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Evaluation of the effect of hot conditioning regimes on flour yield and quality characteristics during the industrial preparation of wheat grain for flour milling

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This study investigated the effect of different hot conditioning regimes on flour yield and quality characteristics during the industrial preparation of wheat grain for flour milling. Industrial-scale experiments were conducted using local wheat grain under production conditions at “Don Xalq-Rizqi” JSC. Wheat samples were hydrothermally treated with water at 20, 35, 45, and 60°C while maintaining a target grain moisture content of 15.5 ± 0.2% and a tempering period of 24 h. The effects of conditioning temperature on flour yield, semolina yield, flour whiteness, wet gluten content, gluten deformation index (IDK), falling number, and damaged starch content were evaluated using standard analytical methods. The results showed that conditioning at 45°C provided the most favorable technological performance, producing the highest flour whiteness, improved gluten quality, and stable flour yield without causing excessive starch damage. The obtained findings demonstrate that optimizing hot conditioning parameters enhances the separation of bran and endosperm during milling, improves flour quality, and increases processing efficiency. These results provide a scientific basis

for implementing optimized hot conditioning regimes in industrial flour milling and contribute to improving the technological and baking quality of wheat flour.

Keywords

wheat grain, hydrothermal treatment, hot conditioning, flour milling, flour yield, flour whiteness, gluten quality, gluten deformation index (IDK), falling number, damaged starch.

Introduction

The quality of the wheat grain milling process is largely determined by the biomechanical properties of the grain layers. Therefore, the conditioning process prior to milling is considered a critical technological stage that regulates moisture distribution within the grain tissues [1, pp. 327–345].

Differences in the endosperm structure of soft and hard wheat grains play a decisive role in selecting appropriate conditioning duration and processing conditions. The optimization of conditioning regimes contributes to improved milling efficiency and reduced energy consumption [2, pp. 189–193].

Previous studies have demonstrated that structural changes in the wheat endosperm may occur within the first hour of conditioning, indicating the rapid response of the internal grain structure to hydrothermal treatment.

Wheat grain consists of the aleurone layer and several outer bran layers [3, p. 127;]. Owing to their different water permeability characteristics these tissues represent the primary target of the conditioning process.

It is well established that flour yield and quality are strongly dependent on grain moisture content [4, p. 46]. Results obtained using magnetic resonance imaging (MRI) have confirmed that, during grain hydration, water primarily penetrates through micropores, embryonic tissues, and the outer bran layers. Similar non-uniform moisture distribution has also been observed in other cereal grains.

During conditioning, the endosperm becomes softer while the bran layers become stronger, facilitating more efficient separation during milling and consequently improving flour quality. Nevertheless, the physicochemical mechanisms occurring within the grain during conditioning have not yet been fully elucidated. Moisture and

temperature significantly influence the elasticity and brittleness of the bran layers, thereby affecting milling performance. Furthermore, due to differences in cell wall composition and the presence of protective outer tissues, moisture distribution within the grain remains heterogeneous.

Materials and Methods

The study was carried out using local wheat grain samples intended for flour milling. The physicochemical and technological characteristics of the grain were determined according to national and international standard methods. The evaluated parameters included grain moisture content, vitreousness, thousand-kernel weight, ash content, protein content, wet and dry gluten content, gluten quality, and enzymatic activity. In addition, the influence of hydrothermal treatment on these quality indicators was investigated.

Grain vitreousness was determined in accordance with GOST 10987–76 using both the visual cassette method and cross-sectional analysis. Whole and partially vitreous kernels were counted, and the total vitreousness was calculated according to the standard procedure. Grain moisture content was determined by the air-oven drying method following GOST 13586.5–2015, while ash content was measured according to GOST 10847–74 using a muffle furnace.

Wet gluten content and gluten quality were determined according to GOST 13586.1–68. Wet gluten was obtained by washing dough prepared from ground wheat samples, and its content was expressed as a percentage of flour weight. Gluten quality was evaluated using the IDK-5M gluten deformation meter, whereas dry gluten content was determined after drying the wet gluten to constant weight.

Hydrothermal treatment (HTT) was applied as the main technological operation before milling to modify the structural and mechanical properties of wheat grain. The primary objective of HTT was to soften the endosperm, strengthen the bran layers, promote uniform moisture distribution, and improve flour yield and quality during milling. The amount of water required to achieve the target grain moisture was calculated using the standard moisture balance equation.

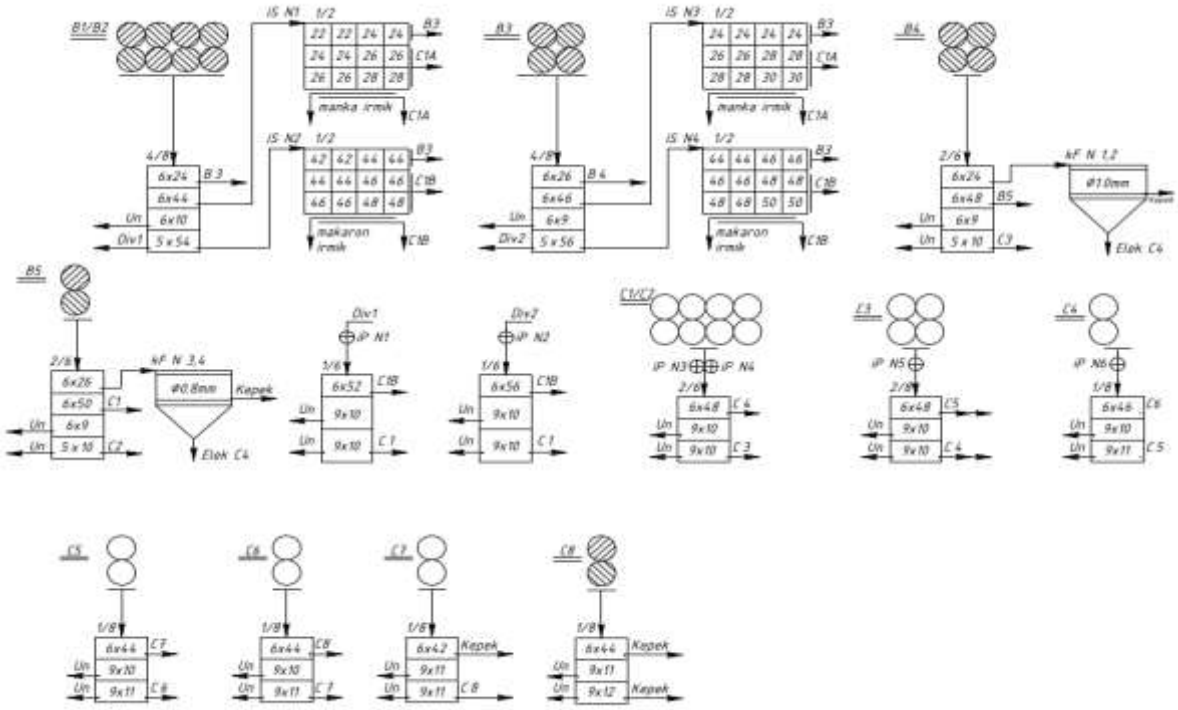
Three hydrothermal treatment methods were evaluated: cold conditioning, hot conditioning, and accelerated conditioning. Cold conditioning consisted of grain moistening followed by tempering and is widely used because of its low energy consumption. Hot conditioning involved moistening the grain with heated water to accelerate moisture diffusion, whereas accelerated conditioning combined moistening, heating, and short-term tempering to intensify the process. The optimum temperature, target moisture content, and tempering duration for each treatment were selected based on preliminary laboratory experiments.

3. Results and discussion

Hydrothermal treatment is one of the key technological stages in the preparation of wheat grain for flour milling, as it stabilizes the technological properties of the grain, facilitates the separation of anatomical components into individual fractions, improves milling efficiency, and enhances the quality characteristics of the resulting flour. Therefore, this study evaluated the effects of different hot conditioning regimes on flour yield and quality characteristics under industrial production conditions.

The industrial experiments were carried out at “Don Xalq-Rizqi” JSC in accordance with the current Regulations for Organizing and Conducting Technological Processes in Flour Mills. Wheat grain batches were initially cleaned and subjected to dry surface treatment before hydrothermal treatment with water at 20, 35, 45, and 60°C. All experiments were performed at a target grain moisture content of 15.5 ± 0.2% with a total tempering period of 24 h. These conditions were selected to promote the elasticization of the bran layers, optimize the mechanical properties of the endosperm, and improve the efficiency of fraction separation during milling.

Figure 1. Technological flowchart of the industrial-scale experimental process for preparing wheat grain for flour milling under production conditions.



To evaluate the influence of hydrothermal treatment regimes on wheat milling performance and flour quality, the following technological indicators were determined: flour yield, intermediate product yield, total flour and semolina yield, flour whiteness, wet gluten content, gluten deformation index (IDK), falling number, and damaged starch content. These parameters provide a comprehensive assessment of the technological performance and baking quality of flour obtained under industrial milling conditions.

Table_1

Effect of Hot Conditioning Regimes on Flour Yield and Quality Characteristics of Wheat Grain under Industrial Milling Conditions

Grain Class	Water Temperature (°C)	Flour (g)	Semolina (g)	Flour + Semolina Yield (%)	Flour Whiteness	Wet Gluten (%)	IDK (units)	Falling Number (s)	Damaged Starch (UCD units)
Class I	20	376	374	75.0	49.1	27.4	76.5	505	28.0
Class I	35	373	380	75.3	50.9	27.3	75.8	516	28.0
Class I	45	374	378	75.2	52.3	27.4	74.6	528	27.8
Class I	60	371	377	74.8	52.1	27.5	77.5	526	28.1

Class II	20	384	364	74.9	50.5	26.7	82.5	490	28.0
Class II	35	378	375	75.1	52.0	26.7	81.2	470	28.0
Class II	45	380	372	75.0	52.9	26.6	79.6	470	27.8
Class II	60	377	371	74.8	51.8	26.7	82.4	457	28.1

According to the results presented in Table 1, the combined flour and semolina yield for Class I wheat increased from 75.0% at 20°C to 75.3% at 35°C and 75.2% at 45°C. These results indicate that conditioning at 35–45°C improved the elasticity of the bran layers and promoted more efficient separation of the endosperm, thereby enhancing milling performance. However, at 60°C, the combined yield decreased to 74.8%, suggesting that excessively high conditioning temperatures have a limited positive effect on technological efficiency.

A similar trend was observed for Class II wheat, where the flour and semolina yield reached 75.1% at 35°C and remained at 75.0% at 45°C. Flour whiteness reached its maximum value at 45°C for both grain classes, increasing to 52.3 units for Class I and 52.9 units for Class II. This finding indicates that fewer bran particles entered the flour under these conditioning conditions. Although the wet gluten content remained almost unchanged, the improvement in the gluten deformation index (IDK) at 45°C suggests enhanced gluten quality. Furthermore, the damaged starch content remained within a narrow range of 27.8–28.1 UCD units, confirming that the selected hot conditioning regimes did not cause excessive mechanical damage to starch granules during the milling process.

Conclusions

Overall, the results demonstrated that hydrothermal treatment with water at 45°C under industrial conditions represents the most suitable conditioning regime, providing the best combination of flour yield, flour whiteness, gluten deformation index (IDK), and falling number. The obtained findings are consistent with those observed under laboratory conditions, confirming the reliability and reproducibility of the selected hydrothermal treatment parameters.

The flour samples produced under the optimum conditioning regime provide a scientific basis for further industrial-scale baking trials and comprehensive evaluation of bread-making quality. At this stage, the relationship between the technological characteristics of flour and the quality of finished bakery products can be verified under real production conditions. Consequently, the optimal hot conditioning regime can be assessed not only on the basis of laboratory measurements but also through its performance in industrial milling and baking processes. The results provide a reliable scientific and practical foundation for implementing the proposed hot conditioning regimes in flour milling and bakery industries, contributing to consistent product quality, more efficient utilization of wheat grain, and improved production efficiency.

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