Technological approaches to the quality management of bakery products

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Abstract. The article studies the influence of the physicochemical properties of wheat grain on the quality indicators of bakery products. Methodological approaches to managing the quality of bakery products through the development of production solutions have been formed by varying the technological parameters of the use of wheat flour (moisture of the leaven when the leaven method of dough preparation is used) taking into account its physicochemical properties (hardness of wheat grain). Wheat grain in a wide range of hardness - from low-hard to ultra-high-hard was studied. Regulated indicators of bread quality were the volume yield of bread and the integral characteristic of the organoleptic evaluation of bread on a 100-point scale. It is shown that the increase of grain hardness of flour and gain in moisture of starter dough (the average yield by weight of bread increases by 1% when the moisture of starter dough is 8 %) lead to increasing bread’s yield by weight. To simplify the model of forming the quality of bread depending on the grain hardness and humidity of the used starter dough, a constant value of the specific work when dough kneading was used. Regression equations for the formation of white bread quality indicators with a high degree of confidence (determination coefficient 0.72-0.89) and corresponding bread quality nomograms are constructed.

1. Introduction

The problem of forming the quality of bakery products is closely related to the low quality of the used grain raw materials [1]. The technological qualities of grain and products of its processing are closely related to its structural and mechanical properties, described by indicators of strength or hardness [2]. Strength is characterized by yield strength, creep strength. Strength can be estimated by the value of the breaking force or stress at a certain type of deformation, as well as by the energy consumption per unit of the newly formed surface [3]. As a comprehensive indicator of technological properties, an indicator of grain hardness can be used, or hardness grain applied to wheat, since it is closely related to the physicochemical properties of grain [4].

The aim of the research was to study the influence of the physicochemical parameters of wheat grain on the formation of the quality of bakery products and, based on the patterns found, to develop methodological approaches to the quality management of bakery products.

In accordance with the goal, the following research objectives were formulated:

- on the basis of the analysis of literature data to determine the most significant factors in the formation of the quality of bakery products on the example of white bread produced by leaven method from wheat flour of the first grade;
2. Materials and Methods

The objects of the research were samples of 13 most common wheat varieties grown in the Orenburg region—Varyag, Orenburg 13, Orenburg 10, Uchitel, Prokhor, Bezenchukskaya Yantar, Step 3 and others [5]. The flour used as raw material was produced from grain, characterized by a wide range of hardness (from 10 to 28 kg/mm²). The flour produced by grinding in a Nagema laboratory mill corresponded to first grade flour [10]. The samples of white bread were made from wheat flour of the first grade.

Grain hardness was defined by its microhardness—the ability of grain to resist indentation—on a PMT-3 microhardness tester. The ranges of hardness values were as follows: low hardness—less than 10 kg/mm², medium hardness—from 10 to 15 kg/mm², high hardness—from 15 to 20 kg/mm², superhigh hardness—more than 20 kg/mm².

The following were analyzed as adjustable indicators of bread quality: the volumetric yield of bread, which varied in the range from 200 to 600 cm³ per 100 g of flour, and the integral characteristic of the organoleptic evaluation of bread on a 100-point scale, which varied in the range from 40 to 80 points according to the method developed at the department bakery production technology methods of Moscow State University of Food Production. This technique allows organoleptically evaluating the main quality indicators of products made from flour, given the significance of each of the indicators in a 5-point system [6]. Volume and weight yield of bread, its shape stability was determined according to GOST 27669-88 “Baking wheat flour. Laboratory test baking method”.

3. Methodology for researching quality of bakery products

The studied process of forming the quality of bakery products is conditionally reflected by the parametric scheme in Figure 1.

![Figure 1. Parametric diagram of bread production processes](image)
Following the generally accepted categorizing of factors and parameters, the following factors of forming the quality of bakery products were taken into account in the studies.

The disturbing parameters include:

\[ Q_1 \] – the external environment parameters of (pressure, humidity and temperature, other)
\[ Q_2 \] – chemical composition and quality of raw materials (including floor grain size distribution);
\[ Q_3 \] – technological deviations (mass of kneaded dough, temperature of components, humidity of raw materials and others);

The controlling parameters include:

\[ X_1 \] – grain hardness, kg/mm²;
\[ X_2 \] – amount of flour crude gluten, %;
\[ X_3 \] – quality of flour crude gluten, units of FDM;
\[ X_4 \] – moisture content of raw materials (flour), %;
\[ X_5 \] – flour ash content, % (whiteness indicator, flour grade);
\[ X_6 \] – falling number, s;

The controlled parameters include:

\[ Z_1 \] – dough moisture content, %;
\[ Z_2 \] – dough temperature, °C;
\[ Z_3 \] – dough kneading time, s;
\[ Z_4 \] – specific dough kneading intensity, kW/kg;
\[ Z_5 \] – specific mechanical work for dough kneading, kW*s/kg;
\[ Z_6 \] – proofing time, min;
\[ Z_7 \] – amount of raw materials (wheat, water) for optimal weight of kneaded dough, kg;

The observed (measured or calculated) parameters include:

\[ Y_1 \] – moisture content of ready products, %;
\[ Y_2 \] – acidity of ready products, deg;
\[ Y_3 \] – porosity, % (specific volume in cm³ per 100 g of flour);
\[ Y_4 \] – form stability;
\[ Y_5 \] – COS (complex organoleptic score), point;
\[ Y_6 \] – shelf life, days;
\[ Y_7 \] – weight yield, %.
\[ Y_8 \] – structural and mechanical properties of crumb.

Since the leaven method is inherently more technologically flexible compared to the non-leaven method, the bread was produced according to the recipe for white bread from wheat flour of the first grade according to GOST 26987-86 "White bread from wheat flour of the highest, first and second grades" pan and hearth leaven method [7]. Preparation of raw materials for bread production, calculation of the main and auxiliary components were carried out according to the collected book "Technological instructions for bakery products".

The following requirements are imposed on pan bread: crumb moisture should be not more than 45.0%; crumb acidity should be not more than 3.0 degrees; the crumb porosity should be not less than 68.0%.
The flour was produced from the studied wheat grain samples in the Nagema laboratory mill, then laboratory baking was performed from the studied flour samples. Samples of leaven were prepared with the moisture content varying from 41% to 72% in 1% increments to cover the entire possible range of humidity used in the production of jars. Based on the quality indicators of the produced bread samples (volumetric yield, shape stability, overall score, weight yield of bread), the optimal moisture content of the dough was established. The dough was kneaded in the MTVK-80 dough mixing machine, later experiments were repeated on factory dough mixing machines.

The minimum weight yield of white bread from flour of the first grade with a pan mass of 0.75 kg was 136.1%, that of bread with a hearth mass of 0.5 kg was 131%. The calculated value of the weight yield should correspond to the planned one or exceed 1-2%. The calculation of the amount of water for kneading dough is based on this planned weight output.

To simplify the model for the formation of the quality of bread depending on the hardness of the grain and the moisture content of the used dough, a constant value of the specific work was used when mixing the dough for all bread samples. The duration of the kneading test was set based on the optimal specific work of the kneading test (40 J/g).

4. Results
The obtained results include equations of the dependences of bread quality indicators on the structural and mechanical properties of the feedstock and the technological parameters of the dough preparation—the moisture content of the leaven selected for the production (Figures 2, 3 and 4):

- **V** is volumetric yield, cm³ per 100 g of flour;
- **H / D** is form stability;
- **Est** is total score;
- **B** is weight yield, %;
- **X₁** is grain hardness, kg/mm²;
- **X₂** is leaven moisture content, %.

Studies have shown that flour from low-hardness grain (with hardness up to 14 kg/mm²) allows producing bread with the highest possible volumetric yield with a minimum moisture content of leaven of 40%; with an increase in hardness to obtain maximum volumetric yield of bread, leaven with a humidity of 50-55% should be used. However, the maximum possible weight yield of bread from the flour of the initial grain hardness of up to 14 kg/mm² is achieved by using leaven with higher moisture content (up to 70%).

The regression equations of the quality indicators of bread show the features of their formation under the influence of hardness of grain and moisture content of the leaven.

\[
V = 79,518 \cdot X₁ - 15,313 \cdot X₂ - 3,489 \cdot X₁^2 + 0,0015 \cdot X₂^2 + 0,852 \cdot X₁ \cdot \bar{O}_2 + 224,099
\]

\[
V = 79,519 \cdot X₁ - 15,153 \cdot X₂ - 3,489 \cdot X₁^2 + 0,852 \cdot X₁ \cdot \bar{O}_2 + 220,063
\]

\[
H / D = 0,099 \cdot X₁ - 0,0179 \cdot X₂ - 0,0041 \cdot X₁^2 + 0,0012 \cdot X₁ \cdot X₂ + 0,1813
\]

\[
Est = 14,124 \cdot X₁ - 2,657 \cdot X₂ - 0,620 \cdot X₁^2 + 0,157 \cdot X₁ \cdot X₂ + 23,185
\]

\[
B = 0,251 \cdot X₁ + 0,107 \cdot X₂ + 128,713
\]
To simultaneously maintain high product quality (which can be estimated by the high volumetric yield) and its profitability (which can be estimated by the high weight yield), it is recommended that a compromise be reached between them when choosing leaven moisture. Such moisture content will allow high-quality bread with a sufficiently high weight yield to be produced. The situation changes when using grain flour with a hardness of 14-15 kg/mm²: the optimal leaven moisture content for bread with the best quality indicators (volumetric yield, overall score) varies from 50 to 55%. For flour
from high-hardness grain (above 22 kg/mm²) it is preferable to use leaven with a moisture content of above 55%, this will also provide the maximum volume and weight yield of bread. However, the quality of the resulting bread is low compared to that produced from medium-hardness grain, which is why it is preferable to use such flour as an improver.

Figure 4. Nomogram of the weight yield of white bread from wheat flour of the first grade

The weight yield of bread increases linearly with increasing hard grain from which the flour was produced, and also linearly increases with increasing moisture content of the leaven (on average by 1% with an increase in moisture by 8%).

Diagrams of changes in bread quality indicators demonstrate the preference for leaven moisture depending on the hardness of the original grain. The maximum possible values of volumetric yield and weight yield for flour from grain with a given hardness in most cases are achieved by using leavens with different humidity. For example, for grain flour with a hardness of 13 kg/mm², the maximum volumetric yield is 475 cm³/100 g of flour when using a leaven with 40% of moisture; maximum weight yield of 139.8% is reached when using a leaven with 70% of humidity.

5. Conclusion
Judging by the results of the studies, the main indicators of the quality of bakery products (volumetric yield, shape stability, overall score, weight yield of bread) can be predicted based on the physical and chemical properties of wheat grain (grain hardness) and production parameters (leaven moisture).

The regression equations for the formation of indicators of the quality of white bread are characterized by high values of the determination coefficient (0.72-0.89), which indicates their reliability. Based on them, for clarity and simplicity of decision making on the preferred moisture content of the leaven and the forecasting of the quality indicators of the bakery products, corresponding nomograms were plotted. Quality control of bakery products is possible by choosing the moisture of the leaven with the leaven method of dough preparation, taking into account information about the hardness of grain, which served as a raw material for the flour.
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