Improving the conditioning of wheat grain when preparing it for grinding into graded flour

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Abstract. The aim of the study was to investigate the use of hydrogen peroxide when conditioning to intensify this process and improve the technological properties of grain. Winter wheat is a crop of strategic importance for agriculture and food security of the country, as it is a raw material for the production of wheat flour - a valuable food product of great consumer value, from which a wide range of bakery, confectionery and pasta products are produced. For the production of wheat flour, high-quality raw materials are needed that meet all requirements of regulatory documents. The quality indicators of wheat flour are largely determined by the initial physical and mechanical properties of grain and are controlled during the technological process of obtaining flour by a given change in these properties. Hydrothermal treatment is the most important stage in the flour production process. Optimal ratios of grain conditioning parameters are selected experimentally in production conditions, depending on its vitreousness and initial moisture content, which depend on the geography, growth conditions, transportation and storage of grain. In modern conditions, when the orderly supply of raw materials is disrupted and the production mode has lost its usual rhythm, it becomes important to search for effective technological methods of intensive processing, which make it possible to minimize the influence of a variety of initial grain properties on the quality of flour. When using hydrogen peroxide in the traditional grain conditioning technology, grain processing properties improve, as a result of which the yield of flour increases, the content of gluten in the flour increases and its quality improves, which has a positive effect on the bread produced from it. Hydrogen peroxide has also a disinfecting effect, which protects flour from being damaged by potato and other diseases and prolongs its shelf life.

1. Introduction

Wheat is one of the most widespread and valuable industrial crops in the world. More than half of the world's population consume its grain. Wheat flour is widely used in bakery, pasta and confectionery industries. Wheat bread is distinguished by high taste, nutritional properties, good digestibility. In terms of sown area and wheat grain production, the Russian Federation is in one of the first places in the world. At present, to supply flour and confectionery products to the population, the milling industry is faced with the task of increasing the production of premium flour. To solve it, the use of innovative technologies, the development of the latest high-performance equipment and other factors are essential [1-12].
When preparing grain for grinding into flour, they strive to give it properties that best ensure the desired results [1; 4; 9].

When planning the technological process for the production of premium flour with the separation of shells, it is necessary to bring the grain to such a state that provides grinding of the endosperm to a much greater extent than that of shells. Consequently, a special technological method is required that would increase the resistance of shells to the action of grinding elements of milling machines and, at the same time, preferably, destruction of the endosperm, or, at least, would not increase its strength. Then it will be possible to separate small particles of the endosperm from larger particles of shells, i.e. get premium flour [2; 10; 13-14].

Under normal conditions of stable relative humidity and ambient temperature, the moisture content of membranes is usually lower than that of the endosperm. In the technology of obtaining premium flour, this state of grain is unfavorable for grinding. The optimum condition is the one when shells have a higher moisture content than the endosperm at a certain grain moisture content. Hydrothermal treatment, called conditioning (from the Latin conditio - condition, state) leads to this state of grain, considering changes in structural and mechanical properties of its constituent parts) [3; 8; 13].

Hydrothermal treatment is not only a technological method that allows increasing the marketable mass of flour produced by increasing grain moisture, but also one of the main methods of changing the technological properties of grain, which makes it possible to improve the conditions for its processing. Conditioning significantly affects the baking value of the flour produced. Recently, there has been a large number of scientific developments to intensify the conditioning process in various ways, including using activated water obtained by heating, passing a direct current through it, exciting cavitation in it and other methods [6; 11; 15].

2. Materials and methods
The aim of the research was to study the effect of hydrothermal treatment with the use of hydrogen peroxide on the technological and milling properties of wheat grain, the positive results of which were obtained in a number of preliminary studies.

The use of hydrogen peroxide (hydrogen peroxide, H$_2$O$_2$) in grain conditioning was dictated by the following circumstances:

- This substance is a powerful oxidizing agent that can significantly activate water molecules;
- Eliminating oxygen, as an oxidizing agent, interacts with microbes, acts bactericidal, promotes grain disinfection;
- Hydrogen peroxide has a deodorizing property, capable of eliminating odor, which is important for stored grain;
- From an environmental point of view, it is important that hydrogen peroxide ultimately decomposes rather quickly into safe water and oxygen;
- It is important that the technology for producing hydrogen peroxide is simple and affordable, and the preparation is transportable, safe and cheap. Its application easily fits into the technological process at flour mills.

In the course of the work, the following tasks were set: study of the technological process of hydrothermal treatment and its effect on grain quality; study of the technological and milling properties of wheat grain when processed during conditioning with hydrogen peroxide and various degrees of moisture.

The studies were carried out in 2019-2020 in the educational laboratory of the Department of Agronomy and Agrotechnology of FSBEI HE Ryazan State Agrotechnological University and the production and technical laboratory of JSC "Ryazanzernoproduct".

The object of the research was winter wheat of variety Moskovskaya 39, grown at the agrotechnological experimental station of FSBEI HE RSATU in Ryazan region.
In the course of investigations, grain with 11% moisture content was moistened with a solution of hydrogen peroxide of various concentrations obtained by dissolving hydroperite tablets in water, according to the following experimental options: 1) to moisture content of 17% when hydrogen peroxide concentration of 1.5%; 2) up to 17% when concentration of 3.0%; 3) up to 17% when concentration of 4.5%; 4) up to 19% when concentration of 1.5%; 5) up to 19% when concentration of 3.0%; 6) up to 19% when concentration of 4.5%; 7) up to 21% when concentration of 1.5%; 8) up to 21% when concentration of 3.0%; 9) up to 21% when concentration of 4.5%. Control options had humidification without hydrogen peroxide up to a moisture content of 17%, 19%, 21%.

The required amount of solution with a temperature of 20°C was applied using manual sprayer "Zhuk" and the grain was thoroughly mixed. It must be borne in mind that the grain in the first 20-30 seconds rather quickly absorbs 3-5% moisture, but, being in the fruit shell, it can easily evaporate. Reliable retention of moisture is ensured in the process of moistening when moving it into the seed coat, the aleurone layer and further into the endosperm. The duration of heating is 16 hours at room temperature in a sealed container. In the first 1.0-1.5 hours, a very high gradient of the moisture content of the membranes and endosperm is established, as a result of which stresses arise in the surface layers of the caryopsis. This leads to uneven swelling of polymers, the appearance of microcracks, along which moisture moves deeper into the endosperm. Its wedging action reduces the strength and loosens the grain. As a result, the formation of intermediate products during the primary crushing of grain is facilitated. After this time, the grain moisture control was carried out according to the method specified in GOST.

A SESH-3M laboratory drying cabinet was used as a drying unit, from which a weighing bottle holder was removed and a metal mesh was placed on the bottom. The grain of experimental variants was placed in mesh containers in an even layer about 1 cm in height, which were installed on the mesh bottom. The mass of a grain sample before moistening was 100 g. The maximum temperature of the heat carrier (heated air) was 80°C, which was controlled and maintained by a contact thermometer. The grain of the experimental variants was dried to the original moisture content. The end of the drying time was determined by the changed grain mass corresponding to 15% moisture.

During the research, the following calculations, observations and analyzes were carried out: the mass of 1,000 grains according to GOST 10842-89, grain nature according to GOST 10840-2017, vitreousness according to GOST 10987-76, quantity and quality of raw gluten according to GOST R 54478-2011. The amount of dry gluten was determined after drying the raw gluten of the experimental variants in a SESH-3M drying cabinet at 105°C for 6 hours.

3. Results

When determining the initial indicators of grain quality, the following data were obtained (table 1).

| Moisture, % | Grain nature, g/l | Weight of 1,000 grains, g | Weed admixture, % | Grain admixture, % | Vitreousness, % | Raw gluten, % | Raw gluten quality, GDI units |
|------------|-------------------|--------------------------|------------------|-------------------|----------------|--------------|-----------------------------|
| 11         | 775               | 34.9                     | 1.4              | 3.1               | 65             | 25.3         | 100 (II gr.)               |

The investigated grain sample meets the requirements of the normative document for all the above indicators. The use of hydrogen peroxide in the process of grain conditioning has a certain effect on its technological properties (table 2).

So, analyzing the data obtained in the course of determining the technological parameters of grain of the experimental variants, which are given in table 2, a decrease in grain nature was noted.

There is a tendency for a gradual increase in the weight of 1,000 grains from 35.8 to 36.4 g with an increase in moisture and concentration of the solution.
Technological and physical-chemical changes in the grain are completed in the process of moistening. It must not be tightened because there is a uniform distribution of moisture over the anatomical parts, relaxation of tension in the grain and the meaning of this technique is lost. The moistening is stopped by drying the grain to a technologically appropriate moisture content (in this case, up to 16 %).

Table 2. Technological indicators of grain quality after moistening.

| Moisture degree, % | Hydrogen peroxide concentration, % | Parameter | Weight of 1,000 grains, g | Grain nature, g/l |
|-------------------|-----------------------------------|-----------|--------------------------|------------------|
| 17                | 0                                 | 35.8      | 770                      |
|                   | 1.5                               | 36.2      | 770                      |
|                   | 3.0                               | 36.3      | 765                      |
|                   | 4.5                               | 36.3      | 765                      |
|                   | 0                                 | 35.9      | 768                      |
| 19                | 1.5                               | 36.3      | 770                      |
|                   | 3.0                               | 36.3      | 760                      |
|                   | 4.5                               | 36.4      | 750                      |
|                   | 0                                 | 35.9      | 766                      |
| 21                | 1.5                               | 36.4      | 765                      |
|                   | 3.0                               | 36.4      | 750                      |
|                   | 4.5                               | 36.4      | 745                      |

Quality indicators after drying are shown in Table 3.

Table 3. Grain quality indicators after drying.

| Parameter                  | Grain moisture level, % | Hydrogen peroxide concentration, % | Quality group |
|----------------------------|-------------------------|-----------------------------------|---------------|
| Weight of 1,000 grains, g  | - 1.5 3 4.5             | - 1.5 3 4.5                        |               |
| Grain nature, g/l          | 35.0 35.4 35.5 35.5     | 35.5 35.2 35.5 35.6               |               |
| Vitreousness, %            | 773 773 769 771         | 759 771 772 766                    |               |
| Raw gluten, %              | 54 50 38 28             | 48 35 24 50                        |               |
| GDI units                  | 25.6 27.6 28.9 26.4     | 28.0 29.0 29.1 26.7                |               |
| Quality group              | 95 90 90 85             | 80 70 65 95                        |               |
| Dry gluten, %              | II II II II III II II I | II I I I I                         |               |
| Water absorption capacity  | 18.0 14.5 14.6 14.2     | 12.3 11.5 8.4 14.5                 |               |
| of gluten, %               | 7.6 13.1 13.6 14.7     | 11.4 15.8 17.6 20.6                |               |

The amount of raw gluten increases by 2.5 % with an increase in the concentration of hydrogen peroxide and an increase in grain moisture, and if in the variants without peroxide treatment, the amount of gluten is 25.6, 26.4 and 26.7 with a moisture content of 17, 18 and 19 %, respectively, then as a result of treating it increases from 27.6 to 29.1 %.

Against the background of an increase in the amount of raw gluten, the amount of dry gluten decreases, which indicates an increase in its water absorption capacity. This is possibly due to a change in the structure of the protein complex when exposed to hydrogen peroxide.

The vitreousness decreases when increasing moisture and hydrogen peroxide concentration, which suggests that this treatment intensifies the process of formation of microcracks, which, when determining this indicator, change the optical properties of the caryopsis and, when transmitted through a diaphanoscope, make it less transparent. When peroxide concentration of 1.5 %, it was 50, 48, 44 % at moisture of 17, 19, 21%, respectively. When 3 % concentration, it was 38, 35, 34 %.
When 4.5 % concentration, it was 28, 24, 20 % and without peroxide treatment it was 54, 53, 50 % with moisture change from 17 to 21 %.

The presented technological and physical-chemical changes in the structure of the caryopsis significantly influenced the yield of premium flour (table 4).

Table 4. The yield of milling products from grain treated with hydrogen peroxide.

| Moisture level, % | Hydrogen peroxide concentration, % | Total flour | Premium | Grade 1 | Grade 2 | Offal |
|-------------------|-----------------------------------|-------------|---------|---------|---------|-------|
| 17                | 0                                 | 71.39       | 25.68   | 35.65   | 10.06   | 24.61 |
|                   | 1.5                               | 76.30       | 28.52   | 38.7    | 9.08    | 22.10 |
|                   | 3.0                               | 76.75       | 28.33   | 40.62   | 7.80    | 20.29 |
|                   | 4.5                               | 79.97       | 29.32   | 40.35   | 10.30   | 18.02 |
|                   | 0                                 | 75.59       | 25.82   | 36.43   | 13.34   | 21.42 |
| 19                | 1.5                               | 79.59       | 27.13   | 42.73   | 9.73    | 17.63 |
|                   | 3.0                               | 80.27       | 28.61   | 39.86   | 11.80   | 18.28 |
|                   | 4.5                               | 81.66       | 29.64   | 38.81   | 13.21   | 18.00 |
|                   | 0                                 | 74.00       | 26.66   | 35.90   | 10.76   | 24.00 |
| 21                | 1.5                               | 77.46       | 26.43   | 41.03   | 10.00   | 19.99 |
|                   | 3.0                               | 70.96       | 23.76   | 37.64   | 9.56    | 27.12 |
|                   | 4.5                               | 78.21       | 26.83   | 36.82   | 14.56   | 18.94 |

The output of premium flour from the grain of the experimental variants increases with an increase in the concentration of hydrogen peroxide and moisture. This is due to an increase in the hydration activity of water and the decomposition of hydrogen peroxide into water and oxygen in the course of an explosive reaction with the release of heat, when grain microstructures are destroyed, that facilitates shell milling and endosperm grinding.

4. Discussion

When 17 % moisture and 1.5 % hydrogen peroxide concentration, the grain nature is 770 g/l. When 19 % moisture and 4.5 % peroxide concentration, this indicator decreases to 750 g/l and when 21 % moisture and 4.5 % peroxide concentration, this indicator is 745 g/l. In variants without hydrogen peroxide and moisture of 17 %, 19 % and 21 %, the nature is 770, 768 and 766 g/l, respectively. This fact indicates that when the grain is moistened, it increases its linear dimensions (swells), but at the same time the packing density decreases, the porosity of the grain mass increases, i.e. there is a smaller number of caryopses per volume unit with a change in the physical properties of the grain, namely, with an increase in the friction force of the grain on the grain, which in turn reduces the grain nature. Hydrogen peroxide increases this effect, since it activates water, which contributes to its better penetration into the caryopsis.

The change in the weight of 1,000 grains indicates an improvement in the sorption capacity of the grain when it is treated with a solution of hydrogen peroxide.

Gluten is strengthened from satisfactory low to good. In variants without peroxide, the GDI is 95 units. In variants with 17 % moisture it is 90, 90, 85 units when concentration of 1.5 %, 3 % and 4.5 %, respectively. When 19 % moisture, it is 80, 70, 65 units and, when 21 % moisture, it is 60 units in all three cases.

The increase in the amount of gluten can be explained by changes in the microstructure of the grain under the influence of hydrogen peroxide, which contribute to shell grinding and the ingestion of a larger amount of aleuronic grains located in the peripheral parts of the grain into the flour.

Gluten strengthening obviously occurs as a result of the reaction of the monomolecular phase of water, formed when exposed to hydrogen peroxide, with grain biopolymers, which leads to changes in the structure of proteins.
The maximum output of premium flour is noted at a hydrogen peroxide concentration of 4.5 % and amounts to 79.97; 81.66 and 78.21% when moisture of 17, 19, 21 %, respectively. Whereas the maximum control output is 75.59 % when 19 % moisture.

5. Conclusion
The use of hydrogen peroxide in the conditioning process of wheat grain leads to changes in quality indicators of the grain, such as the quantity and quality of gluten and an increase in flour yield. Such treatment improves the quality of the resulting flour. The disinfecting effect of hydrogen peroxide prevents damage to products by potato disease and improves storage, which also brings additional profit.

References
[1] Shchur A V, Vinogradov D V and Valckho V P 2016 Effect of different levels agroecological loads on biochemical characteristics of soil. South of Russia: ecology, development 11(4) 139-148
[2] Vasileva V 2015 Aboveground to root biomass ratios in pea and vetch after treatment with organic fertilizer. Global Journal of Environmental Science and Management 1(2) 71-74
[3] Nakayeva A A and Okazova Z P 2017 On the competitiveness of field crops. Successes of modern science 2(12) 191-195
[4] Vasileva V, Kertikov T and Ilieva A 2017 Dry mass yield and amount of fixed nitrogen in some forage legume crops after treatment with organic fertilizer Humustim. Bulgarian Journal of Agricultural Sciences 23(5) 816-819
[5] Vasileva V 2015 Aboveground to root biomass ratios in pea and vetch after treatment with organic fertilizer. Global Journal of Environmental Science and Management 1(2) 71-74
[6] Vinogradov D V, Lupova E I, Khromtse, D F and Vasileva V 2018 The influence of bio-stimulants on productivity of coriander in the non-chernozem zone of Russia. Bulgarian J. of Agric. Sc. 24 (6) 1078-1084
[7] Mustafayev M G and Mazhaysky Yu A 2018 Diagnostic Parameters of Irrigated Meadow-Serozemic and Alluvial-Meadow Soils of the Mugan-Sal’yany Massif of Azerbaijan. Rus. Agric. Sc. 44(6) 551-558
[8] Datta A K and Sengupta A K 2003 Induced autotetraploidy in coriander (Coriandrum sativum L.). Proc. of the national academy of sciences India. Section B, Biological Sciences 73(2) 171-176
[9] Cohen I S, Ibarra M A, Arriaga G E, Paredes J C, Velasquez Valle M A, Hurtado P B and Bustamante W O 2018 The impact of climatic patterns on runoff and irrigation water allocation in an arid watershed of northern Mexico. Meteorol. Hydrol. WaterManage 6(2) 59–66
[10] Ilieva A and Vasileva V 2018 Effect of liquid organic humate fertilizer Humustim on chemical composition of spring forage pea. Banat’s Journal of Biotechnology IV(7) 74-79
[11] Muller S 2014 Parameterfur die N-Dungung der Braugerste in Abhangig-keit von organischer Stickstoff (Nan) im Boden. Getreidewirtschaft 18(12) 272-273
[12] Tanner L H, Nivison M, Arnalds O and Svavarsdottir K 2015 Soil carbon accumulation and CO2 flux in experimental restoration plots, Southern Iceland: comparing soil treatment strategies. Applied and Environmental Soil Science 2015 205846
[13] Tulu T 1990 Estimation of crop coefficients for compilation of PET. International Journal of Tropical Agriculture 8(1) 49-53
[14] Wu Hengan and XuYojiu 1988 Allocation of incremental irrigation benefits. Journal of Irrigation and Drainage Engineering 114(4) 664-673
[15] White P J, Broadley M R and Gregory P J 2012 Managing the nutrition of plants and people. Applied and Environmental Soil Science 2012 104826