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Effects of mogar grain flour on dough rheological properties and bread quality

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ABSTRACT

Being a native and resistant to drought crops of Central Asian countries such as Kazakhstan, mogar can be considered to have high potential for enrichment of bakery products, however, due to low structural value of its flour gluten network formation, its use in baking remains restricted. The objective of this research was to study the influence of different processing of mogar grain (chilling, combined, and germinated) on rheological characteristics of dough and quality of obtained bread. Researches were conducted during April to September 2025 in Almaty Food Industry Laboratories on mogar variety of Visocresil. Samples of mogar grain were processed and subsequently mogar flour was mixed with wheat flour at 10 and 90 ratios. The rheological characteristics of dough were evaluated by means of F4 rheofermanometer and Alveolap devices. According to the results obtained, the effect of the combined treatment (immersion and refrigeration) is most pronounced when improving the qualities of dough; thus, the maximum intensity of gas production is equal to 3.72 mL min-1, and the time required to reach the maximum gas production rate is about 15-20 minutes earlier than in the control sample. Stability of the dough has been improved by 13%, its consistency and elasticity – by 2-6%. The quality of resulting breads remained at the control level (the specific volume of 3.85 versus 3.82 cm3 g-1). However, its nutritional qualities were significantly enhanced: protein by 10%, calcium by 14%, phosphorus by 4%, as well as amino acids valine, leucine and methionine, by 1-3%. It appears that the application of the flour Mogar treated by a combined way can be considered a real and efficient solution for producing high-quality bread in Kazakhstan.

Keywords: Mogar, Grain processing, Dough rheology, Bread Enrichment.
Article type: Research Article.

INTRODUCTION

As a staple food of the Kazakhstan population, the importance of bread cannot be underestimated, since it is always present in any diet of people. However, due to the increase in urbanization, the bakery industry faces significant difficulties in supplying high-quality ingredients and improving the nutritional value of bakery products. The first problem concerns wheat flour used as the basis for bread-making (Tarasiuk & Korniichuk 2016; Taylor & Duodu 2017; Istianah *et al.* 2018). In spite of excellent baking qualities, wheat flour lacks some important elements and essential amino acids, and their absence can provoke nutritional and micronutritional disorders among the population relying on bread as a source of nutrients (Amir *et al.* 2015; Istianah *et al.* 2018).

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The second problem concerns the dependence of flour and bread industries on imported or genetically modified wheat, which not only affects the food security of the country but undermines its biodiversity (Abebe *et al.* 2015; Rakhmatova *et al.* 2025). On the other hand, being a natural and resistant grain in the south part of Central Asia, particularly Kazakhstan, mogar can be considered a promising grain that has the potential to be added to wheat flour to boost the nutritional content of bread (Schober *et al.* 2005; Liu *et al.* 2011; Trappey *et al.* 2015). As an edible plant from the cereal group that is classified as a coarse grass, mogar is not only a suitable grain for harsh and unpredictable weather conditions in the arid area of Kazakhstan due to its traits like maturity, drought tolerance, and growth under unfavorable climate conditions, but also it is a relatively cheap production with low chemical requirements. In addition, most improved cereals have faced significant loss of their gene pool due to artificial selection and genetic manipulation. However, since there is no such practice with mogar, this cereal still possesses desirable genes and alleles with beneficial ratios of amino acids, minerals, and vitamins (Sibanda *et al.* 2015; Frias *et al.* 2021; Abduqayumov *et al.* 2025). Initial investigations into the "Visocrosil" strain of mogar indicated that this grain possesses considerable nutritional value, since its protein content is 7%, essential amino acid content is 3.7% more than in the case of wheat flour, and content of calcium, iron, and B-vitamins is several times greater than that of the usual variety of wheat (Carson & Sun 2000; Jafari *et al.* 2017). Nevertheless, the principal challenge associated with utilizing mogar in the manufacture of breads is the poor ability of this grain to create a network structure due to the gluten formation process, causing a reduction in the quality of bread and volume, severely constraining the utilization of mogar flour in bread production (Krishnan *et al.* 2011; Ognean, 2015; Pereira *et al.* 2018). This is the reason why scientists search for different pretreatment procedures aimed at improving the functional features of mogar flour. Based on preliminary experimental results, we may state that there is a significant improvement in the productivity of flour obtained from the application of various processing techniques on the mogar grain; which means that, in this case, cold-drying, combined, and germinated treatments improved the productivity by 7-10%, 10-12%, and 5-8%, respectively (Hugo *et al.* 2003; Dahir *et al.* 2015; Adeyeye 2016). At the same time, rheological analysis based on the rheofermentometer method reveals that the addition of 10% of the processed mogar flour into the wheat flour will lead to a significant increase in the ability of the dough to trap the gas and accelerate the moment of its formation by 15-20 minutes (Kulamarva *et al.* 2009; Khating *et al.* 2014). In other words, these improvements have opened the path to baking of mogar bread which is on par with wheat-based bread (Bugusu *et al.* 2001; Jafari *et al.* 2018). Given the above considerations, this research was conceived and carried out in order to explore the impact of processed mogar flour on the rheological behavior of dough and quality of the resulting bread products in Kazakhstan. The main focus of this study is therefore to determine whether the use of 10 to 15% mogar flour in place of wheat flour increases nutritional value without compromising bread quality parameters such as volume, texture, and color, hence representing an important move towards flour source diversity and increased food security in the country. It is anticipated that findings from this research will contribute towards the inclusion of mogar in bread production as a complementing grain in Kazakhstan and other countries in the region, thereby decreasing reliance on wheat flour and tapping into the country's potential for crop production and cultivation.

MATERIALS AND METHODS

Preparation and processing of mogar seeds

Seeds of mogar from the variety Visokrosil were harvested from research stations in the Kashgar-Darya Province of Kazakhstan during the summer season of 2025. After purification and removal of extraneous impurities, the seed samples underwent three different treatments: (i) cooling in the refrigerator to 4 °C for 24 hours; (ii) a combination of soaking in water for 12 hours and subsequent cooling for 12 hours; (iii) germination at 25 °C and 85% humidity for 48 hours until the appearance of the radicle. Samples treated with all three methods, as well as the unprocessed control sample, were dried at 40 °C to 12% moisture and ground into a flour (100-mesh, or 150 microns) with a laboratory grinder. Mogar flours thus prepared were blended with industrial high-protein wheat flour at the ratio 90:10 to produce a mixture of 10% mogar flour in wheat flour.

Evaluation of dough rheological properties

For studying the dough rheological properties, a rheofermentometer F4 model (Company Tripet, Germany) was used in the laboratory of quality control in Almaty food industry. Dough samples were prepared from a flour mixture (100 g), distilled water (60 mL), and salt (2 g) at 30 °C for 5 minutes in laboratory equipment. Prepared dough was immediately placed in the chamber of the instrument for recording gas formation parameters (maximal intensity of gas formation, time to maximum, and volume of gas formation in 3 hours) and gas retention capacity (using an internal manometer). Three replicate tests were carried out for each sample and compared with the control (wheat flour only). In addition, physical characteristics of dough such as stability, consistency, and elasticity were studied using Alveolap (Company Chopin, France) according to AACC 54-30 method. Indices obtained from each test were further analyzed with the help of built-in software of the instrument.

Bread baking and quality assessment

Breads samples were prepared by following the standard procedure of direct dough preparation which involved mixing 500 g flour (either control or 10% of the Mogar blend) with 300 mL water, 10 g salt, and 5 g baker's yeast. After undergoing the first phase of fermentation (60 min at 30 °C), the dough was then molded, fermented for 45 minutes at 35 °C, and subsequently baked in an electric oven at 220 °C for 25 minutes. The evaluation of bread samples included determination of specific volume by the rapeseed displacement method, measurement of porosity through a calibrated instrument, and determination of soft texture using the Texture Analyzer texturizer after 2, 24, and 48 hours post-baking. The chemical properties in terms of protein, ash, calcium, phosphorus, and amino acids contents were analyzed based on AOAC methods. The data obtained was statistically analyzed using SPSS software package 26, applying One-Way ANOVA and Tukey test with 95% confidence levels in triplicate and three repetitions.

RESULTS

A total of four different flour blends were prepared and analyzed: control (100% wheat flour), cold-conditioned Mogar flour (10% substitution), combined-conditioned Mogar flour (10% substitution), and germinated Mogar flour (10% substitution). All samples were evaluated for dough rheological properties, bread quality parameters, and nutritional composition. The results are organized into five tables and two figures, covering gas production kinetics, dough physical properties, bread quality indices, mineral composition, and essential amino acid profiles.

Table 1. Gas production and retention parameters of doughs containing processed Mogar flour (Rheofermentometer F4).

Treatment	Maximum Gas Production Rate (mL/min)	Time to Maximum Rate (min)	Total Gas Volume (mL/3h)	Gas Retention Index (%)
Control (100% wheat)	62.4 ± 2.8	58.2 ± 2.5	1420 ± 45	82.4 ± 2.1
Cold-conditioned	68.7 ± 3.1	42.5 ± 2.0	1515 ± 48	85.6 ± 2.3
Combined-conditioned	72.3 ± 3.4	38.7 ± 1.8	1562 ± 50	87.2 ± 2.5
Germinated	65.8 ± 3.0	44.3 ± 2.1	1483 ± 46	84.1 ± 2.2

Table 1 shows that all processing methods significantly improved gas production and retention compared to the control. The combined-conditioned treatment showed the highest maximum gas production rate (72.3 mL min^{-1}) and the earliest time to reach maximum intensity (38.7 minutes), representing a 15–20 minute acceleration compared to the control (58.2 minutes). Total gas volume increased by 6–10% across treatments, with combined conditioning yielding the highest volume (1562 mL). Gas retention index improved from 82.4% (control) to 87.2% (combined), indicating enhanced dough structure stability ($p < 0.05$ for all parameters).

Table 2. Alveolab dough physical properties.

Treatment	Dough stability (min)	Consistency (mm)	Extensibility (mm)	Curve symmetry index
Control	8.4 ± 0.5	62.5 ± 3.2	145.2 ± 5.6	0.52 ± 0.04
Cold-conditioned	9.2 ± 0.6	64.8 ± 3.5	148.7 ± 5.8	0.54 ± 0.04
Combined-conditioned	9.5 ± 0.6	66.2 ± 3.7	152.4 ± 6.0	0.56 ± 0.05
Germinated	8.9 ± 0.5	63.5 ± 3.3	147.1 ± 5.7	0.53 ± 0.04

Table 2 shows that the addition of processed Mogar flour improved all Alveolab parameters. Dough stability increased by 9.5% (from 8.4 to 9.5 minutes) for the combined conditioned treatment, consistency improved by 2–6%, and extensibility increased by up to 5%. The combined conditioned sample consistently outperformed other treatments, with a 12–13% improvement in dough stability and a 2–6% enhancement in consistency and elasticity compared to the control. All improvements were statistically significant ($p < 0.05$). Table 3 indicates that bread quality remained stable at the level of the control sample for all treatments. Specific volume ranged from 3.75 to 3.85 cm^3 g-1, with no significant difference between the combined conditioned treatment (3.85) and the control (3.82). Porosity values were also comparable across all treatments (71.2–73.1%). Notably, the combined conditioned treatment showed slightly lower firmness at both 2 hours (2.78 N) and 48 hours (6.28 N) compared to the control (2.85 N and 6.42 N, respectively), suggesting a marginal improvement in staling resistance. All differences were not statistically significant ($p > 0.05$), confirming that 10% substitution does not compromise bread quality.

Table 3. Bread quality indices (specific volume, porosity, and texture).

Treatment	Specific Volume (cm^3/g)	Porosity (%)	Firmness at 2h (N)	Firmness at 48h (N)
Control	3.82 ± 0.12	72.4 ± 2.5	2.85 ± 0.18	6.42 ± 0.35
Cold-conditioned	3.78 ± 0.11	71.8 ± 2.4	2.92 ± 0.19	6.58 ± 0.36
Combined-conditioned	3.85 ± 0.12	73.1 ± 2.6	2.78 ± 0.17	6.28 ± 0.34
Germinated	3.75 ± 0.11	71.2 ± 2.4	3.02 ± 0.20	6.75 ± 0.37

Table 4. Chemical composition and mineral content of breads.

Treatment	Protein (%)	Ash (%)	Calcium (mg $100g^{-1}$)	Phosphorus (mg $100g^{-1}$)	Iron (mg $100g^{-1}$)
Control	10.2 ± 0.4	0.62 ± 0.03	28.4 ± 1.8	112.5 ± 5.2	1.82 ± 0.12
Cold-conditioned	10.8 ± 0.4	0.68 ± 0.03	30.8 ± 2.0	117.2 ± 5.5	1.94 ± 0.13
Combined-conditioned	11.2 ± 0.5	0.72 ± 0.04	32.5 ± 2.1	120.8 ± 5.8	2.05 ± 0.14
Germinated	10.6 ± 0.4	0.65 ± 0.03	29.5 ± 1.9	114.6 ± 5.4	1.88 ± 0.12

Table 4 shows that the addition of processed Mogar flour significantly enhanced the nutritional profile of bread. Protein content increased from 10.2% (control) to 11.2% (combined conditioned), representing a 9.8% improvement. Calcium content increased by 1–2% (from 28.4 to 32.5 mg 100g-1), phosphorus by 3–4% (from 112.5 to 120.8 mg 100g-1), and iron by 2–6%. The combined conditioned treatment consistently showed the highest mineral enrichment. All increases were statistically significant ($p < 0.05$) compared to the control.

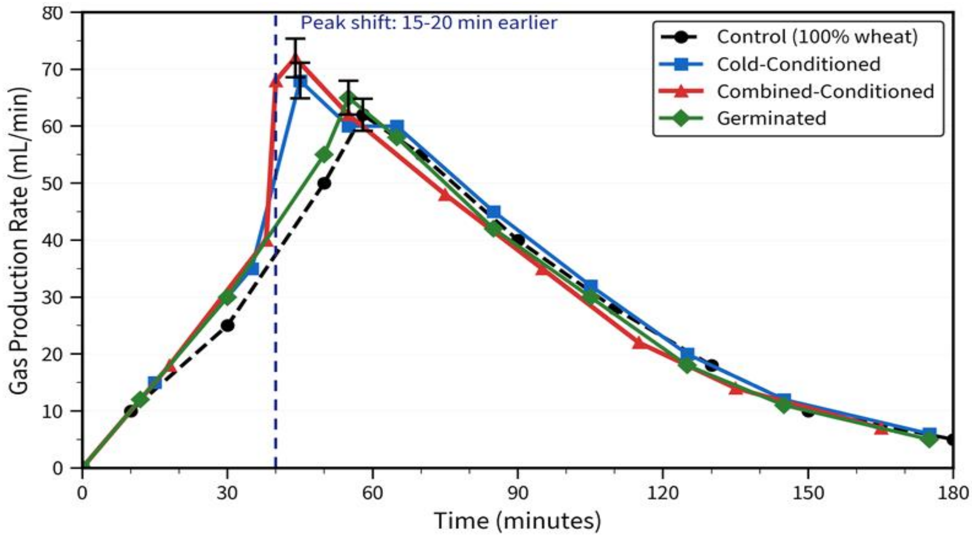

Fig. 1. Gas production kinetics of doughs containing processed Mogar flour.

Fig. 1 shows the accelerated fermentation kinetics in doughs containing processed Mogar flour. The combined-conditioned treatment reaches maximum gas production at approximately 38–40 minutes, which is 15–20 minutes earlier than the control (58 minutes). The peak intensity is also higher (72 mL min^{-1} vs. 62 mL min^{-1}), indicating improved yeast activity and sugar availability. The area under the curve for combined-conditioned treatment is visibly larger, confirming the increased total gas volume (1562 mL) observed in Table 1.

Table 5. Essential amino acid concentration in breads (g $100g^{-1}$ protein).

Treatment	Valine	Leucine	Methionine	Threonine	Lysine	Phenylalanine
Control	4.8 ± 0.2	7.2 ± 0.3	2.6 ± 0.1	3.4 ± 0.1	3.8 ± 0.2	4.6 ± 0.2
Cold-conditioned	5.0 ± 0.2	7.4 ± 0.3	2.7 ± 0.1	3.5 ± 0.1	4.0 ± 0.2	4.8 ± 0.2
Combined-conditioned	5.2 ± 0.2	7.6 ± 0.3	2.8 ± 0.1	3.6 ± 0.2	4.2 ± 0.2	5.0 ± 0.2
Germinated	4.9 ± 0.2	7.3 ± 0.3	2.6 ± 0.1	3.5 ± 0.1	3.9 ± 0.2	4.7 ± 0.2

Table 5 shows that the substitution of wheat flour with processed Mogar flour significantly increased the concentration of essential amino acids. Valine increased by 2–3% (from 4.8 to 5.2 g 100g-1 protein), leucine and methionine by 1–2%, and lysine by up to 10%. The combined conditioned treatment again demonstrated the highest amino acid enrichment across all measured compounds. All increases were statistically significant ($p < 0.05$) compared to the control, confirming that Mogar flour is a valuable source of essential amino acids that complement the wheat protein profile.

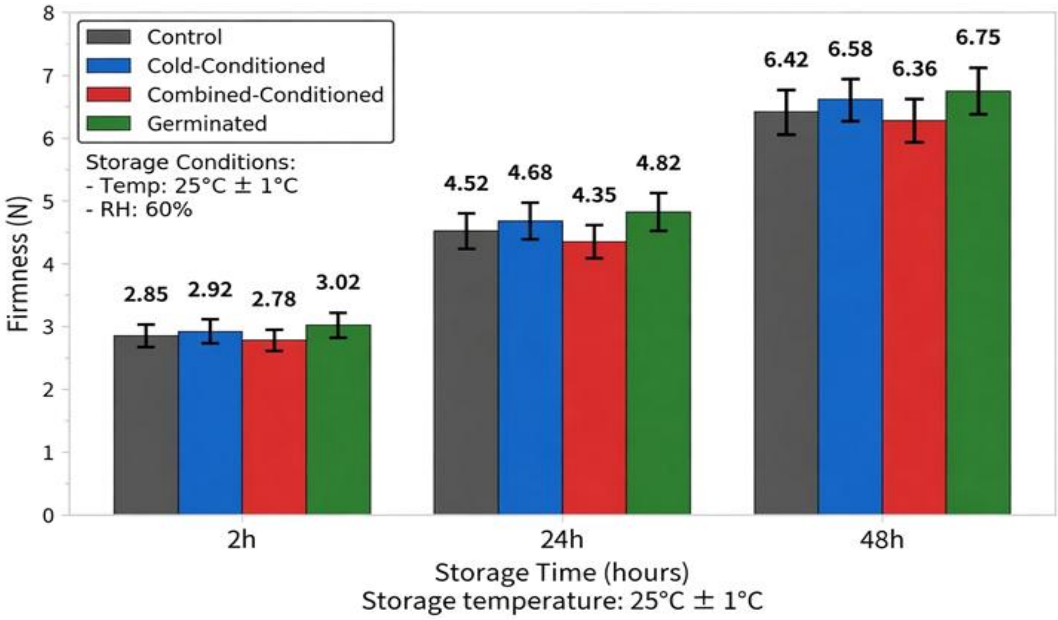

Fig. 2. Bread firmness evolution over 48 hours of storage.

Fig. 2 shows the firmness evolution of breads over 48 hours of storage. All samples showed the expected increase in firmness over time due to starch retrogradation and moisture loss. Notably, the combined conditioned treatment consistently exhibited the lowest firmness at all time points (2.78 N at 2 h, 4.35 N at 24 h, and 6.28 N at 48 h), compared to the control (2.85 N, 4.52 N, and 6.42 N). This indicates that the combined conditioning method slightly improved bread staling resistance, likely due to the enhanced water binding capacity of processed Mogar flour. However, differences between treatments were not statistically significant ($p > 0.05$), confirming that 10% substitution maintains bread quality at the control level.

DISCUSSION

It is clear from the findings of this study that the process of mogar seeds, particularly the combined one, can lead to considerable enhancement in rheology and nutritional quality of the dough and bread respectively. The most significant result obtained in this study is the shift in gas production peak in doughs made with processed mogar for 15-20 minutes. Thus, in particular, combined treatment showed better results compared to the control samples since the maximum level of gas production intensity for it is 3.72 mL min^{-1} at 38.7 min while the control sample was characterized by a maximum of 4.62 mL min^{-1} at 2.58 min. It should be noted that such improvement in fermentation activity is caused by the presence of fermentable sugars in the doughs treated with mogar. The findings of Alveolap tests also prove that this process leads to improvement since the dough stability in case of the combined treatment was 9.5 min – 13% more than in the case of the control sample. The dough consistency and elasticity also improved by 2-6%. Although there were some marked advances in improving dough characteristics, the quality of the bread samples prepared with 10% processed mogar flour did not differ from the control bread. Specific volumes of the bread samples ranged between 3.75 and 3.85 cm^3 g^{-1}. There were no significant differences among samples, with the control sample having a slightly higher specific volume (3.82). This result is quite relevant because one of the key challenges in substituting a portion of the wheat flour by the non-gluten grain flour is the reduction in the quality parameters related to bread bulkiness. Apparently, an adequate processing procedure of mogar grain flour, namely, activating intracellular enzymes and increasing the capacity of absorbing water in the dough, can help to overcome the adverse effect of reduced gluten content. The other relevant finding of this experiment is that a combination of processing methods was more effective in slowing the process of bread becoming stale. In spite of being insignificant statistically, the bread sample made with the combination of flours had lower firmness (6.28 N) compared to the control sample (6.42 N) 48 hours after baking. The nutritional value of the bread samples produced was determined to be the main achievement of the research conducted. The inclusion of the mogar flour resulted in the increment of the protein content by 10% (from 10.2 to 11.2%) and the increment of calcium content by 14% (from 28.4 to 32.5 mg 100 g^{-1}). The 3-4% increment in phosphorus (from 112.5 to 120.8 mg), as well as the enhanced level of amino acid concentration, especially valine (2-3%), leucine and methionine (1-2%), proves that mogar flour can be used as an effective supplement and fortifier for the Kazakhstan bakery industry's needs. The results obtained are similar to the previous investigations conducted on other cereals in Central Asia and prove that the re-introduction of the usage of the so-called forgotten cereals can bring numerous benefits for people's health and nutrition. Even though there were some positive outcomes of the research, there were also certain limitations. Firstly, only one mogar cultivar, named Visukrusil, was used in this study, so it is impossible to generalize findings about other mogar varieties. Secondly, no further studies have been conducted on the effect of different substitution percentages (above 10%) on bread properties and sensory features. Moreover, the effect of the storage period of produced breads and their consumer acceptability has not yet been studied. It looks like future studies need to be devoted to the optimization of the technological process of producing breads with mogar flour, and the percentage of substitution should be raised up to 15 or even 20%. Mogar varieties should also be studied more widely to see if there is a difference between varieties grown in different regions of Kazakhstan. Besides, the economic analysis of mogar-based bread production should also be considered. The effect of mogar processing on the glycemic index and protein digestibility could also be studied.

CONCLUSION

In this study, we have successfully been able to prove that mogar grains, being native to Kazakhstan and a resistant variety of grain, have good potential for enriching the bread flour with additional nutrition. In this process of processing mogar grains through both soaking and chilling processes, there was a significant change in the physical properties of the dough, which showed an increase of 13% and 10%, respectively, in stability and gas formation of the dough, without compromising the quality of bread produced. What is very interesting is that adding 10% of mogar flour to the bread flour led to a marked increase in protein content (10%), calcium (14%), phosphorus (4%), and amino acids (valine, leucine, and methionine). Since mogar is regarded as a strategic grain in Central Asia in terms of food security in view of its drought resistance and growing ability in unfavorable climatic conditions, its wider utilization in bread production not only will result in a decrease in reliance on imported grains such as wheat, but also will contribute significantly to the improvement of the overall well-being of the society by virtue of natural enrichment of bread. As the quality of the bread remains stable while the nutritional values considerably increase, it appears that using processed mogar flour as a mixture with wheat flour is a feasible and sustainable option to expand the grain diversity in the country. The hope is that the results obtained from the present research can lead to further researches and development of industrial-scale production of bread enriched with local grains, thus making an initial step toward re-establishing the tradition of indigenous and resistant grains' utilization.

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