The objects of research are the process of sugar beet processing, sugar beet, sugar and molasses.

The problem of determining critical control points in sugar beet processing and safety indicators of raw materials and products of the sugar industry was solved.

The results were obtained based on the risk analysis and the system of control points for sugar beet processing, five critical control points were identified according to the criteria of physical, chemical and biological contamination. It was also found that in terms of safety indicators, raw materials – sugar beet, and finished products meet the requirements of regulatory documents for microbiological indicators and heavy metal content.

The safety indicators of sugar beet, white sugar, molasses and beet pulp were studied. Microbiological indicators: CGB (coliforms), pathogens and S.aureus were not found in sugar beet samples. Microbiological indicators of QMAFAnM and yeast of white sugar, molasses and pulp 1–5*10^2, 6–7*10^2, 5–8*10^2 and 2–3*10^1, 1–3*10^1, 1*10^1 CFU/cm^3, respectively, are within acceptable limits. The content of toxic elements did not exceed the permissible limits.

For Kazakhstan sugar factories, no studies on hazard analysis and critical control points in the sugar industry have been conducted before, so the results of the study will fill this gap.

The scope and conditions for the practical use of the results obtained are the possibilities of raising the quality of finished products and improving the safety of raw materials and finished products, increasing the shelf life of by-products (molasses, beet pulp) of sugar beet production. These opportunities are based on the hazard analysis and critical control points (HACCP) in sugar beet processing

Keywords: HACCP, sugar industry, safety, beet pulp, molasses, risks, microbiological indicators, toxic elements

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ANALYSIS OF RISKS AND SAFETY INDICATORS OF RAW MATERIALS AND PRODUCTS OF THE SUGAR INDUSTRY OF KAZAKHSTAN

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1. Introduction

The issue of food safety has always raised consumer concerns. Thanks to the HACCP, great success has been achieved in the safety management system of finished food products [1, 2].

The development and implementation of food safety management systems are a prerequisite for food enterprises, including the sugar industry. The introduction and maintenance of HACCP procedures make it possible to prevent the occurrence of hazards at early stages of food production, ensure the quality and safety of the production process and increase the competitiveness of domestic food products.

The ISO 22000:2005 standard combines the principles of risk analysis by critical control points and practical steps developed in the Codex Alimentarius (Food Code). Risk analysis is the key to an effective food safety management system, since it helps to systematize knowledge for creating an effective combination of control measures. Effective and efficient food control systems are necessary to protect consumer health [3, 4].

Sugar beet is one of the most important industrial crops in the fields of our country. Yet now, the giant sugar production is suffering from a crisis caused by the sugar content of root crops and declining yields. Under the limited production capacity of operating sugar plants, a large share of raw materials goes through the storage stage and needs to be protected from adverse factors. Fresh beets deteriorate quickly due to high moisture content, continuous metabolism and microbial exposure [5].

The unbalanced use of mineral fertilizers, the system of short-term rotation and the technology of subsurface tillage lead to a decrease in the quality of raw materials. During storage, harvesting and transportation of sugar beets, significant losses are caused by a high level of mechanical damage to root crops and incorrectly selected technological modes [1, 6]. Due to the fact that fruit and vegetable products and places of long-term storage of vegetables mainly

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have a quality that does not meet the requirements of standards, the safety of such products is low [7].

All this contributes to the favorable development of various groups of microorganisms.

Freezing and drying of root crops also lead to violation of the normal functions of beetroot, weaken its resistance and cause the development of clamp rot during storage. Major bacteria found in the clamp rot cause fermentation of sugar and pectin substances with the formation of acids, alcohol, hydrolysis products of pectin substances and dextrans, having a negative effect in sugar beet processing.

Therefore, research on the analysis of risks and safety indicators of raw materials and products of the sugar industry in Republic of Kazakhstan is relevant.

2. Literature review and problem statement

For sugar factories in Sudan [8], the extent of risk analysis implementation was estimated. The Sudanese sugar industry carefully monitors all quality parameters from cane production to sugar production, but does not concern the food safety of the system. The lack of commitment and involvement of senior management, and also the lack of state support represent the main restrictions and barriers to the implementation of food safety systems in Sudanese sugar companies. The study recommends that the Sudanese sugar industry should establish proper quality control laboratories to help monitor the quality and safety of raw materials and final products.

The work [9] provides a theoretical analysis of critical control points for the production of a line of sugar, molasses and pulp. Data are provided to identify potential hazards for sugar, molasses and beet pulp, as well as critical control points, monitoring and responsible personnel for sugar beet processing.

The authors of [10] present the results of traceability of food safety in a sugar factory, on the example of a large producer of white sugar in Brazil, which has a tracking system for the agro-industry of products. The national sugar and alcohol sector was chosen as it is a leader in the production and export of sugar cane. The work shows the ability of the traceability system under study to identify the source of a chemical. The authors propose to develop, evaluate and implement a tracking system to meet food safety requirements, and ensure customer satisfaction and business continuity.

The studies [8, 10] on the analysis of critical control points at sugar enterprises in various countries, on the example of Sudan and Brazil, emphasize the need for research in this area to reduce the risks of contamination and ensure the safety of sugar products. The main sources of hazards in a sugar factory are pathogens in raw materials, which are infected during the growing, harvesting and storage of sugar beet. In addition to microbiological safety, it is important to control the content of pesticides, heavy metals and radionuclides making raw materials unsafe.

There are studies [11] on the main populations of microorganisms present throughout the beet sugar extraction process. According to the results, beets, pulp and diffusion juice were the most contaminated samples during beet sugar extraction, and gum-forming lactic acid bacteria, thermophiles and yeast were the most abundant microbiota found in the process. The first microbial group was present mainly on beets, while remaining on washed beets, pulp and in diffusion juice. The main source of these bacteria was beet wash water, while the diffusion juice showed very low contamination. Thermophiles were present in the highest concentrations in the diffusion juice, although in smaller amounts than expected, and were also found in beets, pulp and diffusion juice. Finally, yeast was present in high concentrations from beets to the pulp, as well as in the diffusion juice.

In [12], a comparison of beet microbiomes from six storage clamps in Austria and Germany revealed regional differences; however, universal health indicators were identified. In addition to a significant reduction of microbial diversity in decomposing sugar beets ($p \leq 0.01$), a distinct shift in the taxonomic composition of the total microbiome was found. Fungal taxa such as *Candida* and *Penicillium*, along with gram-positive *Lactobacillus*, were major disease indicators in the microbiome of decomposing sugar beets. In contrast, the genera *Plectosphaerella* and *Vishniacozyma*, as well as higher microbial diversity, generally reflect the microbiome of healthy beets. Based on these data, a PCR-based early detection technique was developed, confirming a twofold decrease in health indicators and up to a 10,000-fold increase in disease indicators in beet clamps.

The authors [13] revealed that from the moment of harvesting till the clamping of sugar beets, representatives of the genera Fusarium, Penicillium, Aspergillus, i.e., soil microflora, are isolated from the root crop surface. During storage, beetroot tissue is affected. Along with the aforementioned fungi, representatives of the genera Botrytis, Phoma, Mucor are isolated. Fungi of the genera Botrytis and Phoma were not identified at the initial stage of storage and appeared only during storage. After 30 days of storage, their share is 10.7 and 9.8 %, respectively. The rest of the fungi continued to develop during storage, a decrease in their proportion is explained by the appearance of other fungi.

In [6–10, 12, 13], the issues of monitoring critical points based on the HACCP safety system of the sugar industry, in particular at the regional level, remained unresolved. This may be due to objective difficulties in the use of new varieties of sugar beet, pesticides and the peculiarities of the natural and climatic conditions of Republic of Kazakhstan.

To better understand the impact of storage on the technological value of damaged root crops, it is necessary to expand the scope of research to safety indicators. Along with microbiological safety, it is important to investigate the content of heavy, toxic metals that can affect the efficiency of sugar beet processing.

Studies of the fungal community of sugar beets during storage [13] confirm the need to study the risks and safety indicators of raw materials and products of the sugar industry in Republic of Kazakhstan.

Despite the availability of risk analysis studies for a number of food sectors, they are not enough for sugar production in Kazakhstan due to the small number of enterprises in this industry and the short period of sugar beet processing.

At the same time, sugar is a strategic product and the main raw material for many food sectors, in addition to its direct use in food, and it is important to carry out work aimed at ensuring its quality and safety.

3. The aim and objectives of the study

The aim of the study is to analyze the risks and safety indicators of raw materials and products of the sugar industry of Republic of Kazakhstan. This will make it possible to ensure high quality indicators of white sugar, including safety indicators of all sugar beet processing products.

To achieve the aim, the following objectives were set:

– to identify potential and dangerous risks of sugar beet processing;

– to identify critical control points and develop corrective actions in the production of white sugar from sugar beet;

– to evaluate the safety indicators of sugar beet and products of its processing.

4. Materials and methods

The object of the study is the process of sugar beet processing, sugar beet, sugar and molasses.

The main hypothesis of the study suggests that risk analysis of sugar beet processing can be an effective method to ensure the safety and high quality of sugar industry products.

The study was conducted at the Merken sugar factory in the Jambyl region in the south of Republic of Kazakhstan. Data collection was carried out using a checklist of observations and direct interviews with production specialists.

In the research, Eider and Viorica varieties of sugar beet harvested in 2021 were used.

Samples of sugar beet were taken in accordance with GOST 33887-2016 "Sugar beet". Samplers were used to determine the safety and the presence of rotted and frozen root crops. Three spot samples were taken with beet forks from the transport unit along the waistline of the body. On the front side – after removing a 10–15 cm thick layer, in the center – from the top layer, on the rear side – after removing a 25–30 cm thick layer. The spot samples were used to make a combined sample of sugar beet roots weighing at least 12 kg.

All analyses of the quality and safety indicators of sugar beet and processing products were carried out three times.

The methodology for production risk assessment is based on the following regulatory documents: OHSAS 18001-1999 "Occupational safety and health management system"; GOST 12.0.230-2007 SSBT Occupational safety management systems; TNK-BP procedure for production risk assessment.

Experiments were carried out in an accredited research laboratory for assessing the quality and safety of food products on the basis of Almaty Technological University JSC. The organoleptic parameters were determined according to GOST 33884-2016 "Interstate sugar beet standard. Specifications" and GOST R 52304-2005 "Beet molasses. Specifications".

The content of toxic elements of the selected samples was determined according to GOST 30178-96 "Interstate standard for raw materials and food products. Atomic absorption method for determination of toxic elements", GOST 51766-2001 "State standard of the Russian Federation for raw materials and food products. Atomic absorption method for determination of arsenic", GOST 26927-86 "Interstate standard for raw materials and food products. Methods for determination of mercury".

In accordance with GOST 26968-86 "Sugar. Methods of microbiological analysis", studies on the microbiological safety of the samples were conducted.

5. Results of the study of the system of hazard analysis and critical control points at sugar factories in Republic of Kazakhstan

5. 1. Analysis of potential and hazardous risks of sugar beet processing

The mechanical processing of sugar beet includes the following operations: acceptance, separation from impurities, washing of raw materials, slicing of beets. Thermal processing: obtaining and purification of diffusion juice, pulp, boiling and centrifugation of fillmass, drying, cooling of white sugar, packaging, labeling and storage of finished products.

In the course of processing sugar beets into beet pulp, molasses and sugar, there is the possibility of the spread of microorganisms, the presence of heavy metals, pesticides, etc. Table 1 shows an analysis of hazardous factors in sugar beet processing: biological (B), physical (P) and chemical (C).

Table 1

Analysis of hazardous factors in sugar beet processing

No.	Production stage	Type of contamination	Description of the hazardous factor	Source/cause of contamination
1	2	3	4	5
1	Incoming inspection – acceptance of sugar beets	B	total contamination	soil, clamp storage, transportation: by road, rail, at *t* – 8 °C and above; storage facilities, raw materials (in the destruction of insects, rodents, birds and mold)
		P	beaten, frozen	during storage, transportation
		C	pesticides, toxic elements	soil, water – absorption through the root system of plants from soil pollution
2	Production control – separation from impurities, washing of raw materials	P	Metal-magnetic impurity having the property of being attracted to a magnet; isolation from a light impurity	during harvesting, transportation
3	Slicing of beets	P	foreign impurities	ingress of mineral impurities into processing products
4	Obtaining diffusion juice and pulp	B	total contamination	non-compliance with technological modes
		C	residual disinfectants	high concentration of disinfectants

Continuation of Table 1

1	2	3	4	5
5	Purification of diffusion juice	B	total contamination	non-compliance with technological modes
		C	increase in pH, SO_2	non-compliance with technological modes
6	Boiling of fillmass	P	foreign objects	non-compliance with sanitary and hygienic standards
7	Centrifugation of fillmass	B	total contamination	non-compliance with technological modes and/or sanitary and hygienic standards
8	Drying and cooling of white sugar	P	external contamination of the product	non-compliance with equipment maintenance and/or sanitary and hygienic standards
9	Packaging, labeling and storage of finished products	B	total contamination	violation of storage conditions for finished products and/or sanitary and hygienic standards
		P	external contamination of the product	violation of storage conditions for finished products and/or sanitary and hygienic standards
10	Outgoing inspection – quality control of finished products	B	total contamination	non-compliance with storage temperature and humidity conditions
		P	foreign objects	non-compliance with personal hygiene rules, sanitary and hygienic measures and maintenance of premises
		C	harmful substances in packaging	high concentration of harmful substances in packaging

The analysis of hazards in sugar beet processing showed biological, physical and chemical factors related to unacceptable risks. Further, based on the potential hazards and risks, it is advisable to identify critical control points of production.

5. 2. Identification of critical control points and development of corrective actions in the production of white sugar from sugar beet

The purpose of this stage is to determine the points, procedures at which control will be applied, so that it is possible to prevent the occurrence of a hazardous factor, eliminate or reduce it to an acceptable level. A critical control point can be any stage, which must be carefully studied and all data must be documented. Table 2 identifies critical control points of sugar production from sugar beet.

When determining critical control points, all stages of sugar production from sugar beet were analyzed, taking into account unacceptable risks of the high and medium zones. The severity of consequences (1 – insignificant, 2 – medium, 3 – high and 4 – very severe) and the likelihood of a hazardous event (1 – improbable, 2 – unlikely, 3 – accidental, 4 – likely and 5 – frequent) were considered.

Table 2

Identification of critical control points of sugar production from sugar beet

No.	Stage	Type of contamination	Probability	Consequences	Risk	CCP/CP
1	Incoming inspection – acceptance of sugar beets	B	4	3	12	CCP1
		P	2	3	6	CP
		C	3	4	12	CCP2
2	Production control – separation from impurities, washing of raw materials	P	3	2	6	CP
3	Slicing of beets	P	3	2	6	CP
4	Obtaining diffusion juice and pulp	B	2	2	4	CP
		C	2	2	4	CP
5	Purification of diffusion juice	B	2	1	2	CP
		C	2	1	2	CP
6	Boiling of fillmass	P	4	3	12	CCP3
7	Centrifugation of fillmass	B	3	2	6	CP
8	Drying and cooling of white sugar	P	2	2	4	CP
9	Packaging, labeling and storage of finished products	B	2	3	6	CP
		P	2	2	4	CP
10	Outgoing inspection – quality control of finished products	B	2	3	6	CP
		P	4	3	12	CCP4
		C	5	2	10	CCP5

The development and implementation of corrective actions include the following activities: assessment of the importance of emerging quality assurance problems, in terms of the impact on production costs, consumer properties and product safety; identification and investigation of possible causes of the problem, determination of the cause by analyzing product documentation, related processes, control results:

– development and implementation of preventive measures to solve the problem, preventing its recurrence;

– control over the implementation of corrective actions and evaluation of their effectiveness;

– making corrective changes to production regulation documents and quality system elements associated with the occurrence of the problem;

– in case of a special need related to product safety or legal liability for product quality, making a decision and carrying out work on the return of finished products.

Table 3 shows corrective actions for sugar beet processing [14, 15].

Table 3

Corrective actions for sugar beet processing

No.	Stage	CCP	Frequency	Control parameter	Regulatory document	Corrective actions
1	Acceptance of sugar beets	1	As raw materials are received	QMAFAnM, CGB, pathogens, *S.aureus*, yeast, mold	TR CU 021/2011	In all cases of changes in raw materials, they are isolated by limiting the storage area with red tape in accordance with regulatory documents for standardization and sent to the local laboratory
2	Acceptance of sugar beets	2	As raw materials are received	Lead, arsenic, cadmium	TR CU 021/2011	
3	Boiling of fillmass	3	At least 2 times a shift	Temperature, pressure of the vacuum unit	Not allowed	In case of non-compliance with sanitary and hygienic standards, additional training of the personnel is carried out and the frequency of control by the production technologist is increased
4	White sugar	4	At least 2 times a shift	Quality of packaging material	Not allowed	In case of non-compliance with sanitary and hygienic standards, additional training of the personnel is carried out and the frequency of control by the production technologist is increased
5	White sugar	5	At least 2 times a shift	Quality of packaging material	Not allowed	Careful control upon acceptance of packaging materials

The identification of critical control points in the production of sugar from sugar beet made it possible to create preventive and corrective actions.

5. 3. Study of safety indicators of sugar beet and products of its processing

The lack of specialized storage facilities for harvested sugar beets does not ensure the long-term storage of root crops. In the event of a thaw, thawed root crops are no longer suitable for processing. Beetroot and the products of its processing are good media for the development of microorganisms. Freezing and drying of root crops lead to a violation of the normal functions of beet, weaken its resistance and cause the development of clamp rot during storage. Table 4 shows the results of studying the microbiological safety of sugar beets.

Microbiological indicators of sugar beet processing products (white sugar, molasses, beet pulp) are given in Table 5.

Table 4

Microbiological indicators of sugar beet

Indicator	Unit of measurement	Microbiological indicators of various sugar beet samples		
		whole	frozen	rotten
QMAFAnM	CFU/cm^3	2*10^2	2*10^2	7*10^2
CGB (coliforms)	in 0.01 g of the product	not found	not found	not found
Pathogenic, including salmonella	in 25 g of the product	not found	not found	not found
S.aureus	in 0.1 g of the product	not found	not found	not found
Yeast	CFU/cm^3	4*10^1	3*10^1	3*10^1
Mold	CFU/cm^3	not found	not found	2*10^1

Table 5

Microbiological indicators of sugar beet processing products

Product	Microbiological index, CFU/cm^3	
	QMAFAnM	Yeast
White sugar	1–5*10^2	2–3*10^1
Molasses	6–7*10^2	1–3*10^1
Beet pulp	5–8*10^2	1*10^1

One of the major pollutants in terms of the scale of pollution and the impact on sugar beet losses is also toxic elements, including heavy metals. The content of toxic elements and pesticides in sugar beets is given in Table 6.

Table 6

Content of toxic elements in sugar beets

Toxic element	Content of toxic elements in various sugar beet samples, mg/kg		
	whole	frozen	rotten
Lead	0.0028± ±0.00004	0.0023± ±0.00003	not found
Arsenic	0.002± ±0.0001	0.0008± ±0.00004	not found
Cadmium	not found	not found	not found

Toxic elements, lead in particular, enter sugar beets from soil contaminated with fertilizers and industrial waste.

Toxic elements entering the body, reaching a certain concentration cause various diseases and even mutations [16]. Lead can be characterized as an element of low absorption intensity, since according to the results of the study, the value in mg/kg is less than one.

6. Discussion of the results of the study on the analysis of risks and safety indicators of raw materials and products

Potential and hazardous risks of sugar beet processing arise due to contamination of raw materials with chemical, physical and biological agents and in the course of sugar beet processing. The maximum risk peaks were identified in the following stages: acceptance of sugar beets: CCP1 – biological factor, CCP2 – chemical factor; CCP3 – physical factor, when boiling the fillmass and obtaining granulated sugar; CCP4 and CCP5 in the process of quality control of finished products, the physical and chemical factors, under non-compliance with technological modes, the probability of risk increases.

To determine the critical control points of production, the probability of occurrence of a hazardous factor was estimated (Table 2) based on 4 possible options: almost zero; insignificant; significant; high. The risk assessment was carried out using a scoring system from 0 to 10, where 0 is no risk, 1–4 is a slight risk, 4–6 is a medium risk, 7–9 is a high risk, 10 is a very high risk [17]. By the results of determining the critical control points of production, corrective actions were developed. This allows improving the system of product quality management in the enterprise by strict assignment of responsibility and identifying the most important quality control points.

In terms of safety indicators of sugar beet processing products, 3 samples of sugar beet were examined: whole, rotten and frozen. In a normal biochemical process, each cell of the raw material is frozen during sugar beet storage. The process of freezing raw materials occurs at a temperature of –4–16 °C for 18–20 hours. If the storage conditions of frozen sugar beets (–3–4 °C) are not observed, the process of sucrose inversion is activated, as a result, the turgor of the root crop decreases. The optimum storage temperature for frozen sugar beets should be no higher than –14–16 °C. Frozen beets cannot be in good condition for a long time.

On sugar beet crops, root rot is often observed, which varies from 2 to 20 %, leading to a biotic factor in crop losses. Such pathogens include microscopic fungi and saprophytic bacteria. Such a root crop has an unpleasant putrid odor and releases juice, thus, the beet growing industry faces enormous losses [18, 19].

The data in Table 4 confirm that in rotten sugar beets, the QMAFAnM index is $5*10^2$ CFU/cm^3 higher than in whole beets. CGB, pathogens and *S.aureus* were not found in all samples. Molds in the amount of $2*10^1$ CFU/cm^3 were found in rotten sugar beets, yeasts were also found in all samples, but their content did not exceed the permissible limits (Table 4).

Major bacteria found in the clamp rot are acid-forming mucus-forming species that cause fermentation of sugar and pectin substances with the formation of acids, alcohol, hydrolysis products of pectin substances and dextrans. The permanent microflora of sugar beet is: *Bacillus subtilis, Clostridium perfringes, Leuconostoc dextranicum, Torula alba, Pseudomonas fluorescens, Sarcina lutea*, *Aspergillus, Pennicillium, Mortierella, Mucor* and other types of microorganisms, complicating the processing of raw materials and reducing the sugar quality [20].

From Table 4, it can be seen that when sugar beet is frozen, the QMAFAnM value decreases due to the extinction of thermophilic microorganisms in an unfavorable environment.

Microbial contamination of sugar beet contributes to the accumulation of biomass of various groups of microorganisms during storage and processing and causes many problems in sugar production [21, 22]. The saprophytic mold fungi found include *Mucor mucedo, Rhisopus nigricans, Aspergillus niger*, various species of *Penicillium, Trichohtecium, Cladosporium*. Mold fungi damage the beet root structure, promoting the development of bacteria that complete the spoilage process, making beets unsuitable for processing.

The microbiological data presented in Table 5 show the high QMAFAnM value in molasses and allowable yeast rates. Molasses is a basic raw material for the production of ethyl alcohol, glycerin, butanol, acetone, lactic and other acids. Citric, fumaric, acetic acid, as well as bakery and fodder yeasts are obtained by an aerobic process [23, 24].

The number of mesophilic aerobic and facultative anaerobic microorganisms in beet pulp is $5–8*10^2$ due to the fact that beet pulp is a substrate consisting of dead tissues and cells, while the enzymes in them are activated by high temperature. As a result, during the storage of beet pulp, the transformation of nutrients occurs with the help of enzymes only of microorganisms on the surface of pulp particles. The main contamination of pulp with pathogens occurs after it cools down during transportation and storage. When the raw pulp is stored for 6 months, its loss is 65–67 %, while the nutritional value is reduced by 50 % [25].

The results of the study on the content of toxic elements in sugar beets are presented in Table 6. In frozen sugar beets, the Pb content is only slightly lower, 2.5 times less than in whole beets stored at the optimum temperature. The presence of Cd in all samples was not found, and toxic elements were not found in rotten sugar beets at all.

For Republic of Kazakhstan sugar factories, no studies on hazard analysis and critical control points in the sugar industry have been conducted before, so the results of the study will fill this gap.

The studies were carried out only for the beet processing industry. Further work should be carried out for another type of raw materials in the sugar industry – raw sugar.

In the future, it is necessary to study the content of the mass fraction of ferroimpurities and sulfur dioxide in white sugar from sugar beet and raw sugar.

Studies of safety indicators for sugar beet and the products of its processing should be continued for other growing regions in Kazakhstan. To ensure the effective operation of the HACCP system at the enterprises of the sugar industry in Republic of Kazakhstan, it is important to conduct training of the HACCP system. In turn, management should provide support to the staff on this issue.

7. Conclusions

1. An analysis was made of potential and hazardous risks of sugar beet processing, which were found at the following stages: acceptance of sugar beet; boiling of fillmass and ob-

taining granulated sugar; quality control of finished products by types of contamination: 1 – biological, 2 – physical and 2 – chemical.

2. Five critical control points in the production of white sugar from sugar beets were identified. CCP1 and CCP2 during acceptance of sugar beet (incoming inspection), CCP3 – during boiling of fillmass (production control), CCP4 and CCP5 during quality control of white sugar (outgoing inspection). Corrective actions were developed for all CCPs of sugar beet processing.

3. The safety indicators of sugar beet, white sugar, molasses and beet pulp were studied. Microbiological indicators: CGB (coliforms), pathogens, including salmonella and *S.aureus*, were not found in sugar beet samples. The content of yeast and molds in all samples did not exceed the permissible limits.

Microbiological indicators of QMAFAnM and yeast of white sugar, molasses and pulp $1–5*10^2$, $6–7*10^2$, $5–8*10^2$ and $22–3*10^1$, $1–3*10^1$, $1*10^1$ CFU/cm^3, respectively, are within acceptable limits. Cadmium was not found in all samples, the mass fraction of lead and arsenic did not exceed the permissible limits.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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References

1. Bugaenko, I. F. (1994). Analiz poter' sakhara v sakharnom proizvodstve i puti ikh snizheniya. Kursk: AP «Kursk», 128.
2. Astakhova, N. V., Ermolaeva, E. O., Trofimova, N. B. (2020). Development of a food safety management system based on HACCP principles in the production of chocolate wafers. Food processing industry = Pischevaya promyshlennost', 5, 39-43. doi: https://doi.org/10.24411/0235-2486-2020-10053
3. Varivoda, A. A., Ovcharova, G. P. (2013). Tekhnologiya khraneniya i pererabotki moloka i molochnykh produktov. Saarbryukken: Palmarium Academic Pudlishing, 256.
4. Tungyshbayeva, U., Mannino, S., Uazhanova, R., Adilbekov, M., Yakiyayeva, M., Kazhymurat, A. (2021). Development of a methodology for determining the critical limits of the critical control points of the production of bakery products in the Republic of Kazakhstan. Eastern-European Journal of Enterprise Technologies, 3 (11 (111)), 57–69. doi: https://doi.org/10.15587/1729-4061.2021.234969
5. Liu, Y., Sabadash, S., Duan, Z., Deng, C. (2022). The influence of different drying methods on the quality attributes of beetroots. Eastern-European Journal of Enterprise Technologies, 3 (11 (117)), 60–68. doi: https://doi.org/10.15587/1729-4061.2022.258049
6. Sadovnikova, M. A., Makarova, L. V. (2018). Analiz poter' pri proizvodstve sakhara (na primere OAO «Atmis-sakhar» g. Kamenki). Molodoy ucheniy, 49 (235), 52–55. URL: https://moluch.ru/archive/235/54712/
7. Pusik, L., Pusik, V., Bondarenko, V., Gaevaya, L., Kyruchina, N., Kuts, O. et. al. (2022). Determiningcarrot preservation depending on the root quality and size, as well as on storage techniques. Eastern-European Journal of Enterprise Technologies, 1 (11 (115)), 26–32. doi: https://doi.org/10.15587/1729-4061.2022.251785
8. Gharib-Bibalan, S., Keramat, J., Hamdami, N., Hojjatoleslamy, M. Optimization of fenton oxidation process for the degradation of color precursors in raw sugar beet juice. Sugar Tech, 18 (3), 273–284. doi: https://doi.org/10.1007/s12355-015-0398-6
9. Kotzamanidis, C. Z., Arvanitoyannis, I., Skaracis, G. N., Hadjiantoniou, D. Ch. (2000). Implementation of hazard analysis critical control point (HACCP) to the production line of sugar, molasses and pulp. Sugar industry, 125, 970–925. Available at: https://www.researchgate.net/publication/233985525_Implementation_of_hazard_analysis_critical_control_point_HACCP_to_a_production_line_of_beet_sugar_molasses_and_pulp_A_case_study
10. Wicher, E. W., Hermosilla, J. L. G., Silva, E. C., Azollini, W. (2012). Traceability for Food Safety: the case of a sugar factory and alcohol distillery plant. International conference on industrial Engineering and Operetions Management. Guimaraes. Available at: https://abepro.org.br/biblioteca/icieom2012_submission_145.pdf
11. Robles-Gancedo, S., López-Díaz, T. M., Otero, A. (2009). Microbiological Counts during Beet Sugar Extraction. Journal of Food Protection, 72 (6), 1332–1337. doi: https://doi.org/10.4315/0362-028x-72.6.1332
12. Kusstatscher, P., Zachow, C., Harms, K., Maier, J., Eigner, H., Berg, G., Cernava, T. (2019). Microbiome-driven identification of microbial indicators for postharvest diseases of sugar beets. Microbiome, 7 (1). doi: https://doi.org/10.1186/s40168-019-0728-0
13. Sabyrkhan, A. Zh., Ermakhanova, A. B. et. al. (2019). Analiz gribkovogo soobschestva sakharnoy svekly pri khranenii. VIII Mezhdunarodnaya nauchno-tekhnicheskaya konferentsiya «Novoe v tekhnologii i tekhnike funktsional'nykh produktov pitaniya na osnove mediko-biologicheskikh vozzreniy», posvyaschennaya 90-letiyu tekhnologicheskogo fakul'teta. Voronezh, 450–452. Available at: http://old.vsuet.ru/science/conference2019/mat_28-03-2019.pdf
14. Meyes, T., Mertimor, S. (2005). Effektivnoe vnedrenie KhASSP: uchimsya na opyte drugikh. Sankt-Peterburg: Professiya, 288.
15. Dunchenko, N. I., Magomedov, M. D., Rybin, A. V. (2008). Upravlenie kachestvom v otraslyakh pischevoy promyshlennosti. Moscow, 211.

16. Novikova, A. V., Bartenev, I. I., Kravets, M. V., Gavrin, D. S. (2014). Rezul'taty issledovaniya vliyaniya preparatov fungitsidnogo deystviya na sokhrannost' matochnykh korneplodov. Priemy i sredstva povysheniya produktivnosti sakharnoy svekly i drugikh kul'tur sevooborota. Voronezh, 92–96.
17. Kupriyanov, A. V. (2013). Razrabotka i vnedrenie sistemy KhASPP na predpriyatiyakh pischevoy promyshlennosti. Orenburg, 89.
18. Gharib-Bibalan, S., Keramat, J., Hamdami, N., Hojjatoleslamy, M. (2016). Optimization of fenton oxidation process for the degradation of color precursors in raw sugar beet juice. Sugar Tech, 18 (3), 273–284. doi: https://doi.org/10.1007/s12355-015-0398-6
19. Grigorenko, V. R. (2017). Puti sokhraneniya urozhaya korneplodov sakharnoy svekly i sakharistosti pri ugroze nalichiya kornevykh gniley. Materialy IX Mezhdunarodnoy studencheskoy nauchnoy konferentsii «Studencheskiy nauchnyy forum». Available at: https://scienceforum.ru/2017/article/2017038968
20. Iztaev, A. I., Yakiyaeva, M. A., Arynova, R. A. et. al. (2020). Innovatsionnye tekhnologii dlitel'nogo khraneniya sakharnoy svekly. Almaty: TOO Izdatel'stvo "Fortunv Poligraf", 480.
21. Stognienko, O. I. (2014). Izmeneniya v patogennom komplekse kagatnoy gnili, proizoshedshie za 80 let. Priemy i sredstva povysheniya produktivnosti sakharnoy svekly i drugikh kul'tur sevooborota. Voronezh, 106–109. Available at: http://vniiss.com/ChitZal/Book/Sbornik2014.pdf
22. Dautova, Z. F., Alimgafarov, R. R. (2013). Khimicheskiy sostav korneploda sakharnoy svekly. Sovremennye naukoemkie tekhnologii, 9, 12–13. Available at: https://top-technologies.ru/ru/article/view?id=33159
23. Petenko, A. I., Molotilin, Yu. I. (2008). Konservirovanie sveklovichnogo zhoma s bakterial'nymi zakvaskami. Zemlya i Zhizn'. Rossiyskaya agrarnaya gazeta, 13 (157). Available at: https://биотехагро.рф/zagotovka-kormov/zagotovka-kormov-04
24. Vrednoe vozdeystvie tyazhelykh metallov na organizm cheloveka. Available at: https://www.studsell.com/view/29881/
25. Ovchinnikova, Yu. A., Papikyan, T. A. (2016). Vliyanie gerbitsidov na urozhaynost' sakharnoy svekly. Molodoy ucheniy, 23 (127), 189–192. Available at: https://moluch.ru/archive/127/35138/