Impact of ion-ozon treatment technologies and cavitation on grain quality indices

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Abstract. The results of multifactor studies on the impact of ion-ozon technology of wheat grain treatment technology and cavitation on wheat grain quality indices are presented. On the basis of statistical processing and regression analysis it has been determined that ion-ozon treatment using cavitation improves technological and seed parameters of grain quality.

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Introduction

Currently, in grain-processing production practice considerable attention is paid to introduction of advanced techniques and high-performance equipment aimed to improve efficiency in grain processing [1]. One of the promising technologies that provides significant intensification of production processes and offers great opportunities for expanding the range of cereals, bread and other products, is cavitation processing of raw materials (so-called "wet milling" in which grain grinding is carried out in water medium), which allows to receive cereal suspensions - products with a set of physico-chemical and organoleptic properties [2,3].

Application of the technology in confectionery industry is particularly promising. The technology allows to eliminate the use of any components harmful for health, reduce consumption of fat in operations (greasing of baking equipment - up to 90 % , kneading dough - up to 30 %) [4,5].

For Kazakhstan which has great agricultural potential, production and preservation of harvested grain has great strategic importance. This paper presents the results of investigations on identification of the effectiveness of ion-ozon grain treatment technology using cavitation to ensure preservation of harvested crop without losing its quality. Currently ion-ozon technology and cavitation treatment refer to innovative technologies that are being implemented in various sectors and bring real economic benefit.

Methodology

Results of studies on identification of effectiveness of ion-ozon grain treatment technology using cavitation provides safety of harvest without loss of quality. Research object – is food wheat of "Bagornaya-56" variety, which was subject to ion-ozon treatment with and without cavitation, researches were carried out in the research laboratory of food and processing industries at Almaty Technological University.

The main part

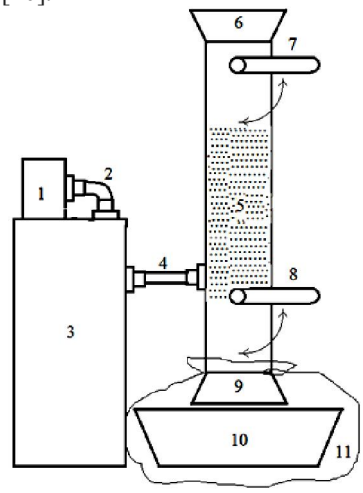
Cavitation occurs as a result of local lowering of pressure in air flow environment which occurs due to the increase of its velocity. Moving with flow to the area of higher pressure or during half-period compression, cavitation air bubble collapses, radiating a shock wave. Therefore it is not surprising that this phenomenon is often viewed as probable source of getting additional "over-unit" energy. Perhaps this is the rationality core [6].

For Kazakhstan which has great agricultural potential, production and preservation of harvested grain is of strategic importance. [7]

Increase of production, improvement of product quality and reduction of its losses, as well as acquisition of new components which have bactericidal and at the same time stimulating biological effects, are the most important tasks that have been resolved in the research laboratory of Almaty Technological University [8]. Solution of this problem involves the use of ion-ozon technology that is not widely applied in the CIS and foreign countries, and represents science on combination of many scientific trends of physico-chemical, biological, physiological, and technological impacts, as well as the newest and most unique devices for their implementation [9].

During the experiments, grain quality indicators have been determined by using state standards with the help of new generation devices. Ion concentration was determined in a small size air-ion meter MAC -01, the ozone concentration was determined by ozone gas analyzer "3.02P - P". Wheat grain was treated on ion-ozon cavitation device. Technological parameters of wheat grain treated and untreated by cavitation were determined in the

laboratory "Food security" at Almaty Technological University on the device "Infralum" FT-10 by spectroscopy method in close infrared area. Seed parameters were determined at the Department of "Technology of bakeries" in accordance with GOST 12038-84 [10].



1 – compressor; 2 – air conductor; 3 – ion-ozon device; 4 – ion-ozon mixture pipeline; 5 – cavitation device; 6 – grain filling nozzle; 7 – grain filling valve; 8 – pressure drop valve; 9 – grain drop nozzle; 10 – volume - grain collector; 11 – grain trap

Figure 1 — Principle scheme of ion-ozon cavitation device work

Ion-ozon cavitation device was made for conducting experimental studies which principal scheme is shown in Fig. 1.

Technological process of ion-ozon cavitation grain treatment is performed as follows: by compressor 1 through air conductor 2, air is supplied at pressure of 0.2 to 0.6 MPa (depending on conditions of technological treatment) to generator of ion-ozon mixture of ion-ozon device 3. Synthesized iono-ozon mixture through a pipeline 4 under pressure fills cavitation capacity device 5 with grain. Grain is delivered through pipe 6. When 2/3 of the container is filled the solenoid closes (valve) 7. After a solenoid valve closes the pressure increases to the designed and after treatment in accordance to the time exposure the valve 8 drops the pressure rapidly to atmospheric. Grain is poured into grain collection 10 through nozzle 9. The sack trap for grain 11 is provided for preserving grain stream.

Combining of electrical circuits of ion and ozone devices, allows neutralizing any harmful synthesized impurities and, ultimately, getting clean ion-ozon mixture without harmful impurities. Nitrogen and carbon oxides together with other substances and radiation in ion-ozon mixture synthesis in ion-ozon device are neutralized.

Ion-ozon treatment of seed and food grain in cavitation zone was done with increased pressure in ion-ozon cavitation device from 0.2 to 0.6 MPa at ozone concentrations of 2.0 to 6.0 g/m^3, concentration of molecular ions from 9 to 64 un/dm^3 and treatment exposure in time from 5.0 to 20.0 minutes, depending on treatment conditions.

Cavitation of ion-ozon mixture has a significant impact on grain (e.i., wheat grain endosperm shell) as the ozone explosive power is directly proportional to compression power, and ion-ozone mixture, being a powerful oxidant, produces disinfecting effect on grain and increases grain biological condition, eliminates odors, etc.

Adjustable concentration of ion-ozon mixture and controlled pressure in cavitation zone makes it possible to obtain a controlled ion-ozon cavitation at grain treatment.

For processing and analyzing of experimental data the following methods were used: multifactor experiment planning, applied mathematical statistics and regression analysis [11]. Data processing and calculations were performed using statistical software Statistica 10.0, SPSS 21, package "Data Analysis" from Excel 2013, and program sequential regression analysis PLAN developed in Odessa National Academy of Food Technologies.

During experimental data processing basic statistical characteristics of the studied parameters (criteria) of assessment of grain quality treated under certain conditions according to experiment plan were determined. For each quality indicator arithmetic mean M, error mean *m*, mediana (*med)* and mode (mod), standard average (quadrate) deviation *s,* minimum (*min* - minimum) and maximum (*max* - maximum) values and range L of sample data have been calculated; standard indicators of asymmetry A and excess E, coefficient of variation V have been calculated. Then using PLAN program regression coefficients were calculated for each quality indicator and necessary statistical characteristics of obtained equations.

For determination of the effectiveness of ion-ozon grain treatment in cavitation field we conducted two series of comparative experiments. In the first series of experiments we used ion-ozon grain treatment without cavitation, in the second – in ion-ozon grain treatment cavitation impact was used.

For reduction of the number of experiments and obtaining accurate assessment of the impact of particular factors of ion-ozon grain treatment on technological and seed indicators of grain quality, methods of multifactor experiment planning were used.

Both series of experiments focused on the following indicators of wheat grain quality:

Y_1 – protein mass share, %;
Y_2 – raw gluten mass share, %;
Y_3 – starch mass share, %
Y_4 – Green index, cm^3;
Y_5 – deformation work share, J;
Y_6 – grain hardness, IT;
Y_7 – germination energy, %;
Y_8 – germination, %.

In the first series of experiments the following three factors have been adopted as independent factors influencing on set parameters of grain quality and determination of ion-ozon grain treatment conditions: Concentration of Ci, u/dm3; Ozone concentration Co, g/m3; Treatment duration τ, min. In second series of experiments to explore joint effect of ion-ozon treatment and cavitation on grain quality indicators, besides these three factors, the fourth factor - pressure P MPa has been included.

For analyzing the impact of this factor on each of the above indicators of wheat grain quality, factors were presented in dimensionless form (coded).

The data in Table 1 shows that, depending on treatment regimes as compared with untreated grain (control), the number of indicators reduces: protein mass fraction to 0.13 ... 0.52%, specific deformation work to 10.12 ... 32.84 J, grain hardness to 13.37… 23.79 IT. Some indicators are rising: starch mass fraction to 1.55 ... 2.00%, germination energy to 7%, germination 6 ... 11%.

At the same time, such indicators as mass fraction of wet gluten and Green index depending on treatment conditions can either increase or decrease. Since mass fraction of wet gluten, in the experience 4 increased by 0.51%, and in other experiments - reduced and the largest decline (1.4%) was observed in experiment 2. Green index in experiments 4 and 8, increased respectively by 1.50 ... 1.53%, and in other experiments - reduced and the greatest decrease (3.41 cm^3) is achieved in the experiment 6.

Ion-ozon treatment causes most changes in grain hardness (variation coefficient is 5.7%), while the smallest changes - in starch mass fraction (variation coefficient is only 0.3%, which may be within experimental error).

To study the effect of each factor (C_i, C_o, and τ) on the considered quality indicators Y1 ... Y8, regression coefficients in the equations were calculated

$$Y_i = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3,$$

In which Y_i – specific quality indices (criteria);

b_i – regression coefficient, determined by method of minimum squares;

x_1, x_2, x_3 – coded values of factors respectively C_i, C_o и τ.

Due to the fact that treatment was done in coded factor type, the linear coefficient value b1 b2 and b3 (on module) shows the strength of influence of each factor Cи, Co and τ on specific quality indicators Y1…Y8, and its sign - indicates the direction of this influence.

It is seen that all three factors have almost same impact on protein mass fraction in wheat grain ion-ozon treatment. Their increase leads to less loss of protein during ion-ozon treatment. Pair interaction between Ci and Co factors is measurable with the influence of specific factors.

Ozone concentration C0 has biggest impact on wet gluten content and concentration of Ci ions is 4 times smaller and period of treatment τ. - more than 20 times smaller. Increasing of these factors also contributes to less loss of wet gluten. However, the biggest influence on wet gluten content has the combined effect of the first two factors - when they both are on the upper levels, the wet gluten content increases (experiment 4) and exceeds its content in the control experiment. It should be also noted that the described regularities are valid only for the center of experiments (where x1=x2=x3= 0), while in other experimental conditions they significantly change (due to the large value of the coefficient b12=0,36375).

As noted above, in the investigated range of factor change, ion-ozon treatment increased starch concentration. However, this increase is more observed in case of decrease of values of all three factors and concentration of ozone C0 has the biggest impact.

Influence of treatment conditions on reduction of Green index is different both in force and direction. Most strong influence has ozone concentration C0, slightly lower is ion concentration of Ci - their simultaneous increase significantly regulates Green index in ion-ozon grain treatment. When treatment period increases, Green index slightly reduces.

Influence of the considered factors on specific deformation work is also contradictory. Ion concentration C_i and duration of τ treatment have the biggest impact, however reduction of C_i and increase of τ lead to the increase of the deformation specific work. If in the center of the experiment ozone concentration C_0 has no effect on the change of Y_5, in other parts this impact is more evident (due to inter-factor interaction b_{12}=3,57125 and b_{23}= –2,86875). Note that all three inter-factor interaction coefficients exceed the effect of each specific factor, which significantly complicates the overall picture of dependence of Y_5 on ion-ozon grain treatment.

Grain hardness changes greatly depending on the duration of ion-ozon treatment τ - the lower it is, the lower is grain hardness. Joint impact of *Ci* and τ factors has significant impact as well as C_o and τ.

Increase of ozone concentration in grain treatment significantly increases germination energy. Factors C_i and τ, have less impact, and to increase germination energy, C_i should be reduced - but τ should be increased, although this trend is greatly complicated by the effects of pair interactions b_{13} and b_{23}.

Germination increase depends strongly on ozone concentration C_o – its increase leads to increase of germination. Other factors have considerably less impact.

Second series of experimental studies have investigated the influence of ion-ozon treatment of wheat grain in cavitation zone. For this purpose four factor plans of PPE -2^4 type experiments has been implemented, which includes the following regime factors: ion concentration Ci, ozone concentration Co, treatment time τ and cavitation pressure P.

Under certain treatment conditions we can achieve increase of all considered criteria Y1…Y8 exceeding the corresponding values in control experiment. However, it should be noted that only germination energy increases regardless of treatment conditions. Other criteria Y1…Y6 can increase and decrease, depending on treatment conditions, suggesting the possibility of controlling these technological parameters.

It is also seen that the average values of quality indicators in the second series of experiments (with cavitation) (except for Y3) are higher than those in the control experiments (without grain treatments), as well as average indicator values in the first series of experiments (i.e., without cavitation).

Ion-ozon treatment using cavitation makes biggest change of Green index (variation coefficient is 7.0%), while the smallest - of starch mass fraction (variation coefficient is only 0.5%).

Conclusion

In general, in both series of experiments with and withour cavitation, major role of pair interactions effects is observed, sometimes exceeding linear factor effects on values (see, for example, Y_2, Y_4 *and* Y_6 in the first series of experiments). This significantly complicates the analysis of patterns of influence of each of the considered factors on specific indicators of wheat grain throughout the whole area of factor determination.

Slight range (range change) L is observed in almost of all criteria $Y_1 \ldots Y_8$ in both series of experiments. This may indicate the need to expand the interval of factor variations, or that close optimal range of variation of criteria $Y_1 \ldots Y_8$ has been obtained. However, this requires further research that is not included into the aim of this work.

Findings

1. It has been found that the use of cavitation in ion-ozon treatment allows to purposefully influencing on changing of technological and seed indicators of wheat grain quality parameters. Ion-ozon grain treatment using cavitation has most significant effect on grain seed properties. Compared with the control, such treatment increases germination energy to16...20%, and germination to 20 ... 23 %.

2. Indicators of soft wheat grain quality: protein mass fraction, crude gluten, starch, Green index, share of deformation and grain hardness, depending on treatment conditions compared to the control, may decrease and increase, which allows to regulate them depending on further grain purpose.

3. Established patterns of change of soft wheat grain quality indices depending on treatment conditions can be used to determine optimal ion-ozon treatment regimes in cavitation zone.

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