

## METHOD FOR THE SAFE STORAGE OF SUGAR BEETS USING AN ION-OZONE MIXTURE

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### ABSTRACT

**Background.** Sugar refineries cannot modernize the current processing technology and increase their capacity in proportion to the increasing harvest of raw beets. This entails an increase in the processing time. Sugar beets are not subject to long-term storage, and when they are stored in inappropriate conditions, root crops rot, resulting in sugar loss. The aim of this study is to increase the safety of beets during long-term storage before processing and to develop a device for its implementation which will lead to an improvement in the biological value of sugar beet root crops and an increase in the efficiency of technological processes.

**Materials and methods.** The experiment used sugar beets from the Koksuy sugar plant and was carried out by treating sugar beets with an ion-ozone mixture to increase their shelf life. The treatment was carried out in an ion-ozone installation. Physicochemical and microbiological analyses were carried out using several methods: chemical extraction, potentiometry and photocolourimetry.

**Results.** The results of the study showed that when sugar beets were treated with ozone at a concentration of 0.5 g/m<sup>3</sup> and 2 g/m<sup>3</sup>, the acidity decreased to 0.6 degrees, and the sugar content increased by 2.3% and 3.3%, respectively. When sugar beets were processed with an ozone concentration of 2 g/m<sup>3</sup> and a molecular ion concentration of 1,000,000 units/cm<sup>3</sup>, a decrease in moisture was observed to 69%, the acidity decreased 2 times and the sugar content increased by 3%. When the beets were processed with an ozone concentration of 2 g/m<sup>3</sup> and a molecular ion concentration of 1,000,000 units/cm<sup>3</sup>, a decrease in acidity was observed to 0.65–0.67 degrees, and the sugar content increased by 2–2.5%. Also, in all the above optimal processing conditions, a decrease in yeast growth was observed.

**Conclusions.** As a result of the study, the following three optimal conditions were established for the processing of sugar beet root crops before storage: an ozone concentration of 0.5 g/m<sup>3</sup> and 2 g/m<sup>3</sup>; an ozone concentration of 5 mg/m<sup>3</sup> and molecular ions of 500,000 units/cm<sup>3</sup>; an ozone concentration of 2 g/m<sup>3</sup> and molecular ions of 1,000,000 units/cm<sup>3</sup>.

**Keywords:** ion-ozone mixture, ozone, processing, storage, sugar beet

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## INTRODUCTION

Storage of raw sugar products, including sugar beets, is possible only after the 1<sup>st</sup> October, when the temperature is more suitable. In non-cooled beets, biochemical processes occur intensively, and thus the products deteriorate. Lime milk is sprayed on the kagat (heap of sugar beet, folded on the ground and sheltered for long-term storage) so that the sun does not heat up the beets. Beets are protected from unsatisfactory conditions by mats or boards made of peat, straw or sawdust. For 100 tons of beets, 80 m<sup>2</sup> of material is needed. Foam plastic and foam rubber are also used. To prevent decay and the development of fungal infections, raw materials should be protected from precipitation. At the same time, straw mats are laid perpendicular to the kagat so that the water drains well. Kagats are sheltered with a layer of earth (25–50 cm) from the sides, and straw mats on top protect the beets from frost.

At least three thermometers are installed in each kagat for continuous temperature control. For more complete observation, holes are formed into which mobile thermometers are inserted. Elimination of self-heating or decaying areas is possible only with their prompt detection. The optimum beet storage temperature is 1–2°C. An increase in this indicator leads to an acceleration in metabolism; as a result, sugar breaks down, and its content rapidly decreases. A decrease in temperature below 0 is not allowed. In the event of self-heating sections, damaged specimens are removed, and lime treated, and the vacated space is filled with healthy ones. If the temperature drops to 1°C, additional mats are required (AgroPK, 2018; Trisvyatsky et al., 1991).

After the tops are removed, the synthesis of sucrose in root crops stops and water does not enter, but the chemical and biological processes continue. During breathing, heat is generated. This energy is released due to the oxidation of sucrose. Under the action of the invertase enzyme, as a result of inversion, fructose and glucose are obtained from sucrose. Healthy fresh beets include up to 0.1% monosaccharides. An increase in their concentration is undesirable, as it results in a worsening of crystallization and a decrease in the molasses content. Subsequently, the formed monosaccharide is broken down under the action of the oxidase enzyme, with the release of 2891.9 kJ of energy:  $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$ .

With every ten degree increase in temperature, there is a double increase in sucrose loss. However, this is only the cost of breathing. The decrease in this important substance also occurs due to the transition to other forms of sugars. Storage under anoxic conditions can reduce the formation of carbon dioxide by half, but intermolar respiration will increase, and sucrose will be spent on the formation of non-sugars. When storing healthy, moisture-free beets at a temperature of 0°C to 2°C and a relative humidity of 94%, breathing is the main reason for this. This process is more intense in sagging, dirty or damaged root crops. Heat and water, which are released at the same time, contribute to an even greater increase in respiration, which leads to self-heating. The respiratory rate varies during storage. In storage, beets breathe more actively; after 14–21 days the process dies out, reactivating in the spring. Smaller sugar losses are found in large vegetables. The storage conditions of beets determine the percentage of sucrose oxidation (Shkalikov, 2010; Trisvyatsky et al., 1991).

The respiratory rate also depends on the degree of maturity, beet variety and development of microorganisms. In storage-resistant varieties, breathing is more even; ripe root vegetables breathe less intensely. Average daily sugar loss indicators are as follows: 0.01% at 1°C, 0.014% at 3°C, 0.02% at 6°C, 0.03% at 9°C and 0.05% at 15°C. The optimum temperature for storage of sugar beets is from 0°C to 2°C, while breathing consumes fewer carbohydrates without the loss of quality characteristics. Withering contributes to a sharp increase in sucrose loss. Raw materials exposed to low temperatures are removed from storage. After defrosting, they undergo decay and are poorly processed. As a result of the destruction of cell membranes, such tissues are an ideal environment for the nutrition and reproduction of pathogenic organisms. Weight loss of vegetables and the sugar contained within them occurs at all stages from harvesting to receipt at the plant. Normally, the loss of beets should not exceed 0.5% during unloading and 5% during storage (AgroPK, 2018; Podporinova et al., 2010).

Microorganisms pose a serious threat: in the case of improper storage, they are capable of destroying an entire stock of raw materials. They fall into kagats along with particles of soil on vegetables, but they are activated only on patients with mechanical or thermal damage to tissues. The main preventive measure is proper

gentle cleaning and transportation. Storage conditions for beets are also not the ultimate factor (Sapronov, 2007). The higher the temperature, the more readily microorganisms develop. It is very important to store beets at a temperature close to 0°C, but not lower. Possible diseases are mycoses and bacterioses. The causative agents of fungal diseases, like the presence of oxygen, affect vegetables first. By destroying the integumentary tissue, they give anaerobic bacteria access to the root. An acidic environment is suitable for mycoses, and an alkaline one for bacterioses (Akhatov et al., 2013).

Kagats must be placed along the direction of the prevailing wind in the area. The surface of the kagat itself must be reduced to reduce losses. The following kagat sizes are appropriate: 1. For long-term storage – height of 5 meters, width of 18 meters; 2. For medium-term storage periods – height of 3 meters, width of 12 meters and 3. For substandard root crops – height of 2 meters, width of 12 meters. Between kagats, a passage of about 10 meters must be left. Before laying the ground for the kagat, the surface must be disinfected with lime mortar. After they are laid, all surfaces must be levelled. At present, more modern storage technologies exist, for example, integrated hydromechanized warehouses. These warehouses have a washable hard floor equipped with a water supply and ventilation system (Gagkaeva et al., 2018; Shkalikov, 2010).

New storage systems can reduce losses before processing and use technical means for loading and unloading raw materials. On the processing side, to reduce losses during storage, root crops are treated with special preservatives, biological preparations, contact fungicides or lime. Various cover materials are used, from straw to special films. The optimal conditions for laying beets in storage kagats are an outdoor temperature not higher than 15°C and the temperature of the root crops themselves up to 10°C. During long-term storage, it is desirable to maintain a temperature no higher than 1–2°C in order to reduce the risk of kagat rot (the causative agents of the disease are fungal and bacterial microorganisms, often *Botrytis cinerea*). Root crops can be affected by kagat rot if they are mechanically damaged, sunken, grown in fields with disturbed crop rotation, damaged by diseases and pests during the growing season or have unbalanced mineral nutrition. An increase in temperature in the kagat, not associated with an increase in the temperature of the

outside air, indicates the occurrence of a focus of lesions on the beets or a massive defeat of beets in the kagat. The development of lesions can also be judged by the appearance of wet spots on the surface of the kagat and the formation of fog over the affected area, especially in the morning when the outside temperature drops (Islamgulov et al., 2013; Gagkaeva and Levitin, 2005). Also, bacterial rot can develop in kagats, but, as a rule, it develops in roots already affected by fungi. The factors that contribute to disease development are an early or late harvest, which can cause root crops to soften or freeze, leading to massive development of disease; mechanical damage during the cleaning process and the development of various diseases during the growing season. Protective measures include crop rotation (repeat the crop no more than after three to four years); balanced mineral nutrition; protection of the roots from drying and freezing during the cleaning process; timely cleaning; rejection of roots when laying for storage; reduction of trauma to root crops during harvesting, transportation and storage; protection of beets against pests and diseases during the growing season; periodic monitoring of the status of the kagat and fungicidal treatment during storage (Gavrilova and Gagkaeva, 2014; Lazarev, 2014).

Low-sugar root crops do not store as well as high-sugar ones. Bacterial diseases of beets can cause serious crop losses, reduce their quality and increase the harmfulness of fungal diseases. Some of them still cause little harm, but given the nature of climate change, we can expect that they will pose a real threat to beet cultivation. The diagnosis of bacterioses is quite complicated and often requires the use of microbiological methods. Other bacterioses are less harmful and result in leaf damage and a consequent decrease in photosynthetic activity. These develop mainly as infections associated with fungal diseases (Bugaenko, 2002; Pekelny, 2012; Sapronov et al., 2011).

A known method of storing sugar beets in kagats (Barabash et al., 1996) includes processing them for storage in an aqueous solution of sodium chloride, previously processed in the anode chamber of a diaphragm electrolyzer using insoluble electrodes. The disadvantage of this method is the use of chemicals that through processed products, although in small quantities, enter the human body and eventually harm it. A prototype method is also known, which involves

laying sugar beet root crops in kagats (Sapronov et al., 2015) and covering them with a three-layer plastic film with a reflective surface modified with an antimicrobial fungicidal preparation synthesized at a temperature of at least 300°C. The disadvantage of the prototype is its use of chemical reagents, as well as its high energy consumption, as a result of which microbiological processes occur on the roots of sugar beets that contribute to a deterioration in the quality of root crops; moreover, with the increase in electricity, the loss of beet mass during storage increases.

When storing sugar beets, the following processes are distinguished: biochemical – metabolic and chemical transformations associated with the activity of enzymes; physiological – respiration and germination of root crops; microbiological – the activity of microorganisms that causes rotting in clumps. These processes not only proceed and intensify in sugar beet roots at the same time, but are also closely interconnected and affect each other. Therefore, with a large amount of sugar beets, sugar refineries do not have time to get sugar from them and the sugar beets will deteriorate. Scientists of the Almaty Technological University have proposed a method for storing sugar beets with ozone and ion-ozone treatment. When fruits and vegetables are exposed to ozone or ion-ozone, there is a sharp decrease in the contamination of putrefactive microflora on their surface, and a decrease in the level of metabolic processes and their germination, i.e. the main causes of damage to agricultural products are eliminated, which has a significant economic effect of up to 30%. The use of ozone or ion-ozone technologies makes it possible to prepare the vegetable store as efficiently as possible for the laying of a new crop. The practical use of ozonizers and ion-ozonizers shows that the products are better preserved if first the empty, and then only the loaded vegetable stores are processed. The proposed technology is adapted for container and onboard storage methods. Ozone and ion-ozone allow you to relieve the vegetable store of a heavy odor, and most importantly, to increase the safety of the crop by 15–20% of the traditional storage method. In practice, it has been observed that ozonizers suppress the spread of rot at the first application. Drying of the affected tuber takes place, thereby preventing the disease of neighboring tubers.

When sugar beets are stored under inappropriate conditions, root crops rot, and sugar is lost. Losses

of sugar during the traditional storage method range from 100 g to 300 g per day per 1 ton of root crops. As a rule, they amount to 0.01% per day in the first week of storage, then 0.05% per day thereafter. In order to reduce the loss and increase the shelf life of sugar beets, we used kagat storage using ozone and ion-ozone treatment. The issues of monitoring the state of sugar beets in the process of acceptance, processing and long-term storage are still not completely resolved. For this purpose, there are no relevant new methods or measuring instruments.

An analysis of literature sources and patents on the storage of sugar beet over the past 10 years has shown that the following shortcomings in storage and other technologies have not yet been resolved, leading to large quantitative and qualitative losses from the moment of harvesting, laying and to processing at sugar factories. The following problems also occur:

- common trench, semi-aboveground, aboveground and stationary kagats (in basements and specially built storage facilities), which are not equipped with installations of active ventilation or chemical gassing for the destruction of pests; and there are no remote control devices for the temperature and humidity of sugar beet in piles
- the methods adopted for storage of covering products with a layer of 25–30 cm, 15–20 cm and 50 cm of fine crumbly earth in different regions make the work laborious
  - before being submitted for processing, they require thorough cleaning of the ground
  - the stones of sugar beet roots increase mechanical injuries, which leads to increased loss
- microorganisms and pests increase in such conditions, which leads to diseases in root crops.

As sources have shown, until now, specialized technology techniques for the long-term storage of sugar beet root crops have not been developed.

For the first time, Scientists of the Almaty Technological University have created a new, highly efficient technology for storing sugar beets in kagat using an ion-ozone mixture.

A universal ion-ozone installation was 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-ozone installation was obtained by

improving and combining the electrical circuits of the ozonator and ionizer installations, selecting the appropriate materials and estimating the geometric dimensions and proportions. According to calculations and experimental research, the optimal modes of IOM synthesis were established as the necessary parameters to impact the processed product. All this universality is united not only by the similarity and stages of the synthesis of IOMs, ionization of water and the interconnected quantum-physical processes that occur in the biological environment during their processing, but also by design. Moreover, the synthesis of ozone is accompanied by the formation of ions of different signs of electrical polarity. 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 et al., 2018a; Yakiyayeva et al., 2016). Therefore, it became necessary to combine ozone and ion technology in order to neutralize the side effects, which are 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, even in the most necessary quantities
- emanation of radium – radon, exceeding its usual concentration in the external atmosphere
- ultraviolet radiation, atomic ozone and nitrogenous compounds accompanying 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 the concentration of ozone, reducing the electricity and the cost of the processed products, reducing the dimensions and weight of the structure, as well as contributing to the production of environmentally friendly ozone, molecular and atomic ions and their mixtures is achieved due to highly efficient technology that has no analogues in the world (Iztayev et al., 2018b; Iztayev et al., 2018c).

Ion-ozone installation can simultaneously produce ozone and ions from the air. Ionization is the process of splitting a neutral molecule into two different molecules. One is positively charged (the one that is left without an electron) and the second is negative (the one that is left with an electron). Air passes through the ion generator of the installation; upon heating and cooling, this air is saturated with negatively charged ions. Free electrons produced by the generator enter the space of the processed product and then bind to oxygen molecules, forming negative ions. After processing, the resulting air ions stimulate the activation of physico-biochemical processes that occur during the storage of sugar beets and improve their quality.

## MATERIALS AND METHODS

### Materials

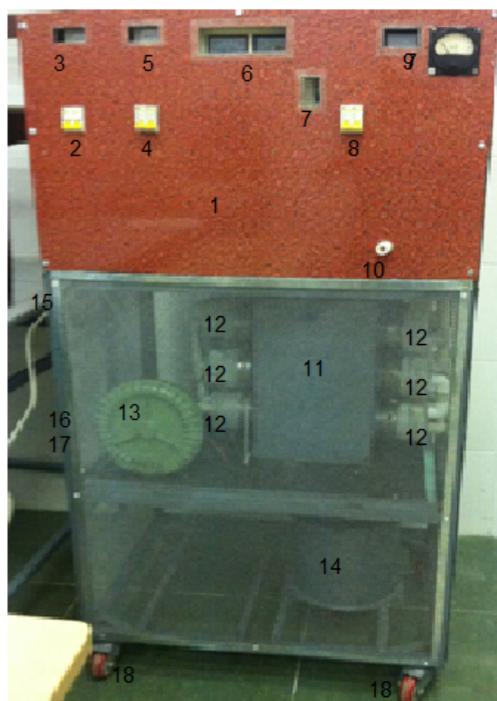
In this work, samples of sugar beet from the 2019 harvest from the economy of the Koksu district of the Almaty region were used. The sugar beets were harvested in early October 2019 and delivered to storage.

### Research methods

The following methods were used to determine the physicochemical and microbiological parameters: the wet and dry mass fractions were determined according to GOST 28561-90, acidity according to GOST ISO 750-2013 and the mass fraction of sucrose according to GOST 28562-90. The following interstate standards were used to determine microbiological indicators, that is, the content of mould 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 moulds.

### Methods of ozone preparation for storage

Ozone is an allotropic modification of oxygen; its molecular formula consists of three oxygen atoms and can exist in all three aggregate states. The boundary ionic structures reflect the dipole character of the ozone molecule and explain its specific reaction behaviour in comparison with oxygen, which forms a radical with two unpaired electrons. The ozone generator absorbs



**Fig. 1.** Ion-ozone installation

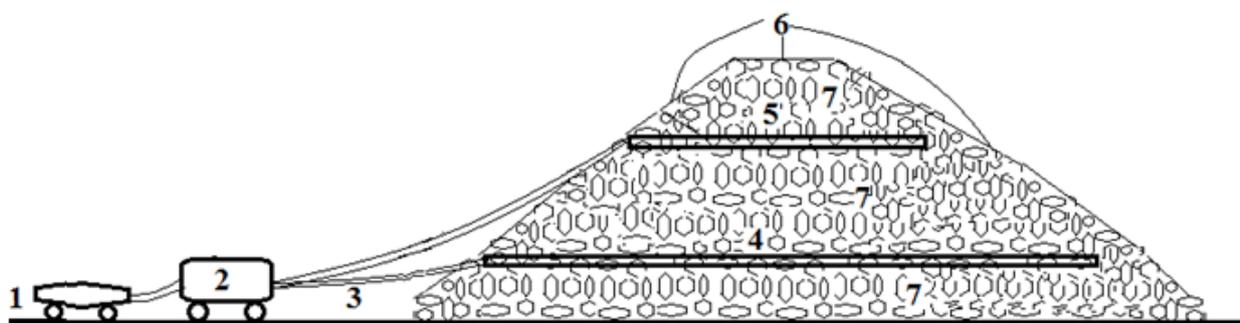
oxygen molecules from the air, resulting in a powerful electric charge. As a result of this reaction, the oxygen composition changes, and ozone is produced. Ozone has a disinfecting, antibacterial and antifungal effect (Erkmen, 2001; Kim et al., 2003; Manzhesov et al., 2009). Ion-ozone installation (Fig. 1) is needed in the food and food processing industries, the microbiological industry, agribusiness, healthcare, medicine, the

pharmaceutical industry, environmental ecology and human ecology, as well as in other areas of national and industrial management, since electrically charged particles are synthesized without the cumulative generation of harmful substances (Zhakatayeva et al., 2020).

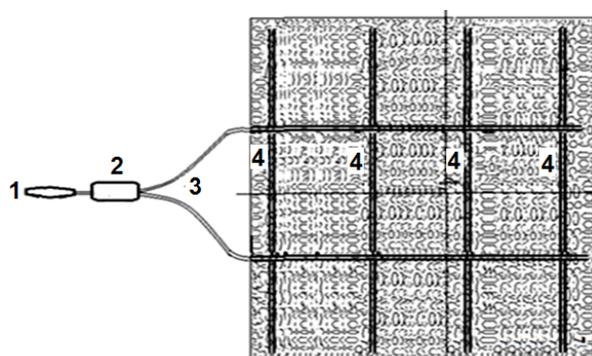
Therefore, in the creation of an ion-ozone installation, it is necessary to provide the concentration and amount of ozone and ions necessary for the successful processing of products. It is very important to determine the product processing technology to know the structure, humidity, oxidizing ability and temperature. 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 positive or negative ions are in 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.

The objective of this work is to increase the storage efficiency of sugar beet root crops by reducing the negative impact of solar insolation and suppressing the development of microbiological processes while increasing the biological value of sugar beet root crops during long-term storage, using an ion-ozone installation and processes for their ozone and ion-ozone processing.

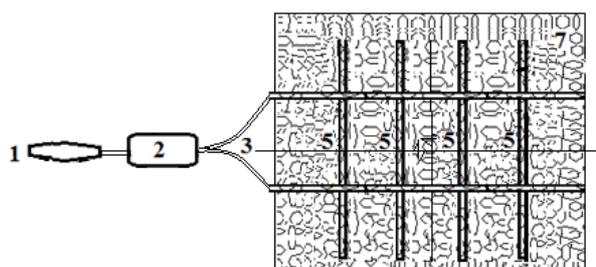
Methods for storing sugar beet root crops in a kagat using an ion-ozone installation are shown in Figures 2–4.



**Fig. 2.** Sections of the sugar beet root crop kagat: 1 – compressor, 2 – ion-ozone installation, 3 – pipeline ion-ozone mixture, 4 – lower bubbler with holes, 5 – upper bubbler with holes, 6 – a polyethylene film with a mirror reflecting side, 7 – sugar beet root crops



**Fig. 3.** The lower location of the bubbler for the processing of sugar beet root crops: 1 – compressor, 2 – ion-ozone installation, 3 – pipeline ion-ozone mixture, 4 – lower bubbler with holes, 5 – upper bubbler with holes, 6 – a polyethylene film with a mirror reflecting side, 7 – sugar beet root crops



**Fig. 4.** The upper location of the bubbler for ozone and ion-ozone processing of sugar beet root crops: 1 – compressor, 2 – ion-ozone installation, 3 – pipeline ion-ozone mixture, 4 – lower bubbler with holes, 5 – upper bubbler with holes, 6 – a polyethylene film with a mirror reflecting side, 7 – sugar beet root crops

The technological process of preparation for the long-term storage of sugar beet root crops in kagats is as follows:

1. During the reception of sugar beet root crops at the receiving points, bubblers 4 and 5 are installed. These are installed as sugar beets arrive and are set so that the bubblers divide the height of the kagat into three equal parts.
2. After the formation of the kagat of sugar beet root crops, their bubbler nozzles are connected to an ion-ozone installation 2, having a compressor 1 and hoses for transporting ozone or an ion-ozone mixture 3.

3. After preparing the ion-ozone installation for processing sugar beet root crops, sugar beet root crops are covered with a plastic film with a sun reflecting coating 7.
4. The kagat is coated completely with a plastic film, leaving 0.5–1.0 meters at the base of the unit for fresh air and exhaust gases.

In the locations of all variants of the experiment, including the control, the same optimal storage regime was created. Sugar beets were stored at a temperature of +10°C with fluctuations ranging from +5°C to +15°C at a relative humidity of 95–98%. According to the literature, it is recommended to store beets at a temperature of +1°C, not lower than 0, at a relative humidity of not more than 95%. But in production conditions it is impossible to provide such conditions, therefore, during the study, the sugar beet samples were stored as usual. Therefore, we investigated modes for storage in a production environment which does not require a lot of storage costs.

Ozone treatment of the sugar beet root crops was carried out: the ozone concentration in three studies was 5 mg/m<sup>3</sup>, 0.5 g/m<sup>3</sup> and 2 g/m<sup>3</sup>, respectively, and the exposure time was 20 minutes. The daily processing schedule was 20 minutes with ozone, 2 hours off, 20 additional minutes of ozone treatment, 2 hours off, and so on around the clock. Next, the processed sugar beet roots were observed for three months.

Processing of the sugar beet root crops with an ion-ozone mixture was carried out: the ozone concentrations in the three studies were 5 mg/m<sup>3</sup>, 0.5 g/m<sup>3</sup> and 2 g/m<sup>3</sup>, respectively; the molecular ion concentrations were 500 units/cm<sup>3</sup>, 50,000 units/cm<sup>3</sup> and 1,000,000 units/cm<sup>3</sup> and the exposure time was 20 minutes. The daily processing schedule was 20 minutes with ion-ozone, 2 hours off, another 20-minute treatment with ion-ozone, 2 hours off, and so on around the clock. Next, the processed sugar beet roots were observed for three months. Changes in the physicochemical and microbiological parameters of the sugar beets were determined.

When sugar beets are treated with ozone with a concentration of 5 mg/m<sup>3</sup> and 0.5 g/m<sup>3</sup> (upper and lower feed), their acidity decreases to 0.46 degrees, and with an ozone concentration of 2 g/m<sup>3</sup> with upper feeds, it decreases from 0.71 to 0.63 degrees. In contrast, and at an ozone concentration of 2 g/m<sup>3</sup> with

a lower feed, it increases to 0.8 degrees. The sugar content increased in all experiments by 1–2.5%. This is due to the fact that ozone molecules penetrating the sugar beet cell contribute to a decrease in intermolecular respiration, and sucrose will not be spent on the formation of non-sugars.

## RESULTS AND DISCUSSION

The technological process for the processing of root crops of sugar beets in piles is as follows:

1. To purge transport pipes and spargers in order to free them from foreign fractions and undesirable gases, the compressor 1 is switched on.
2. The device for processing sugar beet root crops is purged with an ordinary air stream for one hour (depending on the size of the kagat).
3. After the purge, the ion-ozone installation 2 is switched on. It can supply ozone, atomic or molecular oxygen ions separately or as ion-ozone mixtures to the kagats.

Ozone treatment of the sugar beet root crops was carried out, and the ozone concentration in the three studies was 5 mg/m<sup>3</sup>, 0.5 g/m<sup>3</sup> and 2 g/m<sup>3</sup>, respectively, and the exposure time was 20 minutes. The daily processing schedule was 20 minutes with ozone, 2 hours off, 20 additional minutes of ozone treatment, 2 hours off and so on around the clock. Next, the processed sugar beet roots were observed for three months. Changes in the physicochemical and microbiological parameters of the sugar beets were determined. The results of the study of the physicochemical and microbiological parameters of the control sample are shown in Table 1. Table 2 shows the effects of ozone on changes in moisture, acidity, sugar, yeast and sugar beet mould.

From the data in Table 2, it can be seen that ozone treatment reduces the humidity of sugar beets by 1–3%. Also, microbiological indicators show that when treated with ozone with a concentration of 2.0 g/m<sup>3</sup> (upper and lower feed) it reduces yeast growth to 6 CFU/g, and mould growth is not observed. Ozone

**Table 1.** Physicochemical and microbiological parameters of the control sample of sugar beet

Sample	Indicator				
	moisture %	acidity degree	sugar %	mould CFU/g	yeasts CFU/g
Unprocessed sugar beet	74.79 ±0.10	0.80 ±0.01	15.48 ±0.23	not found	solid growth

Mean ±standard deviation (*n* = 3).

**Table 2.** Influence of ozone on changes in moisture, acidity, sugar, yeast and mould of sugar beets

Indicator	Kagat storage					
	upper ozone feed		lower ozone feed		upper ozone feed	
	ozone concentration 5 mg/m <sup>3</sup>		ozone concentration 0.5 g/m <sup>3</sup>		ozone concentration 2 g/m <sup>3</sup>	
Moisture, %	71.97 ±0.35	73.76 ±0.45	75.78 ±0.21	72.68 ±0.40	72.48 ±0.12	73.54 ±0.3
Acidity, degree	0.60 ±0.2	0.46 ±0.01	0.60 ±0.01	0.70 ±0.09	0.63 ±0.02	0.80 ±0.02
Sugar, %	17.93 ±0.26	17.49 ±0.22	17.85 ±0.18	18.58 ±0.2	18.71 ±0.21	18.62 ±0.2
Mould, CFU/g	not found	not found	not found	not found	not found	not found
Yeasts, CFU/g	solid growth	solid growth	11	solid growth	56	6

Mean ±standard deviation (*n* = 3).

**Table 3.** Influence of ion-ozone on changes in moisture, acidity, sugar, yeast and mould of sugar beets

Indicator	Kagat storage					
	upper ion-ozone feed	lower ion-ozone feed	upper ion-ozone feed	lower ion-ozone feed	upper ion-ozone feed	lower ion-ozone feed
	concentration of ozone 5 mg/m <sup>3</sup> and molecular ions 500 units/cm <sup>3</sup>	concentration of ozone 5 mg/m <sup>3</sup> and molecular ions 500 units/cm <sup>3</sup>	concentration of ozone 0.5 g/m <sup>3</sup> and molecular ions 50,000 units/cm <sup>3</sup>	concentration of ozone 0.5 g/m <sup>3</sup> and molecular ions 50,000 units/cm <sup>3</sup>	concentration of ozone 2 g/m <sup>3</sup> and molecular ions 1,000,000 units/cm <sup>3</sup>	concentration of ozone 2 g/m <sup>3</sup> and molecular ions 1,000,000 units/cm <sup>3</sup>
Moisture, %	69.81 ±0.25	69.0 ±0.50	73.35 ±0.15	76.80 ±0.12	77.91 ±0.20	75.51 ±0.41
Acidity, degree	0.30 ±0.01	0.47 ±0.01	0.39 ±0.02	0.35 ±0.04	0.65 ±0.05	0.67 ±0.02
Sugar, %	18.43 ±0.28	18.82 ±0.31	18.41 ±0.18	18.57 ±0.21	17.81 ±0.10	17.36 ±0.10
Mould, CFU/g	not found	not found	21	not found	not found	not found
Yeasts, CFU/g	54	42	solid growth	solid growth	44	126

Mean ±standard deviation (*n* = 3).

has antibacterial properties and helps reduce mould and yeast growth. Therefore, with a high concentration of ozone, a decrease in microbiological parameters was observed.

The results of the study of the physicochemical and microbiological parameters of sugar beet root crops stored after processing with an ion-ozone mixture are shown in Table 3.

According to the data in the literature, ozone and molecular ions have a powerful bactericidal effect, capable of effectively destroying various types of moulds and yeasts, microorganisms and their metabolic products (toxins), and insect pests. With an average ozone concentration of 10 mg/m<sup>3</sup> and an ozonation time of about 4 hours, the shelf life of vegetables, including sugar beets, increases by 1.5–2 times. At the same time, organoleptic and physicochemical properties are almost completely preserved, and intoxication with residual chemicals is excluded.

The data in Table 3 show that the ion-ozone mixture reduces acidity by a factor of 2–3. The sugar content increased in all experiments by 2.5–3.5%. In addition, microbiological indicators show that when treated with an ion-ozone mixture with a concentration of ozone of 5 mg/m<sup>3</sup> and molecular ions of 500 units/cm<sup>3</sup>, the yeast content decreases to 54 (upper feed) and 42 CFU/g (lower feed). When processing is carried out with an ozone concentration of 2 g/m<sup>3</sup> and a molecular ion concentration of 1,000,000 units/cm<sup>3</sup>, the yeast content decreases to 44 (upper feed) and 126 CFU/g

(lower feed). Mould growth is not observed in either mode. Moreover, at an ozone concentration of 0.5 g/m<sup>3</sup> and a molecular ion concentration of 50,000 units/cm<sup>3</sup>, mould and yeast grow, so this treatment mode is not effective for storing sugar beets.

During the long-term storage of sugar beets, the same rates of decrease in moisture and acidity were observed during ozone and ion-ozone processing, and higher accumulations of sugar content are characteristic of ion-ozone processing. Mould was not detected in either processing method, nor from the state of continuous growth, and yeast was reduced to an insignificant level for the safe storage of sugar beet root crops.

## CONCLUSION

In this study, it was found that during ozone treatment the acidity decreased to 0.6 degrees, and the sugar content increased to 3.3%. When sugar beets are processed with an ion-ozone mixture, a decrease in moisture is observed up to 69%, acidity decreases up to 2 times, and the sugar content increases by 2–3%, while the growth of mould and yeast decreases. Therefore, the use of an ion-ozone installation will increase the sugar content of sugar beet root crops during processing, storage, preparation of sugar beet for processing and disinfection of root crops, while increasing the safety of sugar beets during long-term storage. The results of this study show that for the safe long-term storage of sugar beets, the following processing regimes are optimal:

1. An ozone concentration of 0.5 g/m<sup>3</sup> and 2 g/m<sup>3</sup> with an upper feed. 2. An ozone concentration of 5 mg/m<sup>3</sup> and molecular ions of 500,000 units/cm<sup>3</sup> with an upper or lower feed. 3. An ozone concentration of 2 g/m<sup>3</sup> and molecular ions of 1,000,000 units/cm<sup>3</sup> with an upper or lower feed. The synthesis of ozone and ion does not have harmful impurities of nitrogen and carbon oxides in comparison with other ozone synthesizers of world analogues, and the residual ozone obtained during the processing of products of the agro-industrial complex decomposes into oxygen, thereby enriching biological structures with oxygen. Therefore, the physical and organoleptic characteristics of sugar beets (smell, color, transparency, taste) are improved, and when processed with chemical reagents, unreacted chemical elements remain in the processed products that can accumulate in the body, and irritate and affect the corresponding organs of a person or animal. The use of ozone and (or) ion-ozone treatment during the storage of sugar beets provides the ability to preserve juicy products before the sale or processing of beet mass, and the content of water in the beet mass in a free state, as well as normalization of the temperature balance and humidity. As the results have shown, ozone and ion-ozone treatment ensures the maximum preservation of the technological qualities of sugar beet in order to ensure the profitability of processing it into sugar. In general, ozone and ion-ozone technology is proposed for the disinfection of sugar beets, increasing their biological value, environmental safety and economic efficiency in comparison with other similar technologies and chemical reagents.

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