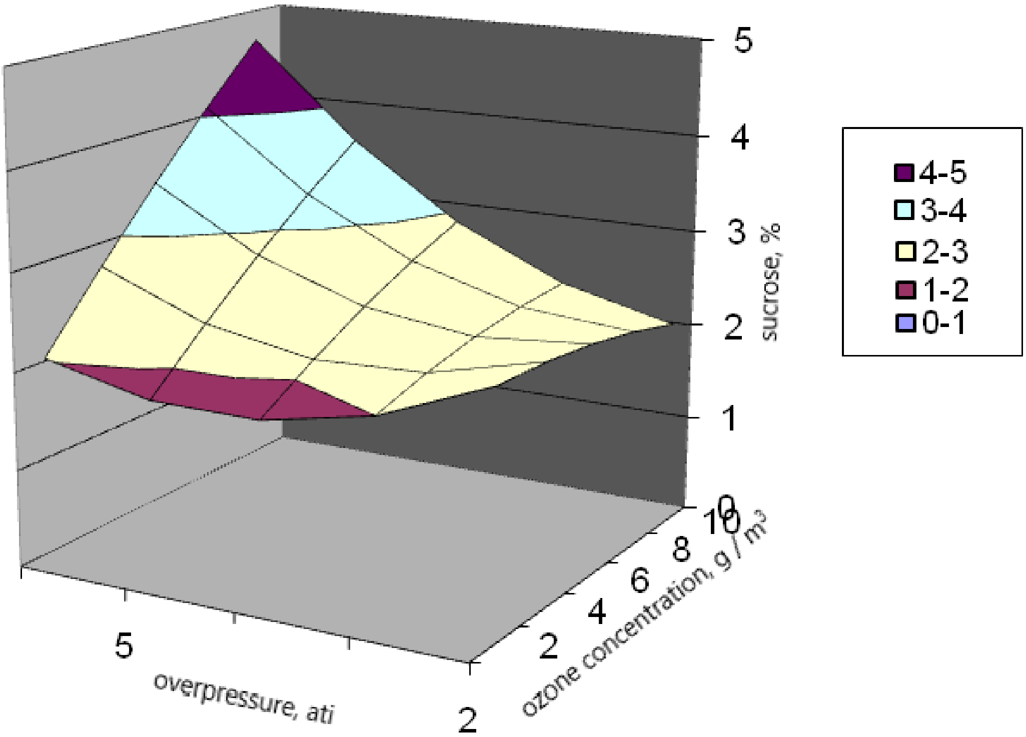

Figure 6. *Changes in the sucrose content of sugar beets of the Koksu sugar factory of the first degree of infection, depending on ozone concentration and pressure*

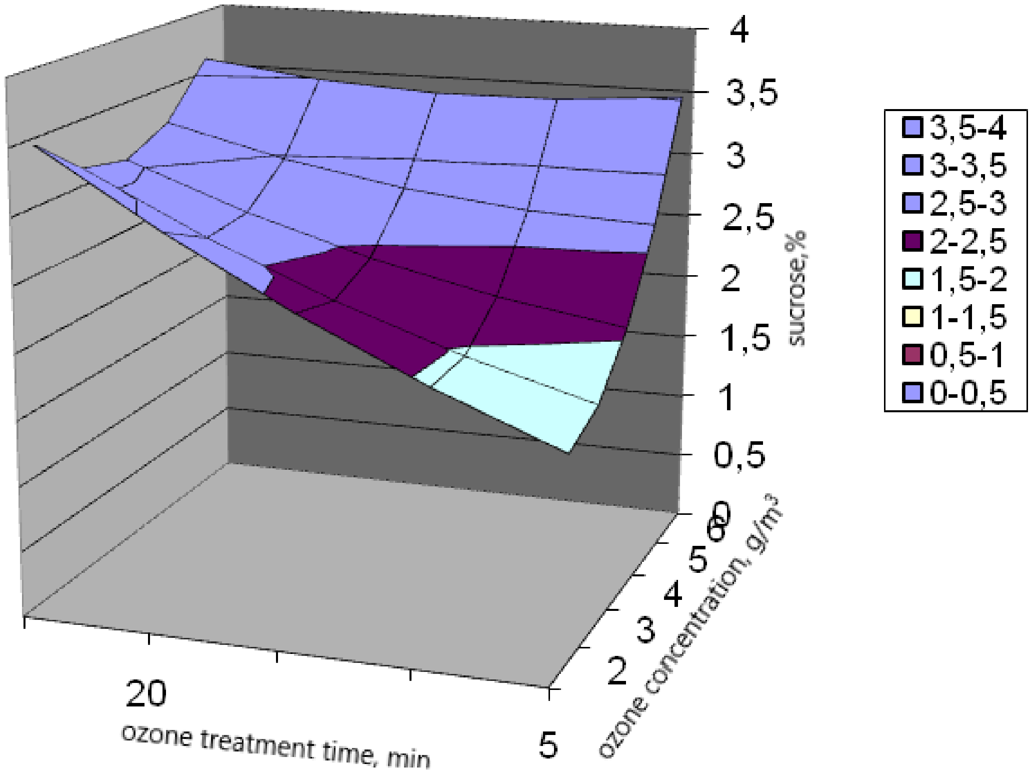

Figure 7. *Changes in the sucrose content of sugar beets of the Koksu sugar factory of the first degree of infection, depending on the ozone concentration and processing time*

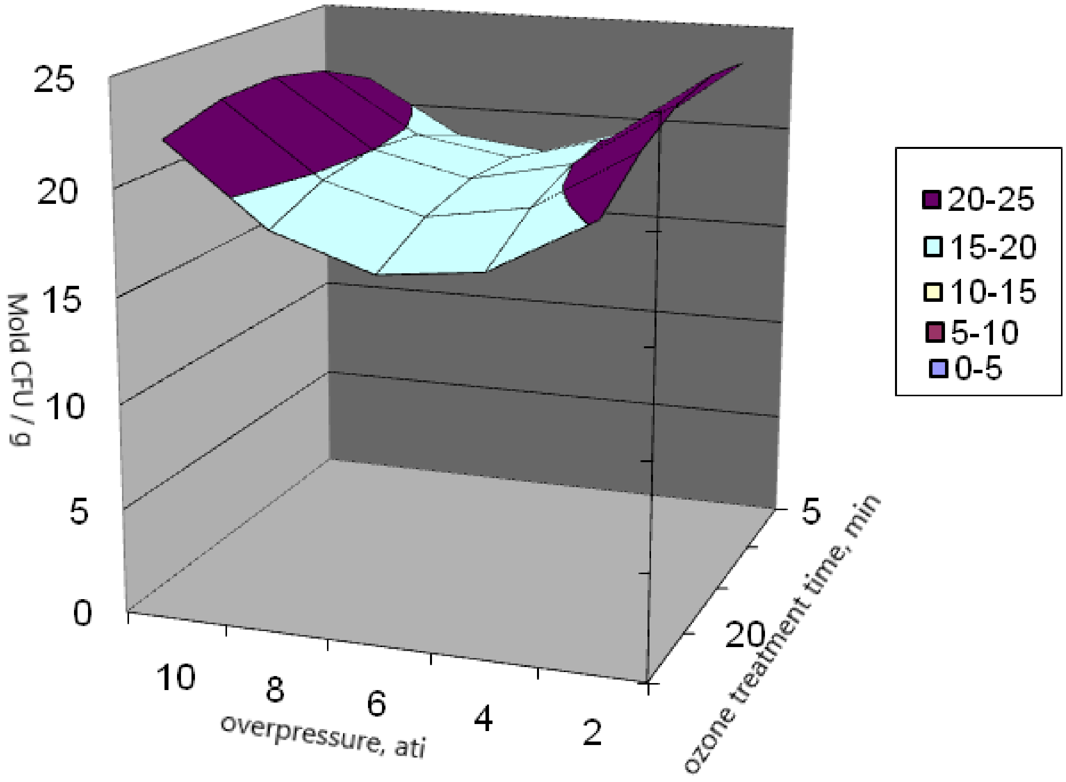

Figure 8. *Changes in mold content of sugar beet of the Koksu sugar factory of the first degree of infection, depending on the concentration of overpressure and processing time*

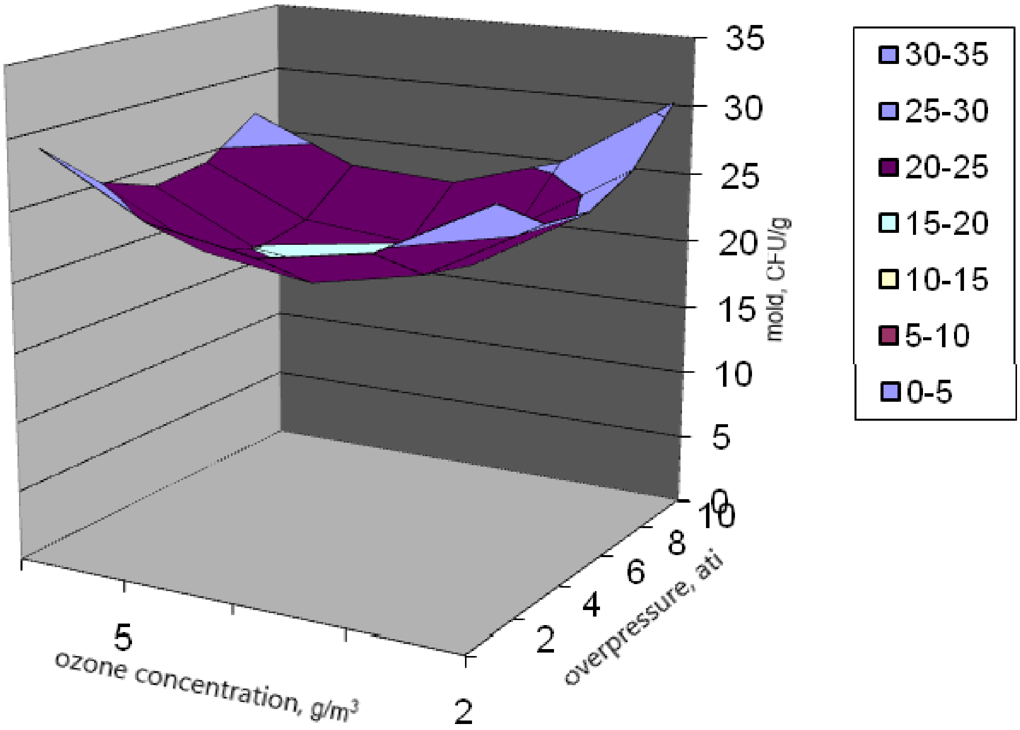

Figure 9. *Changes in mold content of sugar beet of the Koksu sugar factory of the first degree of infection, depending on the concentration of ozone and overpressure*

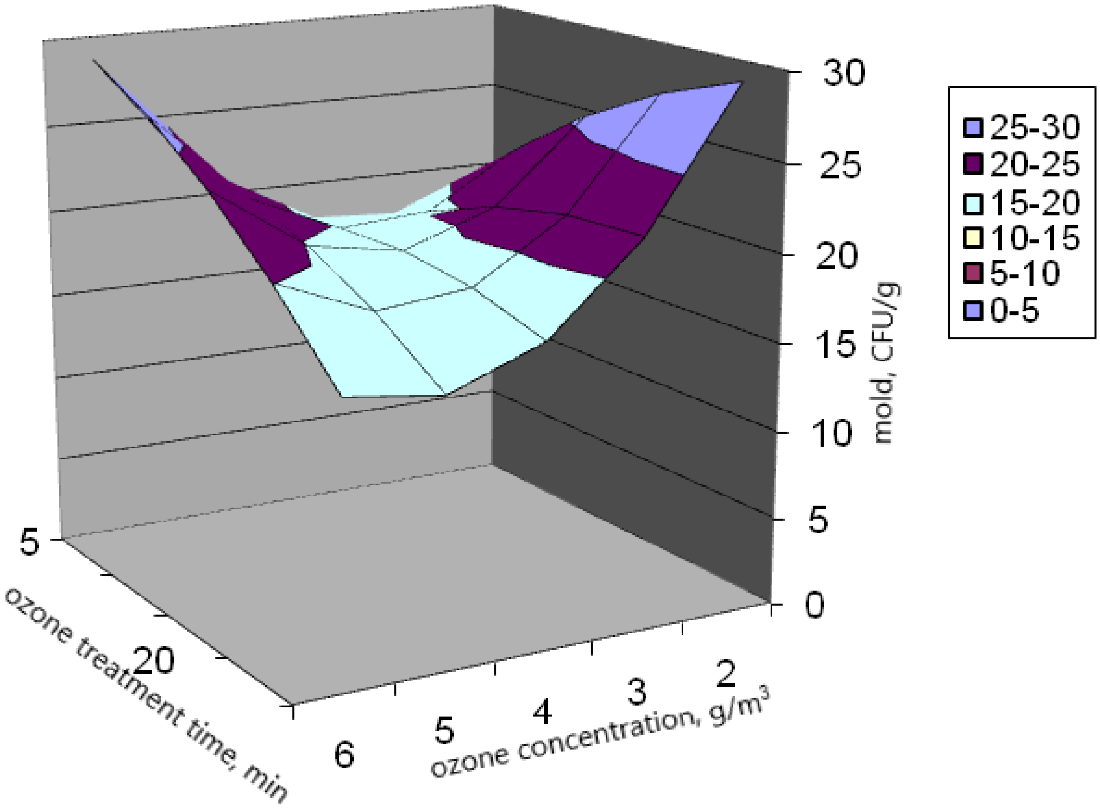

Figure 10. *Changes in mold content of sugar beet of the Koksu sugar factory of the first degree of infection, depending on the concentration of ozone and the processing time*