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ARTIGO ORIGINAL

ESTUDOS EXPERIMENTAIS DO GRÃO DE CEVADA DE BAISHESHEK PROCESSADO PELA MISTURA DE ÍON-OZÔNIO

EXPERIMENTAL STUDIES OF THE BAISHESHEK BARLEY GRAIN PROCESSED BY THE ION-OZONE MIXTURE

ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ ЗЕРНА ЯЧМЕНЯ «БАЙШЕШЕК», ОБРАБОТАННОГО ИОН-ОЗОННОЙ СМЕСЬЮ

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RESUMO

O artigo apresenta os resultados de um estudo experimental do grão de cevada da cultivar Baisheshek tratado com uma mistura de íon-ozônio. O objetivo deste estudo foi desenvolver uma tecnologia inovadora para o processamento de cevada com uma mistura íon-ozônio, a fim de aumentar seus parâmetros tecnológicos, produtividade, qualidade e segurança de grãos. O Cazaquistão aumentou drasticamente a exportação de cevada e todos os agrônomos, produtores e criadores estão migrando ativamente para o desenvolvimento dessa cultura, enquanto aumentam a produção, a produtividade, melhoram a qualidade do produto, reduzem suas perdas e garantem a segurança do armazenamento, que é uma tarefa urgente. Os microrganismos desempenham um papel importante durante o armazenamento, estes penetram nos produtos agrícolas de várias maneiras e, se caírem em condições desfavoráveis de armazenamento após a colheita, os produtos agrícolas se deterioram rapidamente, substâncias nocivas se acumulam - toxinas, fungos e outros, o que reduz o valor da mercadoria. Para resolver esses problemas, foram realizados estudos experimentais em cevada da cultivar Baisheshek, tratada com uma mistura de íon-ozônio com e sem o uso de pressão excessiva (cavitação). O delineamento fatorial completo calculado das experiências dos 2^3 (8 experimentos) e 2^4 (16 experimentos) possibilitou a obtenção de equações de regressão descrevendo a alteração nas propriedades semente, físicos bioquímicos e fisiológicas da cevada de Baisheshek. A solução de um modelo abrangente de otimização de programação para diferentes indicadores de cevada permitiu estabelecer ótimos modos de processamento tecnológico e níveis alcançáveis de qualidades tecnológicas de grãos. O efeito da tecnologia proposta para o tratamento de íons ozônio e cavitação íon ozônio foi a mistura do íon ozônio, que produz a desodorização, desinfecção de grãos, de acordo com processos físicos e químicos, aumenta o valor biológico, acelera os processos de metabolismo de grãos. Os estudos realizados para melhorar a germinação, viabilidade e força de crescimento mostram uma imagem bastante clara em termos de seu valor final. Observações fenológicas mostraram que os efeitos do tratamento com cavitação íon ozônio e cavidade íon ozônio são desencadeados após 25 a 30 dias. Verificou-se que a maior tendência à superioridade é observada no tratamento da cavitação íon ozônio, seguido pelo íon ozônio, e a amostra de controle está significativamente atrás.

Palavras-chave: *cevada, variedade, de tratamento, de íon-ozônio, cavitação.*

ABSTRACT

The article presents the results of an experimental study of Baisheshek barley grain treated with an ion-

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ozone mixture. This study aims to develop an innovative technology for processing barley with an ion-ozone mixture in order to increase their technological parameters, yield, quality, and grain safety. Kazakhstan has sharply increased the export of barley, and all agronomists, producers, and breeders are actively moving to the cultivation of this crop, while increasing production, productivity, improving product quality, reducing their losses and ensuring storage safety are an urgent task. Microorganisms play an important role during storage, they fall into crop production in a variety of ways, and if they fall into unfavorable storage conditions after harvesting, crop production quickly deteriorates, harmful substances such as toxins, mold, and others accumulate in it, which reduces the commodity value. To solve these problems, experimental studies were conducted on barley of the Baisheshek cultivar treated with an ion-ozone mixture with and without using excess pressure (cavitation). The calculated full-factorial design of experiments of the 2^3 (8 experiments) and 2^4 (16 experiments) degrees made it possible to obtain regression equations describing the change in the seed, physico-biochemical, and physiological properties of barley of the Baisheshek variety. The solution of a comprehensive model for optimizing programming for different barley indices made it possible to establish optimal technological processing modes and achievable levels of technological qualities of grain. The effect of the proposed technology for ion-ozone and ion-ozone cavitation treatment is the ion-ozone mixture, which produces deodorization, disinfection of grain, following chemical-physical processes, increases biological value, accelerates the processes of grain metabolism. Studies conducted to improve germination, viability, and growth strength show a reasonably clear picture in terms of their ultimate value. Phenological observations showed that the effects of ion-ozone and ion-ozone cavitation treatment is triggered after 25-30 days. It was found that the greatest tendency for superiority is observed with ion-ozone cavitation treatment, followed by ion-ozone, and the control sample is significantly behind.

Keywords: *barley, variety, treatment, ion-ozone, cavitation*.

АННОТАЦИЯ

В статье приведены результаты экспериментальных исследований зерна ячменя «Байшешек», обработанного ион-озонной смесью. Целью данного исследования является разработка инновационной технологии обработки ячменя с ион-озонной смесью с целью повышения их технологических показателей, урожайности, качества и обеспечения безопасности зерна. Казахстан резко нарастил экспорт ячменя и все агрономы, производители и селекционеры активно переходят к выращиванию этой культуры, при этом увеличение производства, урожайности, повышения качества продукции, сокращение их потерь и обеспечение безопасности при хранении являются актуальной задачей. При хранении большую роль играют микроорганизмы, в растениеводческую продукцию они попадают разнообразными путями и если они попадают после уборки урожая в неблагоприятные условия хранения, то растениеводческая продукция быстро портится, в ней накапливаются вредные вещества – токсины, плесень и другие, что снижает товарную ценность. Для решения данных проблем были проведены опытно-экспериментальные исследования ячменя сорта «Байшешек», обработанного ион-озонной смесью с и без исользования избыточного давления (кавитация). Рассчитанные полнофакторные планирования экспериментов 2^3 (8 опытов) и 2^4 (16 опытов) степени позволили получить уравнения регрессии, описывающие изменение семенных, физико-биохимических и физиологических свойств ячменя сорта «Байшешек». Решение комплексной модели оптимизации программирования по разным показателям ячменя позволило установить оптимальные технологические режимы обработки и достижимые уровни технологических качеств зерна. Эффектом предлагаемой технологии по ион-озонной и ион-озон-кавитационной обработке является ион-озонная смесь, которая производит дезодорацию, дезинфекцию зерна, в соответствии с квантовофизическими процессами, повышает биологическую ценность, ускоряет процессы метаболизма зерна. Проведенные исследования, направленные на повышения всхожести, жизнеспособности и силы роста показывают достаточно четкую картину в смысле их окончательной ценности. Фенологические наблюдения показали, что эффекты от ион-озонной и ион-озонной кавитационной обработки срабатывает через 25-30 дней. Были установлены, что наибольшая тенденция превосходства наблюдается при ион-озонной кавитационной обработке, затем следует ион-озонная, а контрольный образец существенно отстает.

Ключевые слова: *ячмень, сорт, обработка, ион-озон, кавитация*.

1. INTRODUCTION

Carriers of electricity in liquids are called ions: cations (positive ions, that are atomic ions) and anions (negative ions, that are molecular ions). Studying the effect on animals and vegetation of animals only atomic and only molecular ions obtained artificially immediately revealed a remarkable difference in the biological effect of ions: molecular air ions turned out to be a biologically beneficial factor, atomic air ions most often had an adverse or even harmful effect on the body. After it was firmly established in many experiments that molecular ions have a beneficial effect on the viability of animals and plants, increasing their growth and weight, protecting against several diseases, contributing to the conservation and proceeding from some theoretical facts, it was found that the carrier of negative charges polarity in atmospheric air is the oxygen of this air (Maemerov *et al.*, 2006; Urazaliev, 2012; Sagitov *et al.*, 2012).

Grains infected with pathogenic microorganisms are often the cause of mass human diseases and the death of birds and animals, and products prepared from them quickly deteriorate, harmful substances (toxins) accumulate, which reduces nutritional value. Of particular danger are mold fungi, which cause the accumulation of toxins in the finished product. The most dangerous is the complex toxin is aflatoxin, which affects both individual organs and entire body systems. Thus, microorganisms not only lead to the development of infection, but also to toxicosis, which causes great harm to humans, animals, and birds – inhibits growth and development, with severe bactericidal pollution lead to death (Naleev, 1993; Malin, 2005; Tikhonov *et al.*, 2006; Voblikov *et al.*, 2001).

The solution to this problem is ozone technology. The practical application of ozone technology was carried out in the research laboratory of food and processing industries of the Almaty Technological University, which allows cleaning grain, disinfection, increasing yields up to 20%, acquiring good sowing qualities with hereditary transmission to their offspring (Kokhmetova *et al.*, 2014; Maemerov, 2004).

In post-harvest processing, get refined crop products, improve the baking qualities of wheat. By combining the electrical circuits of the ionizer and ozonator installation, an ion-ozonator installation is developed that neutralizes all harmful synthesized impurities. As a result, a pure ion-ozone mixture without harmful side impurities is obtained. The oxides of nitrogen and carbon, together with other harmful impurities and radiation during the synthesis of the ion-ozone mixture in the ion-ozonator installation, are neutralized.

The technology of ion-ozone cavitation treatment of seeds of sowing grain materials is environmentally safe and does not use chemicals and types of radiation harmful to humans, animals, and the environment.

The use of a cavitation installation before sowing almost destroys insect pests, eliminates the need for pesticides, eliminates plant diseases, activates plant growth forces and eliminates the lack of nitrogen and water in plant leaves, which will significantly reduce chemical and soil pollution pesticides and reduce the use of mineral fertilizers (Erkmen, 2001; Akulichev, 1978; Pirsol, 1975; Ivanov, 1980; Maemerov *et al.*, 2011).

Structural and functional changes in the membrane formations of cells and intracellular organelles, which in our understanding are targets of ion-ozone cavitation, are the basis for increasing the biological value of the processed seed and food grains and obtaining the effect.

As a result of this interaction, a physicochemical basis is created for changing metabolic processes associated with proton and electron transfers in cell membranes. On this basis, successive nonspecific reactions of the cell and the organism as a whole arise. Differences exist only in the biophysical subtleties of the interaction of ion-ozone cavitation and biological tissues (Sereev, 2014; Baymagambetova *et al.*, 2014; Kim *et al.*, 2003).

The technical solution to the problem is achieved by the simultaneous processing of the moistened grain with an ion-ozone mixture in the cavitation zone with an overpressure of 2.0-6.0 ati in the moistened grain processing tank with a grain processing exposure of 5.0 to 20.0 minutes, with an ozone concentration of 2.0 to 6.0 mg/m^3, molecular ions from 1000 to 5000 m^3. After the processing time has elapsed in the tank for ion-ozone processing of moistened grain, a sharp discharge of excess pressure to atmospheric pressure occurs (Iztaev *et al.*, 2013; Iztayev *et al.*, 2018c).

Ion-ozone treatment of moistened grain in the cavitation field is carried out at an ozone concentration of 2 mg/m^3 to 6 mg/m^3 and from 1000 units/cm^3 to 50,000 units/cm^3 of molecular oxygen ions, depending on:

- increase the biological value (2,0–10,0 mg/m^3);
- destruction of harmful microorganisms and grain pests, grain disinfection, and rodent disinfection (20,0–80,0 mg/m^3) (Iztaev *et al.*, 2018a).

At the post-harvest stage, to obtain purified grain mass from pests improved the technological qualities of grain crops. From year to year, environmental requirements are violated, and in this regard, special attention is being paid to the food safety of foodstuffs consumed by the population. In meeting the requirements of environmental friendliness and safety of the production of products from seed preparation, in the processes of cultivation, harvesting, transportation, primary processing at grain enterprises, storage, and further processing, the production of flour, cereals, animal feed, bread, pasta, flour and confectionery products and other food products first of all pay attention to the original quality of crops used for this chain (Urazaliev *et al.*, 2010; Knapp *et al.*, 1974).

In this regard, special experimental studies have been carried out to identify the environmental friendliness and food safety of ion-ozone and ion-ozone cavitation technology, processing by electro-ion-charged particles of the air-flow during the cultivation of grain crops.

To improve the seed, yield and technological qualities of grain during short-term and long-term storage, ion-ozone flow processing of grain products in a stream of electrically charged particles is effective, which makes it possible to use the potential of biological and environmental resources.

In order to increase the efficiency of the use of crop products, scientists of the Almaty Technological University have developed various electrophysical methods for processing, storage, and processing of crop products: ion-ozone, ion-ozone cavitation processing of crop products, which contribute to improving the quality and preservation of grain.

The controlled effect on the biological environment of the ion-ozone mixture using ion-ozone cavitation allows for intensive bubbling of biological products of crop production with activation and stimulation, as well as inhibiting viruses, bacteria, spore formations with a delay in the flow of physiological and physicochemical processes in them, with suppression their infectious activity (Tursunbayeva *et al.*, 2019; Iztayev *et al.*, 2018b; Yakiyayeva *et al.*, 2016).

2. MATERIALS AND METHODS

The object of the study is the pre-sowing ion-ozone, ion-ozone cavitation treatment of the pre-sowing material, as well as the treatment of sprouts of crop products in the field in the zone of charged particles of molecular and atomic ions. As an object of research, plots of Baisheshek barley varieties were prepared for the treatment of green plants in the full earing phase.

The following regulatory documents were used in this work: GOST 10845-98. Grain and products of its processing. Method for the determination of starch; GOST 10846-91. Grain and products of its processing. Method for determination of protein; GOST 12041-82. Seeds of crops. Method for determination of moisture content; GOST 12042-80 Seeds of crops. Methods for determining the mass of 1000 seeds; GOST 10968-88. Grain. Methods for determining germination energy and germination capacity; ST RK GOST R 51411-2006 Grain and products of its processing. Method for the determination of ash.

Such indicators as the energy of germination and germinability belong to seed characteristics. As seed germinability, there is understood the quantity of normally germinated seeds in the test, taken for the analysis, evaluated as a percentage. The energy of the germination of seeds characterizes an aggregate of the appearance of normal germinants for the term fixed for each culture.

The seeds are couched in the germinators or Petri dishes, placed in the thermostat with a specified temperature condition. As a ground litter (bed), use quartz sand or filter paper. Quartz sand for decontamination has to be well washed and calcined, and filter paper must be sterilized in an exsiccator at a temperature of 130°C within 1 hour. The ground litter is damped before the seed sprouting: quartz sand - to 60% of the full moisture and filter paper and gauze - completely, allowing draining of excess water.

If the seeds are couched on filter paper, then they are arranged in rows at a distance of not less than 0,5-1,5 cm from each other over the ground litter, which is placed on the bottom of the germinator in 2-3 layers. The germinators are closed by the glass plates and are placed in the thermostat. On each of them, there is stuck down a label with the indication of the sample number and test, date of seed laying, and dates of determination of germinability and energy of germination. The majority of grain crops and leguminous plants are couched at a constant temperature of 20 °C. It is necessary to check constantly moistening of the ground litter, without allowing its drying.

The sprouted seeds are counted in two terms: in 3-5 days for determination of the energy of germination and in 7-10 days for determination of germinability. Both indicators are expressed as a percentage of the sprouted seeds to their total in the test. Sprouted seeds are considered those at which the rootlets or one main rootlet have a length not less than the length of a seed, and a sprout is not less than half of the length of the seed. Average values of germinability and energy of germination of seeds are considered reliable if deviations are expressed in all four tests within ±2% at average germinability from 98 to 100%; ±3% – at 95-97,9%, ±4% – at 90-94, 9% and ±5 – at 85-89,9%. Otherwise, average values are fixed by the three tests if deviations in them don't exceed admissibly; or the analysis is repeated again if admissible values have only two tests (Odjo *et al.*, 2018; Morales-de la Peña *et al.*, 2019; Naumenko *et al.*, 2018; Singh *et al.*, 2015).

In experimental studies, two methods of processing crops were studied:

– ion-ozone treatment of cereals;

– ion-ozone cavitation treatment of cereals.

Carriers of electricity in liquids are called ions: cations (positive ions, that are atomic ions) and anions (negative ions, that are molecular ions). Ions of air allowed to solve a number of mysteries of atmospheric electricity (thunderstorms, lightnings, electrical conductivity of gases, and others).

Molecular ions differ from atomic ions in greater mobility, greater diffusion coefficient, "greater ionizing force". It has been established that molecular ions arise in the air due to oxygen molecules, and atomic ions due to nitrogen and carbon dioxide molecules.

By combining the electrical circuits of the ionizer and ozonator installation, an ion-ozonator installation has been developed that neutralizes all harmful synthesized impurities, as a result, a pure ion-ozone mixture is obtained without harmful impurities. Oxides of nitrogen and carbon, together with other harmful impurities and radiation during the synthesis of the ion-ozone mixture in the ion-ozonator installation, are neutralized.

When the corresponding voltage of the electric current is applied to the electrodes of the ion-ozonizer, an ion-ozone mixture is formed, in accordance with Figure 1, namely, in the ozone generator, the primary processes of ozone formation from air proceed depending on the amount of applied energy. In accordance with the energy potential, the electrons in the ionization volume in the electric field of the ozone generator accelerate, ionizing the gas, creating an avalanche of new electrons. In this case, the emission of electrons from the cathode to the anode is formed by positive ions, subsequently rushing towards the cathode, also ionizing neutral atoms and molecules, forming negative ions. Upon collision with the cathode, ions knock electrons out of it, which, falling into the volume, again cause ionization.

Excitation of an oxygen molecule occurs at an electron energy of 6.1 eV and all free electrons are captured by oxygen molecules, as a result of electron energy of 12.2 eV, molecular ions are formed and, with an increase in energy within 19.2 eV, dissociation occurs in oxygen and with the participation of the atom and molecular ions, when the molecule is excited, ozone formation occurs (Figure 2).

Along with this, oxygen, molecular and atomic ions, nitrogen and carbon oxides, atomic oxygen, atomic ozone, and others are formed. With the appropriate energy, the formation of ions, electrons, and molecules is associated with their collision with other particles (electrons, atoms, ions). In this case, the formation of positive ions and free electrons from atoms or molecules with an appropriate degree of ionization accompany the origin of impact ionization. The probability of the occurrence of impact ionization is characterized by an effective ionization cross-section and depends on the kind of ionizable and bombarding particles, depending on the kinetic energy with a certain minimum (threshold) value. This minimum value is probably equal to zero, and, with an increase in energy above the threshold, it first rapidly increases, reaches a maximum, and then, with corresponding energy potentials, decreases (Iztayev *et al.*, 2018d; Kalinina *et al.*, 2016).

The energy that needs to be reported to an atom (molecule) for its ionization is called the ionization energy. If the energy transferred to ionized particles in collisions is large enough, then under certain conditions, a particle can ionize in collisions. In this case, only part of the energy necessary for ionization is transferred to it, and first, the atoms (molecules) in the primary collisions are transferred to the excited state, after which shock ionization occurs, and it is enough to tell the missing energy (equal to the difference between the ionization energy and the excitation energy), multistage ionization occurs. It is possible if collisions occur so often that the particle in the interval between two collisions does not have time to lose the energy received in the first of them. And also, in the same cases when the particle has metastable states, and with the ability to conserve the excitation energy relatively long, multiple ionization occurs.

The processes associated with impact, multistage, and multiple ionization play an important role in the synthesis of ozone, which occurs in a strong electric field of an ion-ozonator generator. As a result, in such a field, the electrons in the conduction band acquire kinetic energy greater than the bandgap, and electrons are knocked out of the valence band of the molecules with the transformation of the energy of other molecules. At a certain critical field strength, impact, multistage, and multiple ionization leads to a sharp increase in current density, to an increase in ozone concentration, and in the absence of regulation of the energy potential, with repeated ionization, the electrical breakdown is possible.

The ability to transform the energy of nitrogen and carbon into an increase in ozone concentration shows that with an increase in the voltage of the electric current in the ozone generator from 0.5 to 3.0 kV, the rate of ozone formation is higher than after impact ionization. The intensity of ozone formation increases, apparently due to the transformation of the energy of nitrogen and carbon, since the degree of oxygen ionization is 13.618 eV, nitrogen - 14.53 eV, and the degree of carbon ionization - 11.26 eV. When the corresponding energy is supplied during the ionization period, the nitrogen and carbon atoms are able to attract electrons. Namely, the nitrogen atom attracts one electron into the outer orbit, the carbon atom two electrons. As a result, six electrons are obtained in the outer orbit of the nitrogen and carbon atoms, which corresponds to the number of oxygen electrons. Nitrogen and carbon atoms, transforming into oxygen, contribute to the synthesis of ozone.

At the same time, an ion generator having an electric charge of negative polarity produces molecular ions and attracts atomic ions, nitrogen, and carbon oxides having an electric charge of positive polarity, knocking out oxygen not only from the ozone synthesized by it but also from the environment. The synthesized ozone, oxygen, molecular ions, having a negative polarity, slip through an ozone generator having a negative polarity of the electric current and, interacting with each other, form oxygen, and then ozone. Molecular ions, combining with a neutral atom, form a stable molecular ion, and with further connection with the electron 9, form a heavy molecular ion 10. Positive ion 11 and other positively charged particles from the environment rush to the ion generator, where they are neutralized. Further, ozone enters into a chemical reaction with biological substances or, as an unstable gas, decomposes into oxygen, which subsequently forms other compounds. With a positive polarity of the ion generator 6, we obtain the components of the positive sign ion-ozone technology, that is, atomic ozone, atomic oxygen and atomic ions, nitrogen and carbon oxides harmful to all living things.

Ion-ozone cavitation occurs as a result of a local critical increase in excess pressure above 4 ati and a sharp release of excess pressure to the atmospheric environment during product processing. And they can also occur either with an increase in its velocity or with the creation of a sharp drop in excess pressure during the half-cycle of rarefaction (acoustic ion-ozone cavitation), there are other reasons for the effect. Moving with the flow to a region with a higher overpressure or during the half-compression period, the cavitation bubble filled with the ion-ozone mixture slams, emitting a shock wave with an ozone explosion, which facilitates the interaction of the ion-ozone mixture with the processed product. At the same time, bubbling, instant destruction of microorganisms, pests of products of biological origin, on the basis of quantum-physical processes in comparison with similar technologies occurs intensively, the biological value of the product increases more, resistance to external irritants is acquired, and the time of the positive effect of ion-ozone interaction on the processed product is reduced.

Usually, this is achieved due to a critical overpressure of 4 ati or more with a sharp release of excess pressure to atmospheric pressure, the design of hydroturbines, or by passing an ion-ozone mixture through a ring-shaped opening that has a narrow inlet and a significantly larger outlet: a forced decrease in pressure leads to ion-ozone cavitation since the ion-ozone mixture tends to the side of a larger volume (with increasing pressure, ozone acquires potential energy to explode). This method can be controlled by devices that control the size of the inlet, which allows you to adjust the process in various environments. The outer side of the mixing valves, along which the ion-ozone-cavitation bubbles move in the opposite direction to cause implosion (internal explosion), is subjected to tremendous pressure and is often made of heavy-duty or rigid materials, for example, stainless steel, stellite. This device is called the ion-ozone cavitation installation (Kalinina *et al*., 2018; Zhakatayeva *et al*., 2020; Zapevalov *et al*., 2015).

Grain processing was carried out on an experimental ion-ozone cavitation installation, consisting of an ion-ozonator generator 1 and a cavitation capacity 2 (Figure 3).

During ion-ozone treatment, crops are loaded into an ion-ozone cavitation unit pre-filled with an ion-ozone mixture with an ozone concentration of 0.5 mg/dm^3 to 4 mg/dm^3 (or from $0.5 \cdot 10^{-3}$ to $4 \cdot 10^{-3}$ mg/cm^3) and molecular ions ranging from 500 to 60,000 units/cm^3. In this case, the ratio of ion concentration (units/cm^3) to ozone concentration (mg/cm^3) $C_{i/o}$ is $(1\text{-}15) \cdot 10^{-6}$ units/mg, that is 1-15 million units/mg. Then for 10 to 20 minutes produce ion-ozone ventilation of crops.

In the case of ion-ozone cavitation treatment of grain after ventilation, the cavitation installation is hermetically closed, and the ion-ozone mixture is pumped into the tank until an overpressure of 2 to 4 ati is created, after which the overpressure is sharply discharged, while the ozone tends to explode. In this case, a sharp discharge of excess pressure and the power of an ozone explosion adds up. During the explosion, cavitation processes occur, in which the pores of the treated cultures increase, the ion-ozone mixture penetrates more efficiently. At the same time, ozone destroys harmful impurities, and harmful insects, molecular oxygen ions based on quantum-physical processes increase the biological value of the product.

The following factors were selected as factors affecting the properties and quality indicators of the treated crops:

– ratio of ion concentration (units/cm^3) to ozone concentration (mg/cm^3) $C_{i/o}$, units/mg;
– overpressure (for cavitation treatment) *P*, ati;
– sample moisture before processing *w*, %;
– processing time t_1, min.

In the experiments for all the studied crops, the following quality indicators were determined:

y_1 – germination energy, %;
y_2 – germination in 5 days, %;
y_3 – germination in 7 days, %;
y_4 – humidity after processing, %;
y_5 – nature, g/l;
y_6 – grain density, g/cm^3;
y_7 – weight of 1000 grains, g;
y_8 – protein, %.
y_9 – starch, %;
y_{10} – greenery index, ml.

The same quality indicators were also determined for control (untreated) grain samples.

To optimize the processing regimes of grain crops, the following indicators were selected as target functions:

– for seed properties – germination energy (y_1);

– for physical properties – density (y_6);

– for biochemical properties – protein (y_8);

The rest of the above grain quality indicators were considered as limitations.

3. RESULTS AND DISCUSSION

Given the relatively large number of factors, in order to reduce the number of experiments and obtain reliable results in the studies, methods for planning multi-factor experiments were used, in particular, the use of plans for full factor experiments (FFE) of the FFE-2^3 type (for ion-ozone treatment) and FFE-2^4 (for ion-ozone cavitation treatment).

Based on the least-squares studies of the developed algorithms and sequential regression analysis programs (Ostapchuk *et al*., 1992; Ostapchuk, 2007), regression equations were obtained that adequately (according to the Fisher's Criterion) describe the dependences of the above quality indicators of processed crops, respectively, on conditions and modes of their ion-ozone (IO) and ion-ozone cavitation treatment (IOC).

The concentration of ozone in the ion-ozone mixture is from 2.0 to 6.0 g/m^3, molecular ions from 1000 to 50,000 units/cm^3. Exposure time from 5 to 20 min, which is determined to a greater extent by the quality and infection of the grain.

The optimal regimes of ion-ozone processing of seed and food grains identified during experimental studies are of practical value, which made it possible to develop, with a refinement in the engineering calculation of the plant parameters, and to create a laboratory-controlled ion-ozone mixture for processing seed and food grains.

Quality indicators of control (unprocessed) cereal crops are given in Tables 1. The matrices for planning experiments with the experimental conditions and the results of determining the quality indicators of the treated crops are given in Tables 2 and 3.

here:
$C_{i/o}$ – ratio of ion concentration (units/cm^3) to ozone concentration (mg/cm^3), units/mg;
P – overpressure (for cavitation treatment), ati;
w – sample moisture before processing, %;
t_1 – processing time, min.
y_1 – germination energy, %;
y_2 – germination in 5 days, %;
y_3 – germination in 7 days, %;
y_4 – humidity after processing, %;
y_5 – nature, g/l;
y_6 – grain density, g/cm^3;
y_7 – weight of 1000 grains, g;
y_8 – protein, %.
y_9 – starch, %;
y_{10} – greenery index, ml.

The regression equations obtained based on processing the results of the experiments are given below in the corresponding mathematical models used in optimizing the processing regimes of the cultures studied. All the equations obtained adequately describe the experimental data.

From the data in Tables 1 to 3, it can be seen that during processing, the preparation of seeds of barley of the Baisheshek variety requires bioenergetic activation due to ion-ozone and ion-ozone cavitation treatment. As a result, the germ cells of these cultures pass from the deceased to an active state, and the seed germination energy is manifested rapidly.

With ion-ozone and ion-ozone cavitation treatment of seeds of grain crops, the energy of germination and germination of seeds is significantly increased. It accelerates their germination, increases the productivity of agricultural plants, and the technological quality of food products by 25-30 %. After ion-ozone cavitation treatment of barley seeds, the biological and nutritional value of processed grain seeds increases more intensively due to increased accumulation of proteins, sugars, organic acids, vitamins, and macronutrients in them.

Ion-ozone treatment of the dry and wet state of seeds of grain crops helps to maintain stability during the storage of barley varieties without increasing acidity and respiratory rate. Ion-ozone cavitation treatment of the dry and wet state of grain seeds allows creating more favorable conditions for the storage of barley varieties compared to ion-ozone treatment.

Data processing and calculations were carried out using the algorithm developed by the Odessa National Academy of Food Technologies and the sequential regression analysis program PLAN. The program first gives the values of all the regression coefficients and their confidence intervals (errors), then checks the significance of the regression coefficients and, after removing all the insignificant coefficients, the remaining significant coefficients and their confidence errors are printed.

Mathematical models of ion-ozone seed treatment of grain crops are shown in table 4.

here:
y_{ger} – germination, %;
x_2 – overpressure, ati;
sy, sag – Root mean square deviation;
Fr, Fcr – Fisher's Criterion;
t_{cr} – Student Criterian.

Restrictions on the range of variation in the regime parameters of ion-ozone treatment of all the investigated cereal crops were as follows:

1 mln. unit/mg $\leq C_{i/o} \leq$ 15 mln.unit/mg

13 % $\leq w \leq$ 20 %; 10 min$\leq t_1 \leq$ 20 min

The mathematical model for optimizing the modes of ion-ozone treatment of barley of the variety Baisheshek has this form:

Seed properties:

– objective function:

$80 \leq y_1 = 132{,}50 - 2{,}50 \cdot w - 2{,}32 \cdot t + 0{,}129 \cdot w \cdot t$, % $\leq 100 \rightarrow$ *max* (Eq. 1)

– restrictions on quality indicators:

$85 \leq y_2 = 119{,}89 + 1{,}61 \cdot w$, % ≤ 100 (Eq. 2)

$85 \leq y_3 = 117{,}57 - 1{,}43 \cdot w$, % ≤ 100 (Eq. 3)

Physical properties:

– objective function

$1,0 \leq y_6 = 1,105$, g/cm^3 $\leq 1,2 \rightarrow max$ (Eq. 4)

– restrictions on quality indicators:

$12,0 \leq y_4 = 4,47 + 0,634 \cdot w$, % $\leq 22,0$ (Eq. 5)

$600 \leq y_5 = (62,86) \cdot 10$ g/l ≤ 650 (Eq. 6)

$45,0 \leq y_7 = 16,55 + 1,59 \cdot C_{i/o} + 2,23 \cdot w - 0,0867 \cdot C_{i/o} \cdot w$, g $\leq 65,0$ (Eq. 7)

Biochemical properties:

– objective function

$5,5 \leq y_8 = 12,04 - 0,174 \cdot w$, % $\leq 10,0 \rightarrow max$; (Eq. 8)

– restrictions on quality indicators:

$56,0 \leq y_9 = 62,67$, % $\leq 75,0$ (Eq. 9)

$28,0 \leq y_{10} = 33,01$, % $\leq 35,0$ (Eq. 10)

here:

$C_{i/o}$ – ratio of ion concentration (units/cm^3) to ozone concentration (mg/cm^3), units/mg;
P – overpressure (for cavitation treatment), ati;
w – sample moisture before processing, %;
t_1 – processing time, min.
y_1 – germination energy, %;
y_2 – germination in 5 days, %;
y_3 – germination in 7 days, %;
y_4 – humidity after processing, %;
y_5 – nature, g/l;
y_6 – grain density, g/cm^3;
y_7 – weight of 1000 grains, g;
y_8 – protein, %.
y_9 – starch, %;
y_{10} – greenery index, ml.

The nature of the dependence of the energy of barley germination Baisheshek on the factors w and t is shown in Figure 4. The remaining dependencies of objective functions on the investigated factors, as follows from mathematical models, do not need graphical representation.

Using ion-ozone processing (IO), mathematical models were obtained for optimizing the technological regimes and quality indicators of barley of the Baisheshek variety. The results are shown in Table 5.

here:
$C_{i/o}$ – ratio of ion concentration (units/cm^3) to ozone concentration (mg/cm^3), units/mg;
w – sample moisture before processing, %;
t_1 – processing time, min.
y_1 – germination energy, %;
y_2 – germination in 5 days, %;
y_3 – germination in 7 days, %;
y_4 – humidity after processing, %;
y_5 – nature, g/l;
y_6 – grain density, g/cm^3;
y_7 – weight of 1000 grains, g;
y_8 – protein, %.
y_9 – starch, %;
y_{10} – greenery index, ml.

The data in Table 5 indicates that there is no need for the nature of the dependence of the germination energy of Baisheshek barley on the factors w and τ and the rest of the dependence of the objective functions on the factors studied.

Restrictions on the range of variation in the regime parameters of ion-ozone cavitation treatment of all the investigated cereal crops were as follows:

1 mln. unit./mg $\leq C_{i/o} \leq$ 15 mln. unit./mg

1 ati $\leq P \leq$ 4 ati

13 % $\leq w \leq$ 20 %

10 min $\leq t \leq$ 20 min

Taking into account the acceptable ranges of changes in the investigated factors ($C_{i/o}$, P, w, and t), mathematical models for optimization of ion-ozone cavitation processing of grain are presented below.

The mathematical model for optimizing the modes of ion-ozon cavitation processing of barley of the variety Baisheshek has this form:

Seed properties:

– objective function

$84 \leq y_1 = 113,95 - 0,929 \cdot w - 0,275 \cdot t$, % $\leq 100 \rightarrow max$ (Eq. 11)

– restrictions on quality indicators:

$86 \leq y_2 = 113,48 - 0,893 \cdot w - 0,200 \cdot t$, % ≤ 100 (Eq. 12)

$88 \leq y_3 = 98,25 + 0,769 \cdot t - 0,0557 \cdot w \cdot t$, % ≤ 100 (Eq. 13)

Physical properties:

– objective function

$1,0 \leq y_6 = 1,11$, g/cm^3 $\leq 1,14 \rightarrow$ *max* (Eq. 14)

– restrictions on quality indicators:

$12,0 \leq y_4 = 4,14 + 0,660 \cdot w$, % $\leq 18,0$ (Eq. 15)

$600 \leq y_5 = 627,3$, g/l ≤ 650 (Eq. 16)

$47,0 \leq y_7 = 35,68 + 1,05 \cdot w$, g $\leq 62,0$ (Eq. 17)

Biochemical properties:

– objective function

$7,0 \leq y_8 = 11,59 - 0,167 \cdot w$, % $\leq 11,0 \rightarrow$ *max* (Eq. 18)

– restrictions on quality indicators:

$55,0 \leq y_9 = 62,49$, % $\leq 67,0$ (Eq. 19)

$28 \leq y_{10} = 33,78 - 0,121 \cdot C_{i/o} + 0,127 \cdot t + 0,0434 \cdot C_{i/o} \cdot P - 0,0321 \cdot P \cdot t$, % ≤ 38 (Eq. 20)

From the mathematical models, it can be seen that all the objective functions of barley have a simple character - the germination energy depends only on two factors (grain moisture and processing time), the density of barley grain does not change statistically (constant), and the mass fraction of the birch depends only on the moisture content of the grain. Therefore, the graphical dependence is presented only for the germination energy (Figure 5). It is seen that it inversely decreases with increasing barley moisture and the duration of its treatment.

The optimal modes and quality indicators of the grain of barley Baisheshek after ion-ozone cavitation treatment are shown in table 6.

here:
$C_{i/o}$ – ratio of ion concentration (units/cm^3) to ozone concentration (mg/cm^3), units/mg;
P – overpressure (for cavitation treatment), ati;
w – sample moisture before processing, %;
t_1 – processing time, min.
y_1 – germination energy, %;
y_2 – germination in 5 days, %;
y_3 – germination in 7 days, %;
y_4 – humidity after processing, %;
y_5 – nature, g/l;
y_6 – grain density, g/cm^3;
y_7 – weight of 1000 grains, g;
y_8 – protein, %.
y_9 – starch, %;
y_{10} – greenery index, ml.

Table 6 indicates that in order to improve the seed and biochemical properties of Baisheshek barley, ion-ozone cavitation treatment should be carried out at $C_{i/o}$ = 1 million units/mg, P = 1 ati, W = 13% and t = 10 min. With the same values of $C_{i/o}$, P, t, physical properties will also improve, but grain processing should be carried out at grain moisture of 20 %.

To compare the quality of control (unprocessed) samples of the studied cultures and the optimal parameters obtained after their ion-ozone (IO) and ion-ozone cavitation (IOC) treatment.

Summary of the optimal indicators of the quality of barley after ion-ozone and ion-ozone cavitation treatment in comparison with control (unprocessed) samples are shown in Table 7.

here:
y_1 – germination energy, %;
y_2 – germination in 5 days, %;
y_3 – germination in 7 days, %;
y_4 – humidity after processing, %;
y_5 – nature, g/l;
y_6 – grain density, g/cm^3;
y_7 – weight of 1000 grains, g;
y_8 – protein, %.
y_9 – starch, %;
y_{10} – greenery index, ml.

Analysis of these tables showed that the optimum regimes of ion-ozone and ion-ozone cavitation treatment to improve the considered seed, physical, biochemical properties and the state of preservation of grain is the same, in the moisture content of the grain – optimal results were obtained when processing wet grain (20%). For seed, physical, biochemical, and state of preservation, the best results were obtained when processing dry grain (13%).

The full-factor planning of experiments of 2^3 and 2^4 degrees made it possible to obtain regression equations describing the change in the seed, physico-biochemical and physiological properties of grain crops from the influencing factors of ion-ozone and ion-ozone cavitation processing of grain and to identify priority grain indicators for constructing a linear and non-linear programming model with the indication of target and restrictive functions.

Integrated programming optimization models for individual varieties of grain crops made it possible to establish optimal technological processing modes (IO and IOC) and increase achievable levels of seed, physico-biochemical, flour, baking, physiological properties, and their technological qualities for the intended purpose.

Thus, mathematical models have been calculated and developed that describe changes in the seed and technological properties of grain seeds during ion-ozone and ion-ozone cavitation preparation of grain seeds, which subsequently allow optimizing processing conditions. As a result, regression models were obtained based on 2^3 and 2^4 full-factor experts for the Baisheshek barley variety.

Photographs were taken of growing Baisheshek barley under experimental conditions. When growing crops, the treatment with electrically charged air particles was carried out in two versions: open and closed in the form of greenhouses during treatment with air ions with a duration of 25 minutes, and the results are shown in Figures 6-8.

The physical and biochemical studies aimed at increasing germination, vitality, and growth strength show a reasonably clear picture in terms of their final value. Phenological observations have shown that the effects of ion-ozone and ion-ozone cavitation treatment are triggered after 25-30 days, where the greatest tendency of the superiority of ion-ozone cavitation treatment is observed, ion-ozone follows, and the control, of course, significantly lags.

4. CONCLUSIONS

Determining the strength of seed growth provides higher objectivity in assessing seeds by their ability to germinate and form seedlings. Along with a high growth force, seeds during germination formed seedlings with four and five roots and seedlings with three roots predominated in those variants.

Studies of changes in the seed properties and technological qualities of grain crops using ion-ozone (IO) and ion-ozone cavitation (IOC) processing of cereals into full-factor experiments 2^3 (8 experiments) and 2^4 (16 experiments) allowed to create the basis for the development of regression models to describe the change indicators of seed properties and technological qualities and in the future for the rational organization of equipment and technology of IO and IOC processing.

Ion-ozone treatment of seeds for sowing barley varieties and further cultivation with the treatment of plants with a stream of electrically charged air particles generally increase their yield, seed, and technological properties. The obtained data of these properties during ion-ozone treatment are much better compared to the traditional version, while there is an improvement in physical and biochemical parameters, and the seeds become more stable during storage, providing an increase in their safety.

The obtained results of the above properties during ion-ozone cavitation treatment (IOC) become better compared to traditional and ion-ozone treatment (IO). Moreover, indicators characterizing the studied properties of grain varieties in terms of their physical and biochemical properties and state of conservation have high potentials for their effective use in the production of grain products and meeting the requirements for preparing export batches of grain crops.

The developed mathematical models describe changes in the seed and technological properties of grain seeds during ion-ozone and ion-ozone cavitation preparation of barley seeds, and they can be used to optimize processing conditions.

5. REFERENCES

1. Akulichev, V. A. (1978). *Cavitation in cryogenic and boiling liquids*. Moscow: Science, 280.
2. Baymagambetova, K. K., Nurpeisov, I. A., Gass, O. S., Sereda, G. A., Chudinov, V. A., Bekenova, L. V., and Bishimbaeva, N. K. (2014). *Ecological test of wheat precociolous lines obtained by biotechnology methods.* Plant biology and biotechnology international conference. Almaty, 93.
3. Erkmen, O. (2001). Uses of Ozone to Improve the Safety and Quality of Foods. *J. Gida Teknolojisi, 5 (3)*, 58–64.
4. GOST 10845-98. (2001). Grain and products of its processing. Method for the determination of starch. *M.: IPK Standards Publishing House*, 1-4.
5. GOST 10846-91. (2009). Grain and products of its processing. Method for determination of protein. M.*: Standartinform*, 1-8.

6. GOST 12041-82. (2011). Seeds of crops. Method for determination of moisture content. *M.: Standartinform*, 109-114.
7. GOST 12042-80. (2011). Seeds of crops. Methods for determining the mass of 1000 seeds. *M.: Standartinform*, 116-118.
8. GOST 10968-88. (2009). Grain. Methods for determining germination energy and germination capacity. *M.: Standartinform*, 1-3.
9. Iztaev, A. I., Kulajanov, T. K., Maemerov, M. M., Assangalieva, J. R. (2013). *Elektromagnetik ion-ozone grain processing*. Materials of International scientific and practical working Conference Pakistan Engineering Council at National University of Sciences Technology: 5-th World Engineering Congress (WEC-2013), Islamabad, 31.
10. Iztaev, A., Kulazhanov, T., Yakiyayeva, M., Maemerov, M., Iztaev, B., and Mamayeva, L. (2018a). The Efficiency of Ionocavitational Processing and Storage in the Nitrogen Medium of Oilseeds. *Journal of Advanced Research in Dynamical and Control Systems, 10 (7)*, 2032–2040.
11. Iztayev, A., Urazaliev, R., Yakiyayeva, M., Maemerov, M., Shaimerdenova, D., Iztayev, B., Toxanbayeva, B., and Dauletkeldi, Ye. (2018b). The investigation of the impact of dynamic deterioration of ozone on grass growth and the consequence of ion-ozone cavitation treatment. *Journal of Advanced Research in Dynamical and Control Systems, 10(13)*, 663-671.
12. Iztayev, A., Yakiyayeva, M., Maemerov, M., Iztayev, B., Urazaliev, R., Dauletkeldi, Y., Shaimerdenova, D., and Toxanbayeva, B. (2018c). Regress models of ion-ozon treatment without and with cavitation, describing changes of indicators for grain crops quality. *Acta Technica CSAV (Ceskoslovensk Akademie Ved), 63(1B)*, 1-8.
13. Iztayev, A., Yakiyayeva, M., Kulazhanov, T., Kizatova, M., Maemerov, M., Stankevych, G., Toxanbayeva, B., and Chakanova, Zh. (2018d). Controlling the implemented mathematical models of ion-ozon cavitation treatment for long-term storage of grain legune crops. *Journal of Advanced Research in Dynamical and Control Systems, 10(13)*, 672-680.
14. Ivanov, A. N. (1980). *Hydrodynamics of developed cavitation currents-55.* Leningrad: Shipbuilding, 237.
15. Kalinina, I. V., and Fatkullin, R. I. (2016). Application of the effects of ultrasonic cavitation effects as a factor in the intensification of the extraction of functional ingredients. *Vestnik SUSU. Series "Food and Biotechnology", 4(1),* 64–70.
16. Kalinina, I., Naumenko, N., and Fatkullin, R. (2018). *Perspectives of Using of Ultrasonic Cavitation in Water Treatment Technology for the Food Productions*. IOP Conference Series: Earth and Environmental Science, 272, 1–9.
17. Kim, J. G., Yousef, A. E., Khadre, M. A. (2003). Ozone and its Current and Future Application in the Food Industry. *J. Advances in Food and Nutrition Research, 45*, 167–218.
18. Knapp, R., Daily, J., and Hammit, F. (1974). *Cavitation*. Moscow: World, 678.
19. Kokhmetova, A., Sapakhova, Z., Yessimbekova, M., Yeleshev, R., and Morgounov, A. (2014). Principles and methods of selection of grain crops at the present stage. *J. Vestnik of Agricultural Science of Kazakhstan, Almaty, 1*, 3-19.
20. Maemerov, M. M. (2004). *Increase in the role of ozone as an environmentally friendly method for treating plant raw materials*. Materials of International Conference Strategy for the development of food and light industry, Almaty, 59–60.
21. Maemerov, M. M., Kulazhanov, K. S., and Iztaev, A. I. (2006). *Ion-ozone technology – the way to prosperity and well-being*. Materials of International Conference dedicated to the 70th anniversary of the National Engineering Academy of the Republic of Kazakhstan. J. Light and food industry, Almaty, 175-177.
22. Maemerov, M. M., Iztaev A. I., Kulazhanov, T. K., and Iskakova, G. K. (2011). *Scientific bases of ion-ozone technology of grain processing and products of its processing*. Almaty: LEM, 258.
23. Malin, N. I. (2005). *Grain storage technology*. Moscow: Kolos, 280.
24. Morales-de la Peña, M., Welti-Chanes, J., and Martín-Belloso, O. (2019). Novel technologies to improve food safety and quality. *Current Opinion in Food Science, 30*, 1–7.
25. Naleev, O. N. (1993). *Grain storage technology*. Almaty: RIK, 212.
26. Naumenko, N. V., Potoroko, I. Yu., Kretova, Yu. I., Kalinina, I. V., Paimulina, A. V., and Caturov, A. V. (2018). On the issue of intensification of the process of grain

germination. *Far Eastern Agrarian Bulletin, 4 (48)*, 109–115.
27. Odjo, S., Bera, F., Beckers, Y., Foucart, G., and Malumbad, P. (2018). Influence of variety, harvesting date and drying temperature on the composition and the in vitro digestibility of corn grain. *Journal of Cereal Science, 79*, 218–225.
28. Ostapchuk, M. V. (2007). *Mathematical modeling on the computer*. Odessa: Druk, 313.
29. Ostapchuk, N. V., Kaminsky, V. D., Stankevich, G. N., and Chuchuy, V. P. (1992). *Mathematical modeling of food production processes*. Kiev: Vishcha shola, 175.
30. Pirsol, I. (1975). *Cavitation*. Moscow: Mir, 96.
31. Sagitov, A. O., Dixanbaeva, F. T., and Asangalieva, J. R. (2012). *Environmental safety of the grain reserves protection system from pests*. Materials of V World International Congress of Engineering Technologies – Wcet-2012 "Science and technology is a step into the future", Almaty, 206-207.
32. Sereev, I. (2014). Effect of spring biomass removal on expression of agronomic traits of winter wheat. *World Applied Sciences Journal, 30 (3)*, 322-329.
33. Singh, A. K, Rehal, J., Kaur, A., and Jyot, G. (2015). Enhancement of attributes of cereals by germination and fermentation: a review. *Critical Reviews in Food Science and Nutrition, 55 (11)*, 1575–1589.
34. ST RK GOST R 51411-2006. (2007). Grain and products of its processing. Method for the determination of ash. *Nur-Sultan: KazInSt*, 1-6.
35. Tikhonov, N. I., and Belyakov, A. M. (2006). *Grain storage*. Volgograd: VolGU, 108.
36. Tursunbayeva, Sh. A., Iztayev, A., Magomedov, M., Yakiyayeva, M. A., and Muldabekova, B. Zh. (2019). Study of the quality of low-class wheat and bread obtained by the accelerated test method. *J. Periodico Tchê Quimica, 16(33)*, 809-822.
37. Urazaliev, R. A. (2012). *State, problems, mechanisms of development of innovative innovation in selection and seed farming of agricultural crops. Cultures*. Materials of International Conference State and Prospects of Seed Growing in Agricultural Crops. Cultures in Kazakhstan, Almalybak, 10-24.
38. Urazaliev, R. A., Absattarova, A. S., Roder, M. S., Kenjebaeva, S., and Morgounov, A. I. (2010). *Allelic diversity at XGWM261 locus in Kazakhstan bread wheat varieties*. Materials of 20-th International Triticeae Mapping Initiative, 2-nd Wheat Genomics in China conference. Beijing, 180.
39. Voblikov, E. M., Bukhancov, V. A., Maratov, B. K., and Prokopec, A. S. (2001). *Post-harvest processing and storage of grain*. Rostov-na-Donu: MarT, 229.
40. Yakiyayeva, M., Iztaev, A., Kizatova, M., Maemerov, M., Iztaeva, A., Feydengold, V., Tarabaev, B., and Chakanova, Zh. (2016). Influence of ionic, ozone ion-ozone cavitational treatment on safety of the leguminous plants and oil-bearing crops at the storage. *Journal of Engineering and Applied Sciences, 11(6)*, 1229-1234.
41. Zapevalov, M.V., Kovalenko, N.V., and Petrova, G.V. (2015). Post-harvest grain processing. *News of the Orenburg State Agrarian University, 3 (53)*, 80-83.
42. Zhakatayeva, A., Iztayev, A., Muldabekova, B., Yakiyayeva, M., and Hrivna, L. (2020). Scientific security assessment of safety risk of raw sugar products. *J. Periodico Tchê Quimica, 17(34)*, 352-368.

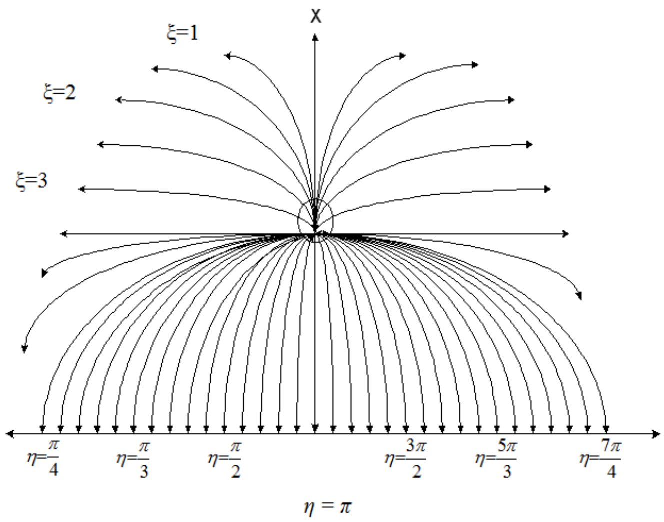

Figure 1. *Picture of the "wire - plane" field in a bipolar coordinate system*

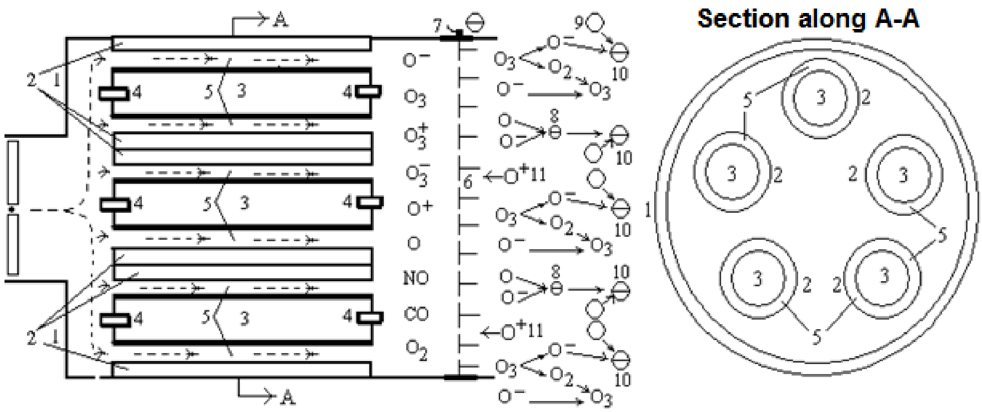

Figure 2. *The formation of the ion-ozone mixture, nitrogen oxides and carbon from the air in the ion-ozonator generator: 1 – the body of the ion-ozonator; 2 – metal electrodes of the ozone generator; 3 – glass electrodes; 4 – contacts of glass electrodes of an ozone generator; 5 – discharge gap; 6 – generator of oxygen ions; 7 – contact of the ion generator; 8 – stable molecular ion; 9 – a neutral atom; 10 – heavy molecular ion; 11 – a positive ion.*

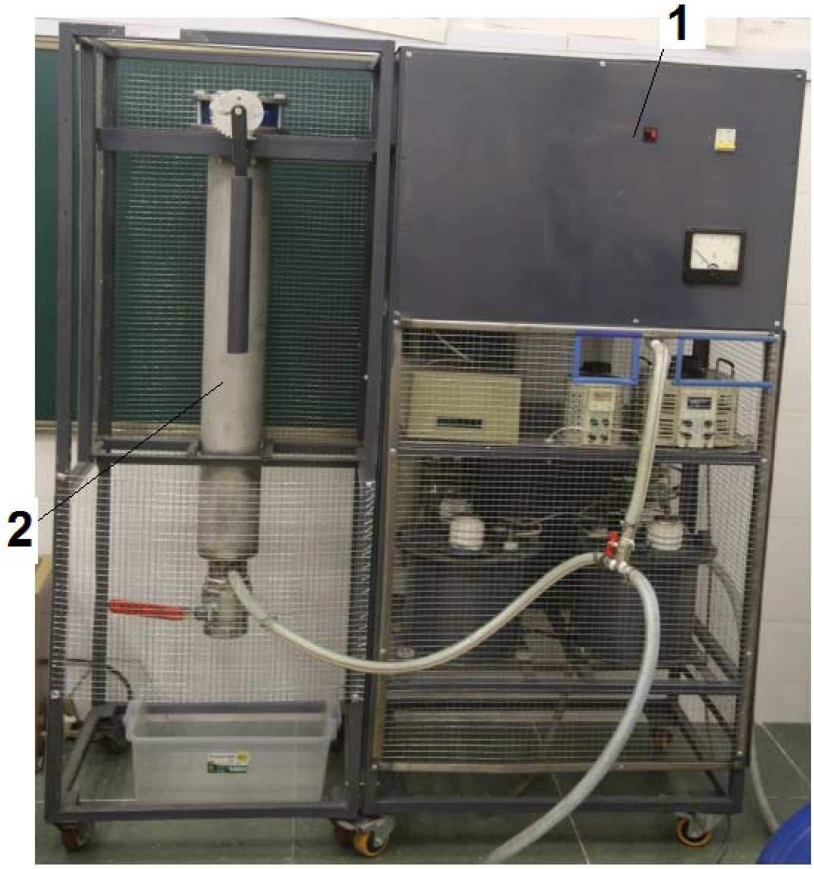

Figure 3. *Ion-ozone cavitation installation: 1 – ion-ozone generator; 2 – cavitation capacity*

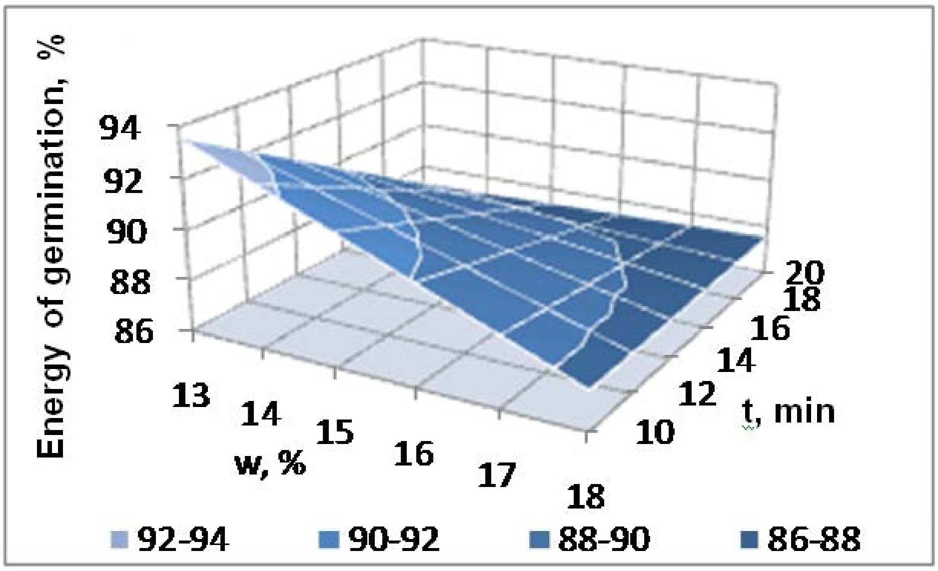

Figure 4. *Surfaces of the response of the dependence of the energy of barley germination "Baisheshek" treated with ion-ozone streams on the factors w and t*

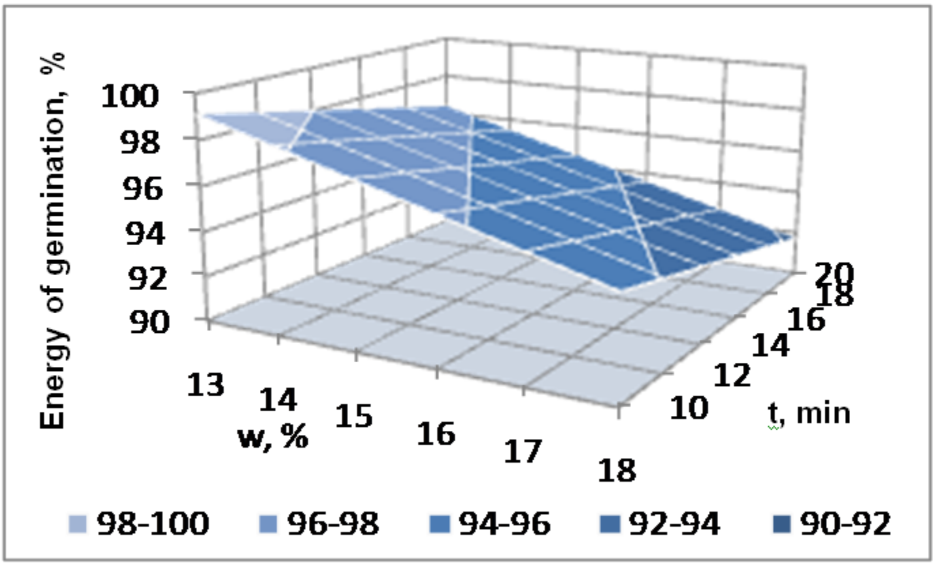

Figure 5. *Surfaces of the response of the dependence of the energy of barley germination Baisheshek treated with ion-ozone cavitation streams on the factors w and t*

Figure 6. *Barley Baisheshek – a control sample*

Figure 7. *Barley Baisheshek processed by ion-ozone flows*

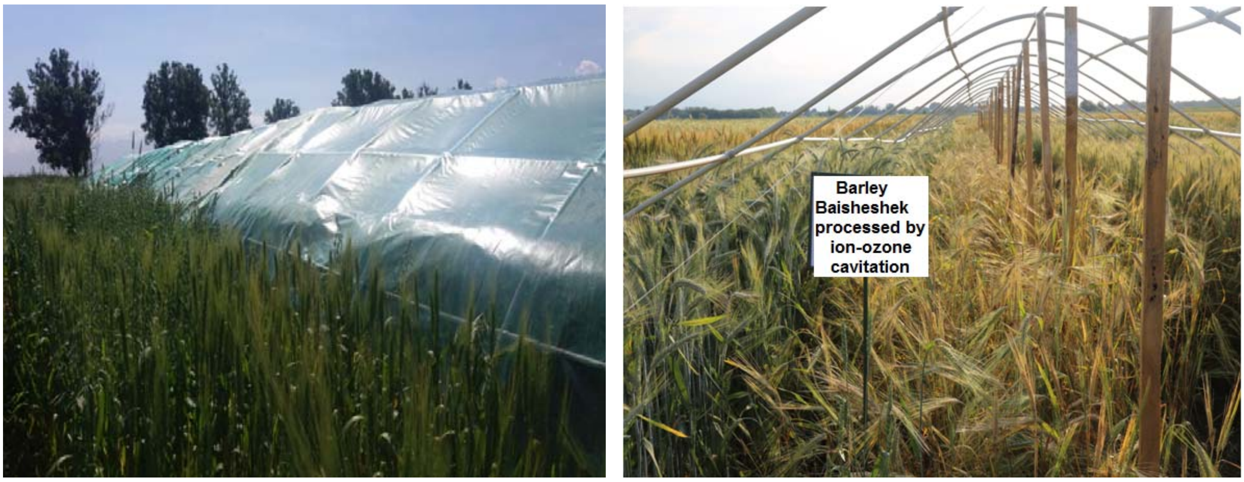

Figure 8. *Barley Baisheshek processed by ion-ozone cavitation*

Table 1. *Quality indicators of control (unprocessed) samples of barley Baisheshek*

Seed properties			Technological properties						
			Physical				Biochemical		
Germination energy in 3 days,%	Germination in 5 days, %	Germination in 7 days,%	humidity, %	Nature, g / l	Density, g / cm^3	Weight of 1000 grains, g	Mass fraction of protein, %	Starch, %	Greenery Index, ml
Function Indicators									
y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}
97	98	100	12,66	642	1,12	49	9,59	65,03	32,12

Table 2. *Conditions and results of full-factorial experiments of FFE-2^3 on the ion-ozone treatment of barley Baisheshek*

Experiment Numbers	**Ratio of ion concentrations to ozone, million units/mg**	**humidity before processing, %**	**Processing time, min**	**Seed properties**			**Technological properties**						
							Physical				**Biochemical**		
				Germination energy in 3 days,%	**Germination in 5 days, %**	**Germination in 7 days,%**	**humidity after processing, %**	**Nature, g / l**	**Density, g / cm^3**	**Weight of 1000 grains, g**	**Mass fraction of protein, %**	**Starch, %**	**Greenery Index, ml**
	Experimental conditions			**Quality indicators**									
	$C_{i/o}$, mln. units/ mg	*w*, %	t, min	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}
1	15	20	20	89	89	90	16,68	627	1,11	60	8,88	61,34	32,24
2	1	20	20	86	88	89	17,32	622	1,12	62	8,15	61,05	32,54
3	15	20	20	85	99	99	12,75	634	1,11	52	9,82	63,96	33,48
4	1	20	20	89	99	99	12,72	638	1,09	46	9,60	64,24	33,27
5	15	13	20	84	87	88	17,11	621	1,09	58	8,42	60,98	32,74
6	1	13	20	86	87	89	17,47	614	1,11	60	8,78	61,34	33,15
7	15	13	20	95	99	99	12,72	638	1,12	53	9,83	64,29	32,63
8	1	13	20	92	99	99	12,64	635	1,09	46	9,85	64,19	34,03

Table 3. *Conditions and results of full-factorial experiments of FFE-2[4] on the ion-ozone cavitational processing of barley Baisheshek*

Experiment Numbers	Ratio of ion concentrations to ozone, million units/mg	Overpressure (cavitation), ati	humidity before processing, %	Processing time, min	Seed properties: Germination energy in 3 days,%	Germination in 5 days, %	Germination in 7 days,%	Technological properties – Physical: humidity after processing, %	Nature, g / l	Density, g / cm³	Weight of 1000 grains, g	Biochemical: Mass fraction of protein, %	Starch, %	Greenery Index, ml
	Experimental conditions				**Quality indicators**									
	$C_{i/o}$, mln. units /mg	*P*, ati	*w*, %	t, min	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}
1	15	4	20	20	92	93	93	17,57	615	1,11	57	8,10	61,19	35,42
2	1	4	20	20	88	92	92	17,04	625	1,11	60	7,75	60,37	33,10
3	15	1	20	20	85	87	89	17,44	615	1,11	56	8,03	61,15	33,53
4	1	1	20	20	90	91	92	17,27	622	1,11	61	8,77	61,19	36,96
5	15	4	13	20	98	98	99	12,64	635	1,11	49	9,41	64,15	34,45
6	1	4	13	20	96	98	98	12,48	639	1,11	50	9,00	64,55	33,28
7	15	1	13	20	98	99	99	12,75	632	1,11	48	9,26	63,83	35,89
8	1	1	13	20	98	100	100	12,72	639	1,11	48	9,58	63,85	34,28
9	15	4	20	10	91	91	91	17,51	618	1,11	60	8,26	60,64	35,76
10	1	4	20	10	94	95	95	17,18	616	1,12	54	8,55	61,56	34,76
11	15	1	20	10	97	98	98	17,43	621	1,11	53	8,33	60,83	33,27
12	1	1	20	10	93	94	94	17,22	622	1,12	53	8,19	61,18	34,51
13	15	4	13	10	96	97	97	12,8	634	1,11	49	9,19	63,74	32,52
14	1	4	13	10	98	100	100	12,77	637	1,11	50	9,70	63,85	34,58
15	15	1	13	10	98	99	99	12,77	631	1,11	50	9,59	64,27	33,49
16	1	1	13	10	100	100	100	12,78	636	1,09	51	9,62	63,57	34,29

Table 4. *Calculation of the least-squares regression coefficients according to the linear plan taking into account inter-factor interactions, germination in 7 days – 2[3]*

Name	**Type of equation (Optimization)**	**Numeric characteristics: Average value**	**Root mean square deviation**	**Fisher's Criterion – F_r**	**Student's Criterion – t_{cr}**
Barley Baisheshek	Y_{ger}=117,5714-1,4285*x_2	94	sy = 1.2500 sag = 0.5774	Fr= 4.69 Fcr=5.14	4.304

Table 5. *Optimal regimes and quality indicators of Baisheshek barley grain after ion-ozone treatment*

Properties (purpose) of grain	Processing modes			The objective function	Quality indicators (limitations)
	$C_{i/o}$, mln units/mg	*w*, %	t, min		
Seed	1	13	10	y_1 = 93,57 %	y_2 = 98,96 %; y_3 = 98,98 %
Physical	1	20	10	y_6 = 1,105 g/cm^3	y_4 = 17,15 %; y_5 = 629 g/l; y_7 = 61,01 g
Biochemical	1	13	10	y_8 = 9,78 %	y_9 = 62,67 %; y_{10} = 33,01 ml

Table 6. *Optimal regimes and quality indicators of Baisheshek barley grain after ion-ozone cavitation treatment*

Properties (purpose) of grain	Processing modes				The objective function	Quality indicators (limitations)
	$C_{i/o}$, mln units/mg	*P*, ati	*w*, %	t, min		
Seed	1	1	13	10	y_1 = 84,12 %	y_2 = 99,87 %; y_3 = 98,70 %
Physical	1	1	20	10	y_6 = 1,11 g/cm^3	y_4 = 17,34 %; y_5 = 627 g/l; y_7 = 56,68 g
Biochemical	1	1	13	10	y_8 = 9,42 %	y_9 = 62,49 %; y_{10} = 34,65 %

Table 7. *Summary of the optimal indicators of the quality of barley Baisheshek after ion-ozone and ion-ozone cavitation treatment in comparison with control (unprocessed) samples*

Indicators	Ion-ozone treatment		Ion-ozone cavitation treatment	
	Optimum	Control	Optimum	Control
y_1, %	93,57	97	84,12	97
y_2, %	98,96	98	99,87	98
y_3, %	98,98	100	98,70	100
y_4, %	17,15	–	17,34	–
y_5, g/l	629	614	627	614
y_6, g/cm^3	1,105	1,11	1,11	1,11
y_7, g	61,01	52	56,68	52
y_8, %	9,78	5,57	9,42	5,57
y_9, %	62,67	57,87	62,49	57,87
y_{10}, ml	33,01	29,81	34,65	29,81