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Improving the quality of brewing malt with the use of ion-ozone explosive cavitation

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Abstract

Currently, a large amount of barley grain of different quality is supplied to malting plants. The use of non-compliant grains leads to a reduction in malt quality. The aim of the study is to improve the process of malting barley and improve the quality of malt through exposure to ion-ozone explosive cavitation processes. The optimal ozone concentration of 2 mg/m^3, ions of 500±20 u/cm^3, cavitation of 2 at and treatment time of 5 minutes were determined. The positive effect of ion-ozone explosive cavitation in the recommended concentration on malt quality indicators is shown. The estimated method of processing allows to reduce the protein content of malt by 1.64%, to increase the extract content by 0.38%, amylolytic activity by 76.9%, diastatic force by 75.2% relative to the control. The effect of barley contamination on the color and transparency of the wort has been established. Mathematical processing of experimental data showed an increase in the ability of germination as the concentration of the ion-ozone mixture decreases and the percentage of the swelling ability. The resulting malt has high quality and technological parameters. This is important because the quality of barley is of great importance not only for the malting, but also for the brewing industry as a whole. Ion-ozone explosive cavitation as an innovative approach allows to solve the problems of grain with unstable indicators of quality and opens up new prospects for its use in enterprises for the storage and processing of grain.

Keywords: barley, malt, ion, ozone, explosive cavitation

Abbreviations: swelling ability (SA), germination ability (GA), amylolytic activity (AA), diastatic force (DF), proteolytic activity (PA)

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INTRODUCTION

The Problem of Reducing the Efficiency of Brewing

Worldwide, barley is the main raw material used in the production of malt and beer (Lidia Di Ghionno *et al.* 2017). The pace and volume of world trade in malting barley and malt is increasing. Barley demand for beer continues to increase. Over the past decade, beer production has increased by 19% (Alshanov 2006). The quality of the malt is important for the brewing industry (Christian Mueller *et al.* 2015). One of the main problems of reducing the efficiency of brewing in the Republic of Kazakhstan and the decline in production in recent years, according to experts, is the deterioration in the quality of malting barley (Shintassova et al. 2017).

The Reason for the Low Quality of Malt

The increase in beer production requires a certain amount of raw materials, the main of which is brewing malt. However, the quality of domestic brewing malt leaves much to be desired and a significant amount of it is purchased for import from abroad in large volumes. One of the reasons for the low quality of domestic malt is the critical condition of the primary raw material base. The quality of barley grown in the Republic of Kazakhstan does not meet the requirements of the standard for malting barley. In addition, the weather conditions in Kazakhstan (sharply continental climate, high temperatures), do not allow to achieve stable quantitative and qualitative characteristics of barley for brewing production (Ozsay et al. 2018, Shintassova *et al.* 2017). In this regard, the technological cycle requires a reasonable and purposeful process of grain processing before malting. Modern research development allows not only to improve this process, but also to improve it (Kretova 2015).

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New Methods of Influence on Barley Grain

Currently, there is a search for new methods of influence on barley in order to increase germination ability, reducing the time of sprouting malting barley, increase enzymatic activity and improve the quality of the finished malt.

Scientists in the world are looking for methods to accelerate the preparation of malt, providing new technological modes, the use of chemical and biologically active substances, the impact of electrically charged particles.

By Agafonov, V.P., Ivanov, E.G., Chavachina, E.E. a new acoustic-cavitation method has been proposed to intensify the process of grain germination. Seeds that have undergone acoustic-cavitation treatment have increased germination ability, as well as accelerated development, which makes it possible either to improve the quality of products from germinated grain, or to reduce the germination time and reduce its cost at the initial quality level (Agafonov *et al.* 2016).

Lorenzo Albanese, scientist at the Institute of Biometeorology in Florence, and his colleagues have developed a new brewing technology that completely changes the chemistry, technology and influence on the nature of the brewing process (Mohammadi and Shakib 2014).

The object of their attention was cavitation, the process of vaporization and the subsequent collapse of vapor bubbles with simultaneous condensation of steam in a fluid flow. The first advantage that cavitation has given is that malt is ground by itself, no need to grind it in advance. In a few minutes, malt is crushed into particles with a size of 0.1 mm or less. This also increases the degree of biodegradation of brewer's grain, the disposal of which is a problem for brewers (MIT Technology Review 2016).

Applying the effects of the phenomenon of cavitation in the processing and food industries is undoubtedly effective, as it can significantly reduce, and in some cases completely eliminate, the use of chemical food additives (Kapustin *et al.* 2016, Kılıç et al. 2015).

Recently, a relatively new method of extending the shelf life of food products through their treatment with ionizing radiation has become increasingly widespread in the world. Different sources of ionizing radiation are used for irradiation of food products: radioisotope (cobalt-60 or cesium-137), particle accelerators are also used. Such countries as the USA, China, to a lesser extent – Germany, France, Italy widely use the radiation technique. In Russia, too, increasingly use this method. Radiation treatment has become a common technology for bacteria control, insect eradication and seed disinfection (Nosova *et al.* 2017, Premkumar et al. 2018).

It should be noted that soil salinity is one of the most important problems in agricultural areas of the world. Almost 20% of the world's cultivated land and almost half of the world's irrigated land is subject to salinization (Cavusoglu *et al.* 2014). If consider the use of chemicals, it can be said that as an effective practice to increase the germination ability in saline environments, Tunisian scientists have proposed fertilizing seeds by soaking them with nitrogen compounds, which led to its increase (Ounissi *et al.* 2015, Ye *et al.* 2015).

Many of the methods described above are still in the experimental stage of implementation, but they have already contributed to the understanding of the role of intensification of the malting process (Narziss 2007).

New Direction - the Use of Ion-ozone Explosive Cavitation

One of the newest directions in the brewing industry is the production of malt, which differs from the traditional technology of preparation using ion-ozone explosion cavitation processes.

Over the past 50 years, technique and technology have changed significantly. Following modern views, professor of Almaty Technological University, Maemerov M.M. developed a universal ion-ozone explosive cavitation unit for processing barley grain, which allows to improve malt technology.

The specially designed construction of ion-ozone explosive-cavitator allows using the effect of corresponding ion-ozone explosive cavitation, at which the shell and the endosperm of barley grain are destroyed, the volume of grain increases, and the pores increase. Under the influence of directional and controlled explosive cavitation with a limit of permissible concentration of the components of the ion-ozone mixture and an overpressure, complex bonds of organic substances at the molecular level break in the barley grain. As a result of this process, the number of cracks in the grain becomes larger according to the energy fluxes of the electromagnetic field, and they are evenly spaced from each other in accordance with the appearance of an electric field. At the same time, the structure of the shell and the endosperm of barley grain is destroyed, which effectively affects the process of crushing the malt, while microorganisms and pests of the grain are instantly destroyed (Iztaev *et al.* 2015).

This work presents the results of studies on the effect of ion-ozone explosive cavitation treatment on the grain quality of barley, malt and wort.

METHODOLOGY

Malting Barley

GOST (state standard) 5060-86 "Barley for brewing. Specifications" (state standard, 1986).

Barley belongs to the *Gramineae* family of cereals, the genus *Hordeum*. The Botanical name of barley adopted by ISO 5525 for double row barley is *Hordeum vulgare convar Distichon (23)*. For the experiment used malting barley varieties *Sanshine*, german selection, but grown in Kazakhstan and used for the production of malt

Table 1. Factors and their dimensionality

Indicators	Coded value	Factors and their dimensionality			
		x_1 - the ratio of the concentration of ozone (mg/m^3) and ion (u/cm^3)		x_2 - cavitation (pressure), at	x_3 – processing time, min
Upper level	+	6	100000±25	6	15
Zero level	0	4	50250±250	4	10
Lower level	–	2	500±20	2	5
Variation interval		2	49750	2	5

at JSC (Joint stock company) “Malting plant Soufflé Kazakhstan” in the city of Tekeli of the Republic of Kazakhstan. Barley was treated in the following treatment modes: ozone concentration 2, 4, 6 mg/m^3, ion – 500±20, 50250±250, 100000±25 u/cm^3, explosion cavitation - 2, 4, 6 at, time – 5, 10, 15 minutes.

Ion-ozone Explosive Cavitation Installation

For processing malting barley, a laboratory ion-ozone explosive cavitation installation was used. The main technical characteristics of this installation: 1) the range of ozone synthesis is 0.1 mg/m^3 to 8-10 g/m^3; 2) the range of synthesis of molecular ions is from 100 u/cm^3 to 1000000 u/cm^3; 3) overall dimensions: 1000x1000x1500 mm; 4) weight 200 kg; 5) rational indoor temperature for an ozone counter of 10°C; 6) the minimum flow rate of the liquid is not less than 0.6 m^3/min; 7) installation service life of at least 5 years (Iztaev *et al.* 2015).

Light Barley Malt

Interstate standard 29294-2014 “Brewing malt. Technical conditions” (interstate standard, 2014).

Obtained by the classical technology with the use ion-ozone explosive cavitation processes: 1) cleaning of the barley grain; 2) sort; 3) disinfection (ozone concentration 2, 4, 6 mg/m^3, molecular ions – 500±20, 50250±250, 100000±25 u/cm^3, explosive cavitation – 2, 4, 6 at, time – 5, 10, 15 minutes); 4) wash in ion-ozone water (ozone concentration of 2 mg/l, the molecular ions of 1000±20 mg/l); 5) soaking in ion-ozone water (ozone concentration of 2 mg/l, the molecular ions of 1000±20 mg/l); 6) treatment of the grain after soaking (ozone concentration 2, 4, 6 mg/m^3, molecular ions– 500±20, 50250±250, 100000±25 u/cm^3, explosive cavitation – 2, 4, 6 at, time – 5, 10, 15 minutes); 7) germination in the flow of electrically charged particles (the concentration of molecular ions is 200000±25 u/cm^3); 8) drying in a stream of electrically charged particles (the concentration of molecular ions is 200000±25 u/cm^3); 9) separation of sprouts; 10) binning and storage of finished malt.

The Main Indicators of the Quality of Barley used for the Production of Malt and Research Methods

- The infestation of pests was determined according to ISO 6639-4:1987 (international standard, 1987);
- the mass fraction of protein substances was determined by ISO 20483: 2013 by the Kjeldahl method (international standard, 2013);
- extract content was determined according to the methods ASBC, EBC adopted (IM) (6.3) using malt extract (methods ASBC, EBC (IM);
- ability of germination was determined by the method of EBC (3.5.1) (method EBC);
- the ability to swell was investigated during soaking by weighing on analytical scales with an accuracy of 0.0000 g (Narziss 2007).

The Main Indicators of the Quality of Light Barley Malt and Research Methods

- the mass fraction of protein substances in the dry matter of malt was determined according to GOST R 54390-2011/ISO/TS 16634-2: 2009 by Duma (state standard, 2011);
- extract content of malt was determined by the method of EBC (4.5.1) (method EBC);
- amylolytic activity was determined by EBC method (4.12) using Windish-Kolbach method (method EBC);
- determination of the diastatic force was carried out similarly to the amylolytic activity by the EBC method (4.12), but with some differences in the preparation of solutions (method EBC);
- proteolytic activity was determined by refractometric method.

The Main Indicators of the Quality of Laboratory Wort and Research Methods

- The color and transparency of the wort were determined by the method EBC (8.5) adopted by MEBAC (method EBC, MEBAC).

Full-factor Experiment

Before the experiment, the study factors were determined, which were assigned a coded value, and the interval of variation of levels was indicated.

To study the mechanism of the effect of ion-ozone explosive cavitation treatment on the grain of malting barley, and later on malt and wort obtained from it were considered three factors with respective sizes (**Table 1**).

Based on the three factors presented in **Table 1**, a plan of eight full-factor experiments was drawn up using the zero level in addition (**Table 2**).

For the highest accuracy, intermediate concentrations of ions were used: 25000 ± 10, 50000 ±250, and 75000±15 u/cm^3.

Table 2. Plan for conducting full-factor experiments

Experiment	The ratio of the concentration of ozone and ion			Cavitation (pressure)		Processing time	
	ozone -mg/m³	ion - u/cm³	x_1	at	x_2	min	x_3
1	6	100000±25	+	6	+	15	+
2	2	500±20	–	6	+	15	+
3	6	100000±25	+	2	–	15	+
4	2	500±20	–	2	–	15	+
5	6	100000±25	+	6	+	5	–
6	2	500±20	–	6	+	5	–
7	6	100000±25	+	2	–	5	–
8	2	500±20	–	2	–	5	–
9	4	50250±250	0	4	0	10	0

Table 3. Barley and malt quality indicators

Indicators, %	Sample	Control	Ozone concentration, mg/m³, ion, u/cm³, cavitation, at, duration of treatment, min							
			6 / 100000±25 / 6 / 15	2 / 500±20 /6 / 15	6 / 100000±25 / 2 / 15	2 / 500±20 / 2 / 15	6 / 100000±25 / 6 / 5	2 / 500±20 / 6 / 5	6 / 100000±25 / 2 / 5	2 / 500±20 / 2 / 5
Protein	Barley	10,01	12,00	10,97	11,66	10,71	11,78	10,82	11,04	10,66
	Malt	8,61	8,48	8,86	8,61	9,00	8,57	8,93	8,74	9,02
Extract content	Barley	63,84	77,08	79,10	78,09	79,53	77,30	79,26	78,75	79,62
	Malt	79,61	76,76	79,73	78,60	79,85	77,20	79,80	79,00	80,00

Statistical Analysis

Mathematical processing of the data was performed using the computer program STATISTICA 10.0, which allowed us to estimate the sample characteristics and conduct a comparative analysis.

RESULTS AND DISCUSSION

Pest Infestation

When studying the infestation of barley by pests, it was found that the number of ticks and weevils after the grain treatment with ion-ozone explosive cavitation was zero, while the control sample had the first degree of infection with pests (2 weevils and 15 ticks) (Shintassova *et al.* 2017).

It should be said that scientists from China investigated the effect of high hydrostatic pressure treatment (400 MPa/15 min; 500 MPa/10 min; 600 MPa/5 min at 20°C and 60°C/15 min) on physicochemical and sensory characteristics wheat beer, during which its effects on microorganisms were studied. It is noted that an alternative to heat treatment is high hydrostatic pressure, which can effectively lead to the destruction of microorganisms in order to increase the safety and shelf life of food products (Hua Yin *et al.* 2016).

Protein and Extract Content

When the ozone concentration of 2 mg/m^3, the molecular ions of 500±20 u/cm^3, excess pressure of 2 at and exposure time of 5 minutes is a protein made up of 10.66 %, and the extract content 79.62 %. Compared with the control, the extract content of processed barley is increased by 15.3-15.8 % (**Table 3**).

According to Narziss L. - a famous german specialist, professor, for the production of high-quality malt it is better to use barley grain with a protein content of from 9 to 11.5%. A higher protein content reduces the yield of the extract and makes it more difficult to process (Narziss 2007). In the control and prototypes of malt there was a decrease in protein content. The higher the processing parameters, the lower the protein content compared to the low processing parameters. As it should be, the mass of proteins in malt is less than in barley with all processing parameters. With malting from 1.4 to 3.6% of protein in comparison with barley decreases, this is due to the fact that barley protein substances undergo significant changes. According to many studies, about 50% of barley protein in malting turn into a soluble state, of which about 10% pass into sprouts (Maltsev 1980).

Ability to Swell

Further, the kinetics of swelling of dry grain in water after treatment under different conditions was investigated. When soaking for the control sample, ordinary water was used, and for the treated samples ionized water with an ozone concentration of 2 mg/l, molecular ions of 1000±20 mg/ml.

Figs. 1 and **2** show that the process of swelling of the grain consists of two stages: the initial relatively slow or rapid swelling with access to the first plateau and the subsequent smooth swelling with the achievement of the second plateau.

As can be seen from **Fig. 1**, the kinetics of swelling, especially in the first phase, depends significantly on the concentration of ion-ozone explosive cavitation in which the treated grain. The maximum speed is observed in the range of 2 mg/m^3 / 500±20 u/cm^3 / 2 at/5 min and 2 mg/m^3 / 500±20 u/cm^3 / 2 at/15 min.

When processing barley grain with high concentrations of ion-ozone explosive cavitation (**Fig. 2**), swelling in the first phase is fast enough and the first plateau, as well as the second, is achieved at higher values of humidity than the grain treated at low concentrations. This is due to the high degree of grain injury.

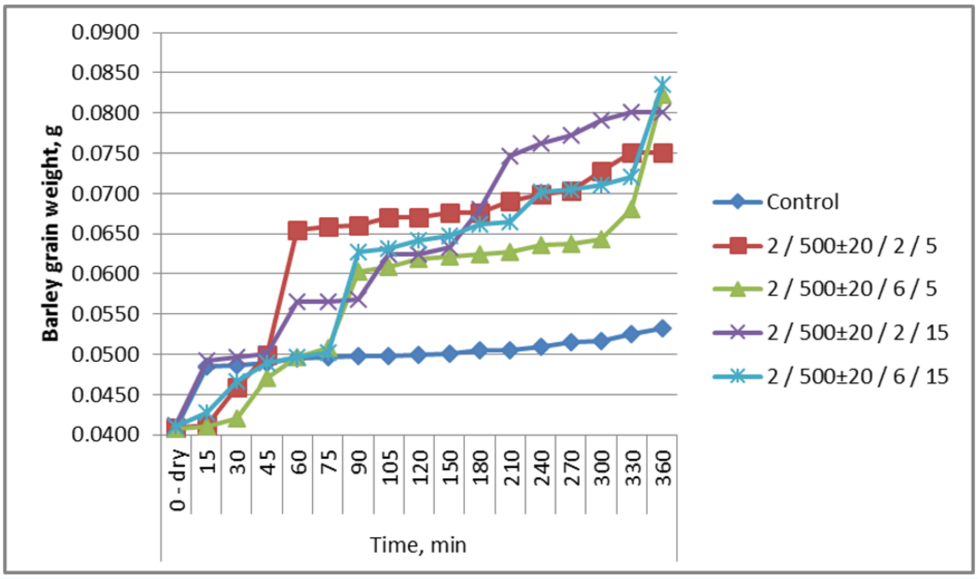

Fig. 1. Kinetics of barley swelling at low concentrations of ion-ozone explosive cavitation

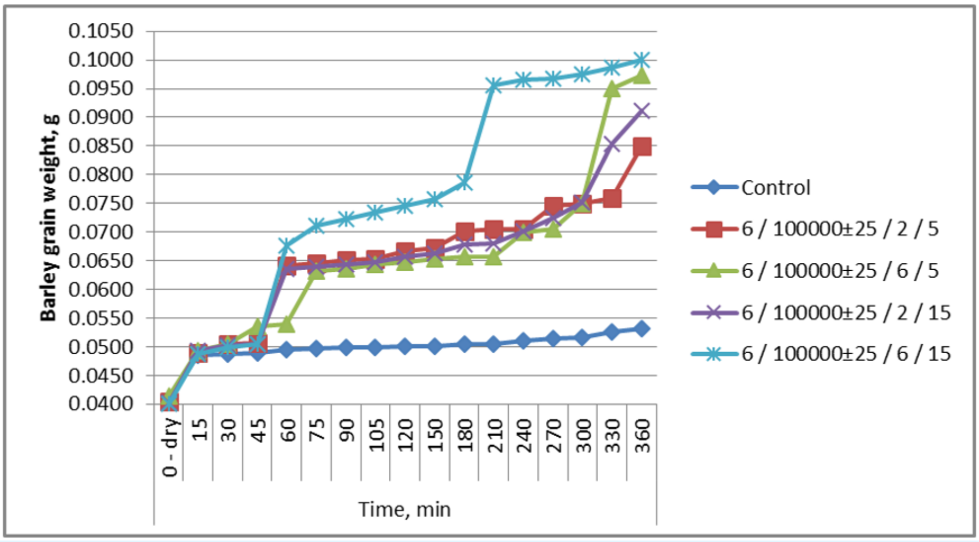

Fig. 2. Kinetics of barley swelling at high concentrations of ion-ozone explosive cavitation

Dependence of the Swelling Degree and Germination Ability

To assess the effect of swelling on the germination of barley, a comparison of the magnitude of swelling (by the end of the fifth hour of soaking) with the values of the ability of germination obtained after treatment of barley was carried out.

Figs. 3 and **4** show that in the region of some high processing options (6 mg/m^3/100000±25u/cm^3/6 at; 2 mg/m^3/500±20 u/cm^3/2 at) value of germination ability and degree of swelling are in opposite phase, i.e., peaks on one correspond to troughs on the other. The difference between the two dependencies is 2.8-20.1 %.

The other low and high processing parameters have a different picture, the germination ability and the swelling degree have relatively close values with a difference 0.3-1.1-2.2 %.

In highly traumatized grain treated at high parameters, the effect of ion-ozone explosive cavitation on the permeability of the inner shells of the grain is accompanied by additional opening of pores, loosening of membranes, a large number of micro-injuries, leading to a high rate of swelling (stretching and elongation of its cells), compared with other processing parameters and control, which leads to a relatively low germination rate as a result of waterlogging (in control samples, the germination capacity of 95.2 %). This causes waterlogging of the grain, the so-called “water shock”.

In the case of grain treated with low ion-ozone explosive cavitation parameters, with a minimum of micro-injury, there is a partial closure of micro-cracks and micro-channels, which indicates a decrease in its swelling compared to others. This leads to the normalization of all processes in the grain and

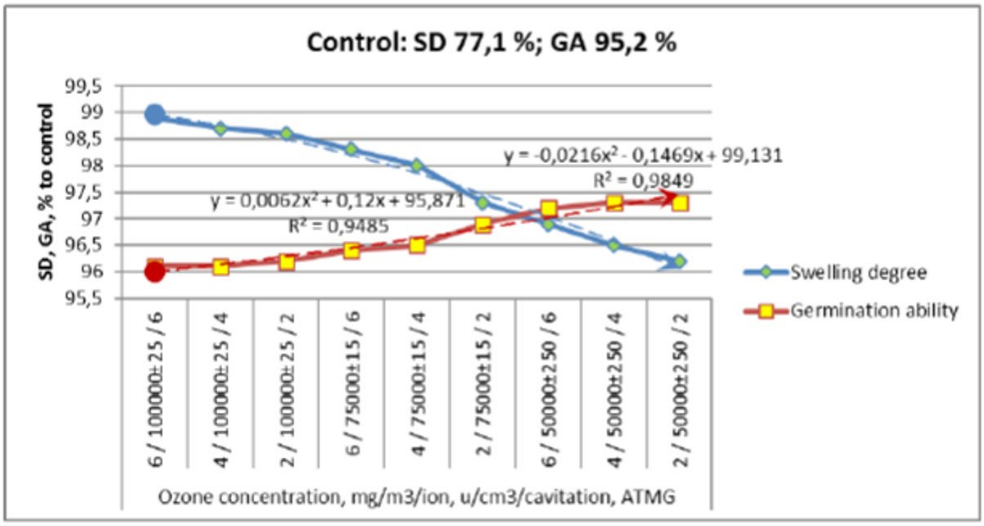

Fig. 3. The dependence of the swelling degree and germination ability of barley from high and medium concentrations ion-ozone explosive cavitation

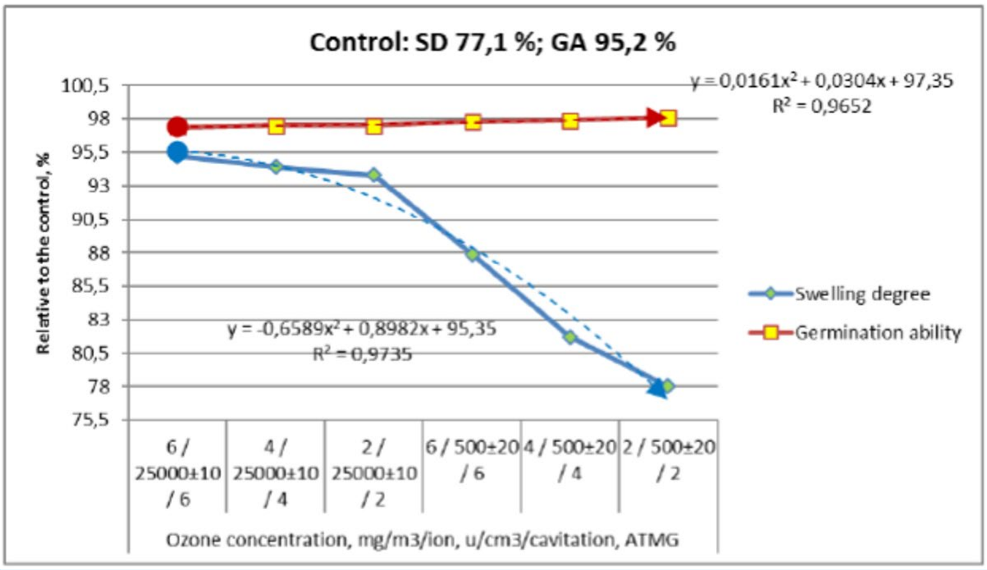

Fig. 4. The dependence of the swelling degree and germination ability of barley from low concentration ion-ozone explosive cavitation

acceleration of germination (**Fig. 1**). In this case, there is a relatively similar change in germination and degree of swelling (**Figs. 3** and **4**).

Experimental data were confirmed by polynomials of the second degree with a sufficiently high degree of approximation (R^2 = 0.984 and 0.965 for germination ability and R^2 = 0.948 and 0.973 for the degree of swelling).

Statistical Analysis

In the study of the impact ion-ozone mixture and of the swelling ability on the germination ability, the obtained regression equation, reflecting the level of factors of the experiment.

The regression equation (1) describing the effect of ion-ozone mixture and cavitation on the ability of germination has the form:

$$Z = 9.5552 - 0.006 * x + 0.0227 * y \quad (1)$$

where Z - the capacity of germination, %; x – the ability of swelling, %; – ion-ozone mixture.

A graphical interpretation of the regression equation that reflects the dependence of the resulting (Z) on two influencing variables (x and y) is shown in **Fig. 5**.

Built regression model in **Fig. 6** shows the increase in the ability of germination with the decrease of concentration ion-ozone mixture and of the ability of the swelling. Thus, mathematical processing of experimental data, one can observe the dependence of the ability of sprouting from influencing factors: the highest value of indicator of the germination ability (98.1 %) was achieved at 0.25 (500±20 u/cm^3 ions / 2 mg/m^3 of ozone) and the swelling ability was 96.9 %, the lowest (96.1 %), while 16.7 (100000±25 u/cm^3 ions /6 mg/m^3 of

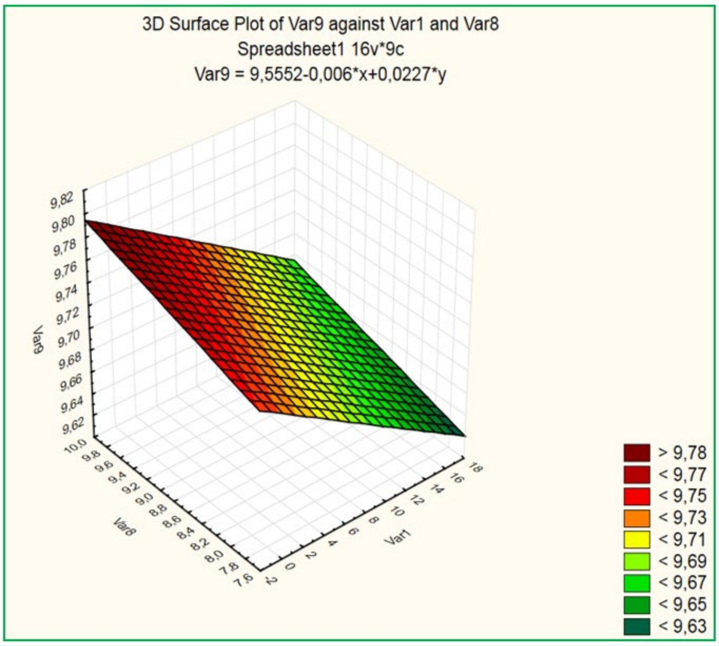

Fig. 5. Influence ion-ozone mixture and of the swelling ability on the germination ability of barley grains

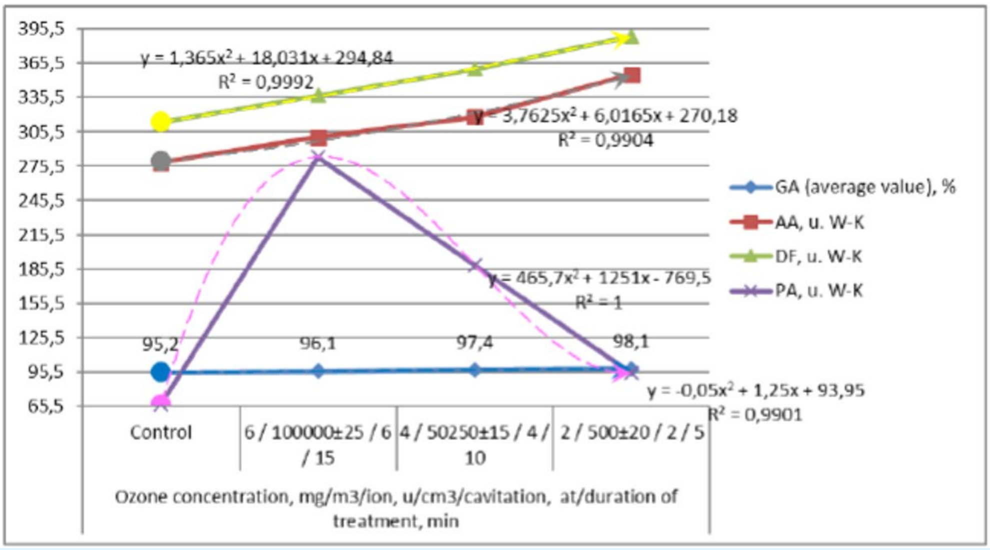

Fig. 6. The dependence of the germination ability and enzymatic activity from ion-ozone explosive cavitation treatment

ozone) and the swelling ability of 98.9 %. The regression equation is statistically reliable, which confirms the correctness of the experimental studies and the validity of the conclusion that in the process of soaking in the treatment of barley with ion concentration of 500±20 u/cm^3, ozone 2 mg/m^3 and the swelling ability of 96.9%, the best percentage of germination capacity is observed, depending on the dose of the ion-ozone mixture and the swelling ability.

The Dependence of the Germination Ability and Enzymatic Activity from Ion-ozone Explosive Cavitation

Since the main purpose of malting is the accumulation of the maximum number of active enzymes in the grain, it was important to trace the effect of ion-ozone explosive cavitation on the enzymatic activity of the finished malt.

From the data presented in **Fig. 6**, it can be seen that the use of ion-ozone explosive cavitation has had a positive effect on the activity of amylases in the finished malt. The concentration dose of 2 mg/m^3/500±20 u/cm^3/2 at/5 min gave the greatest effect compared to other treatment modes.

The increase of amylolytic activity in this variant in relation to the control was + 76.9 %. In the dosage of 4 mg/m^3/50000±250 u/cm^3/4 at/10 min indicator of amylase activity increased by + 39.6 %. However, the treatment dose of 6 mg/m^3/100000±25 u/cm^3/6 at/15 min showed the least effect, the deviation from the control sample – 22.2 %.

From the graphs clearly visible positive effect of treatment in the case of accumulation of amylolytic activity and diastatic force. The increase in diastatic force is more pronounced, and is 75.2 % compared to the control. The increase in diastatic force is noticeable and obvious, in particular, with respect to the option at low processing, as in the case of amylolytic activity.

In addition, the analysis of the data shows that the effect of ion-ozone explosive cavitation on the enzymatic activity of malt is much greater (75.2 and 76.9%) than on the germination of barley (1.9-3.9 %).

In the case ion-ozone explosive cavitation treatment also draws the attention of the tendency to reduce activity of proteolytic enzymes.

If the proteolytic activity in the control sample and in the sample with low processing was 67.5 and 94.5 mg/100 g, which is the closest to the norm, then in the test samples with medium and high processing its values increased, reaching the maximum values – 189 and 283.5 mg/100 g. It should be noted that such high values indicate an undesirable over-solubility of malt protein, which entails a decrease in foam resistance in beer production and requires a reduction in the duration of the protein pause during mashing.

Experimental dependences were confirmed by polynomial lines of the second degree with a sufficiently high value of approximation reliability (R^2 = 0.990 – for germination ability and amylolytic activity; R^2 = 0.999 – for diastatic force and R^2 = 1 – for proteolytic activity).

Color and Transparency of the Wort

The color indicator of the laboratory wort can also characterize the quality of soluble malt. Measuring the color of wort obtained from malt is one of the most important quality parameters to be monitored (Giuseppe Perretti *et al.* 2012). In high quality light malt, the color should be no more than 0.18 ABS. According to our research, the color of the laboratory wort of the control sample is 1.687 ABS, in prototypes processed at high parameters 0.200-0.240, and in samples with low processing parameters 0.028-0.075 ABS. As shown by the research data, ion-ozone explosive cavitation has a positive effect not only on the color of the laboratory wort, but also on the transparency. The wort prepared from the treated malt samples was clear, unlike the control sample, which had a slight opalescence.

This can be attributed to the fact that when determining the infection by pests, the control sample had 1 degree of infection. As is known, the transparency of the wort depends on the microbiological quality of barley. Contamination of barley with fungi, insects and bacteria leads to turbidity of the original wort (Giuseppe Perretti *et al.* 2012).

CONCLUSION

Theoretical Justification of Experimental Studies

The theoretical substantiation of experimental studies shows that ozone, penetrating into the biological cell of barley protein, produces disinfection, and decomposition of unused ozone provides the cell with oxygen. Molecular ions, penetrating into the cell, energize first the cations, and then, the anions, as a result of which the liquid phase of the cell splashes more intensively, thereby increasing the biological value of the product. Cavitation produces an increase in the pores of the product, thereby improving the penetration of the ion-ozone mixture into biological cells. The best exposure time of 5 minutes indicates the completion of biological processes occurring during the processing of barley.

Optimal Processing Parameters

On the basis of the conducted research, it can be concluded that the use of ion-ozone explosive cavitation with an ozone concentration of 2 mg/m^3, ions of 500 ± 20 u/cm^3, cavitation of 2 at and time of 5 minutes in the production of barley brewing malt is a perspective way to produce high-quality malting. The main grain processing is recommended at the soaking stage. In this case, the effective concentration of ozone and ions for water is 2 and 1000±20 mg/l. In this case, it is possible to shorten the malting process by 2 days while maintaining the required quality of the finished product.

Features of Experimental Studies

It should be noted that high processing modes in some cases have a negative impact on the grain of barley, and low, on the contrary, have a positive effect on the quality of barley, malt and wort.

This feature can be seen in the experiments of scientists from Korea, who studied the effect of ultrasound on the kinetics of beer fermentation using six-row barley grown in Korea and concluded that the high power of ultrasound (200 W) adversely affected the viability of yeast. A moderate power (120 and 160 W) clearly increased the final concentration of alcohol (Eun Ji Choi *et al.* 2015). Also, scientists from Turkey have observed that low concentrations of exogenous salicylic acid significantly increase seed germination and growth of barley seedlings, and its high concentrations have the opposite effect on these parameters (Cavusoglu *et al.* 2014).

Possible Prospects for Further Research

It does not find an adequate explanation for the fact that by studying the effect of ion-ozone explosive cavitation on the enzymatic activity of malt, it was found that in the analyzed series of experiments the content of soluble protein fraction increased, as evidenced by higher values of proteolytic activity in samples with high processing. As a rule, high amylolytic activity in samples with low treatment should have led to greater dissolution of protein substances. If the proteolytic activity in the control sample and in the sample with low processing was 67.5 and 94.5 mg/100 g, which is the closest to the norm, then in the test samples with medium and high processing its values increased, reaching the maximum values – 189 and 283.5 mg/100 g. It should be noted that such high values indicate an undesirable over-solubility of malt protein, which entails a decrease in foam resistance in beer production and requires a reduction in the duration of the protein pause during mashing. Therefore, the obtained results make it appropriate to further studies on the effect of different concentrations of ion-ozone explosive cavitation on the technological process of malt production.

The Development of Research in the Future

Improving the quality of malt is an important issue of modern technology. It is significant and innovative today, modern producers of malting and brewing plants are very interested in it as it will significantly affect the solution of questions of import substitution, increase of profitability of production due to introduction of the new technology allowing to reduce expenses on disinfectants, to reduce consumption of energy resources.

In conclusion, it should be noted that in this work, we first studied the possibility of using ion-ozone explosive cavitation treatment of barley with the aim of improving the production of brewing malt and improve quality indicators. Given that the literature has not previously encountered information on the application ion-ozone explosive cavitation in the technology of malting, the rationale for its use in the production of barley malt has an important practical interest.

This suggests that the use of various physical methods of processing has a further promising path of development in the future for the food and processing industry.

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