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Investigation of wheat gluten properties and its effect on bread quality

Inna Hetman
PhD, Senior Researcher
Institute of Food Resources of the National Academy of Agrarian Sciences of Ukraine
02002, 4-A Ye. Sverstyuk Str., Kyiv, Ukraine
https://orcid.org/0000-0002-9448-9956

Ivanna Lukianchuk
Postgraduate Student
Institute of Food Resources of the National Academy of Agrarian Sciences of Ukraine
02002, 4-A Ye. Sverstyuk Str., Kyiv, Ukraine
https://orcid.org/0009-0007-4876-0470

Oksana Naumenko
Doctor of Technical Sciences, Professor
Institute of Food Resources of the National Academy of Agrarian Sciences of Ukraine
02002, 4-A Ye. Sverstyuk Str., Kyiv, Ukraine
https://orcid.org/0000-0002-1691-1381

Volodymyr Kovbasa
Doctor of Technical Sciences, Professor
National University of Food Technologies
01033, 68 Volodymyrska Str., Kyiv, Ukraine
https://orcid.org/0009-0001-8876-3373

Liubov Tkachenko*
PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-2731-1178

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**Corresponding author*

Abstract. Enriching bakery products with hemp flour increases their nutritional value, but the absence of gluten requires the addition of structure-forming additives, such as wheat gluten. However, technological indicators and the impact on the dough system of various samples of wheat gluten presented on the Ukrainian market remain unexplored. The purpose of the study was to analyse the effectiveness of wheat gluten from various manufacturers to improve the rheological properties of dough and the quality of wheat-hemp bread. It was shown that in the gluten samples "Viten-Vital" and "Gluvital 21020", the largest fraction was prolamins, 69.2% and 68.59%, respectively, and a smaller amount contained glutelins: 21.91% and 30.45%, respectively. In the "BeneoPro VWG 75" and "NVG-Vital" samples, the average distribution of these fractions was approximately 50:50. It was found that the introduction of wheat gluten in the amount of 3% by weight of flour increased the amount of raw gluten by 25.5-27.6%, depending on the sample. Based on the results of trial laboratory baking, it was established that wheat-hemp bread with gluten "BeneoPro VWG 75" or "NVG-Vital" had the best quality in terms of a combination of indicators: volume, porosity, and freshness retention. Bread with the gluten sample "Gluvital 21020" was characterised by a 7.7% higher specific volume than in the control, but its porosity increased slightly. The established differences in the technological indicators of wheat gluten from different manufacturers can help in the correct choice of this raw material for use in the production of wheat bread varieties, in particular, with the addition of hemp flour

Keywords: hemp flour; sourdough; quality indicators; nutritional value; bakery products

Introduction

The consumer value of bakery products is determined by many factors, among which a significant place is occupied by physical and chemical indicators, terms of freshness preservation, and nutritional value. These characteristics depend primarily on the recipe ingredients and how the dough is prepared (Sciacca *et al*., 2023). One of the most promising additives for enriching bakery products is non-narcotic cannabis seeds and processed products. The high interest in using cannabis seeds in the food industry is conditioned by its valuable chemical composition. According to I. Švec & M. Hrušková (2015) and S. Kornpointner *et al.* (2021), hemp products can contain up to 25-35% oil, 20-25% protein, 20-30% carbohydrates, 20-30% dietary fibre, vitamins and minerals (calcium, zinc, magnesium, phosphorus, potassium, sulphur, and iron), omega-3 and omega-6 fatty acids, which are also in an optimal ratio for the human body. Most non-conventional ingredients, having low technological properties, can reduce the volume and porosity of bread, hold the shape of products, etc. This is especially true if a certain percentage of wheat flour is replaced in the recipe with a functional ingredient. A significant deterioration in the physical and chemical parameters of finished products in this case leads to restrictions in the dosage of functional ingredients and, as a result, the nutritional value of bread does not improve significantly. Thus, the research conducted by S. Gunko *et al*. (2024) showed that the inclusion of grain processing products, alternative types of flour, in particular, from hemp seeds in bread recipes worsened the structural and mechanical properties of dough and bread, but positively affected the organoleptic parameters and nutritional value of products.

An effective technological solution can be the use of structure-forming additives, among which wheat gluten (WG) deserves special attention. Dry wheat gluten, or wheat gluten, is a complex of protein components that do not show solubility in aqueous or saline solutions. According to M. Schopf *et al*. (2021), this substance retains its native protein properties, since its direct isolation from grain is carried out by separation, followed by mechanical processing (grinding) and dehydration (drying). The technological process includes pre-cleaning and hydration of wheat grains, after which they are ground to produce a whole kernel. The next step involves crushing the kernel to maximise the release of starch. The resulting suspension containing protein and starch is centrifuged (separated) to concentrate the protein fraction. The final product – wheat gluten – is dried and packaged.

One of the reasons for using WG is the unsatisfactory quality of wheat grain flour grown in too hot or rainy regions, and therefore, it contains a reduced amount of protein (Kryzhanovskiy, 2022). This problem is even more acute, as with the beginning of Russia's full-scale invasion of Ukraine, the geography of wheat cultivation has changed, and the number of acreage has decreased due to the occupation of certain regions and the threat of military operations. Data by D. Zhygunov *et al.* (2023) regarding the quality of wheat grain presented on the market, it is shown that only 15-20% of wheat can produce varietal flour, in particular the highest grade. One of the key motivations for using wheat gluten is the lack of protein in the modern diet, which is critical for human health. Accordingly, enriching food products with gluten is a simple and effective method of increasing their protein value. As stated by X. Zhang *et al.* (2021), WG is widely used not only in baking, but also in other sectors of the food industry, such as meat processing and dairy.

The Ukrainian market offers WG samples only of foreign production, which differ in cost. However, there is no scientific data on their technological characteristics and impact on the quality of finished bread, which requires research. The purpose of the study was to investigate the technological properties of millet gluten from various producers and their impact on the development of consumer characteristics of bread with functional vegetable raw materials. To achieve this goal, the following tasks were set: to determine the effect of WG on the quantity and quality of gluten; to investigate the effect of WG on the quality of dough (gas-forming ability, mass fraction of moisture, titrated acidity, lifting force, gas-holding capacity of the dough for the period of fermentation and proofing, shape-holding capacity, fermentation duration, proofing duration); to study the effect of WG on physical and chemical parameters, and the preservation of freshness of wheat-hemp bread.

Materials and Methods

The research was conducted between June and August 2025 at the Department of Bread Technology and Biotransformation of Grain Products of the Institute of Food Resources of the National Academy of Agrarian Sciences of Ukraine (IFR NAAS). Raw materials were used for the test laboratory baking: wheat flour of the highest grade (LLC "Nash Mlyn", Ukraine), whole grain hemp flour (LLC "Agrosnab", Ukraine), hemp seeds (LLC "Agrosnab", Ukraine), pressed baking yeast (PJSC "Enzim Company", Ukraine), sugar (LLC "Sarkara-Group", Ukraine), table salt (SE "Artemsil", Ukraine), sunflower oil (SE "Santrade", Ukraine). The following manufacturers of WG were used: sample No. 1 – "BeneoPro VWG 75" (manufacturer "Beneo", Belgium); sample No. 2 – "Viten-Vital" (manufacturer "Roquette", France); sample No. 3 – "NVG-Vital" (manufacturer "Viresol", Hungary); sample No. 4 – "Gluvital 21020" (manufacturer "Cargill", Poland).

Physical and chemical parameters of wheat flour of the highest grade: mass fraction of moisture – 12.8%; whiteness – 55 units of the device; number of drops – 220 seconds; ash content – 0.4% to dry matter (DM). Physical and chemical parameters of whole-grain hemp flour: mass fraction of moisture – 9%; acidity – 4.8 degrees; mass fraction of metal and magnetic impurities – no more than 0.0003%; no foreign impurities. Physical and chemical parameters of hemp seeds: mass fraction of moisture – 10.2%; seed purity – 99.0%; mass fraction of oil – 38.7% per DM; no impurities of castor seeds, poisonous weeds. Physical and chemical parameters of WG samples are presented in Table 1.

Table 1. *Physical and chemical parameters of wheat gluten samples*

Indicator	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Mass fraction of moisture, %	5.5	8.0	8.0	5.9
Mass fraction of protein, %	83.7	83.0	83.0	83.5
Ash content, %	1.0	2.0	1.0	1.0
Granulometry, particles >200 μm	2.0	1.0	3.0	1.0
Water binding capacity, %	156.0	160.0	155.0	154.0

Source: compiled by the authors

Bread was made according to the recipe of "Wheat-hemp" bread according to TU 00419880.068:2023, IFR NAAS. Recipe for a control sample of bread, g: premium wheat flour – 240; whole-grain hemp flour – 30; hemp seeds – 30; pressed baking yeast – 4.5; table salt – 4.5; sugar – 6.0; water – 180. In prototypes of bread (4 pcs.), WG was added in the amount of 3% by weight of the flour mixture (9 g), the remaining ingredients and the amount of water remained unchanged. The preparation of the samples consisted of sifting bulk raw materials and mixing flour with seeds (in prototypes also with GP) to form a dry flour mixture. Yeast was introduced as a yeast suspension by mixing with water in a ratio of 1:3. Salt and sugar were added as solutions with concentrations of 26% and 50%, respectively. Water for the preparation of solutions and suspensions was subtracted from the total amount of water intended for kneading. The further technological process of production took place in the same way for both the control sample of bread and prototypes.

The dough was prepared in a non-paired way, mixing solutions, suspension with flour mixture for 5-7 minutes in a KVL4100S dough mixing machine (China). Next, the dough was left to ferment. The fermentation duration was (100 ± 2) min at (32 ± 2)°C until the volume increased by 1.5 times. The dough was divided into dough pieces weighing (250 ± 2) g, shaping was carried out manually. Proofing of samples was carried out for (36 ± 2) minutes at a temperature of (35 ± 2) °C in a proofing cabinet XLT 133-UNOX (Italy), the weight of dough pieces was (290 ± 10) g. The readiness of dough pieces during the proofing process was determined by their volume. Then the dough pieces were sent to the Unox XFT133 oven (Italy), where they were baked at a temperature of 180-200°C for (32 ± 2) minutes.

To determine the raw gluten content of the flour mixture, a dough was kneaded, which consisted of 40 g of premium wheat flour, 5 g of whole-grain hemp flour, 5 g of hemp seeds, 1.5 g of WG for each of the samples and 28 cm^3 drinking water at temperature (20 ± 2)°C. The results were compared with a control sample of the dough without WG, the amount of other ingredients and water remained unchanged. Gluten was taken at a concentration of 3% by weight of flour. Raw gluten was washed from the kneaded dough manually and the raw gluten content was determined in accordance with DSTU ISO 21415-1:2009 (2011). In raw gluten, hydration capacity, elasticity (quality index), and stretchability were determined according to the generally accepted methods described by V. Ionescu *et al.* (2010). The obtained results of gluten elasticity and stretchability were the basis for assessing the quality of gluten, assigning gluten to a certain quality group according to the method developed by V. Drobot (2019).

The fractional composition of proteins was determined by the Osborne method, which is based on extraction in various solvents, followed by firing of fractions by the Kjeldahl method, which was described by R. Horax *et al.* (2011). The mass fraction of dough moisture was determined by express drying on the Chizhov device ("Olis" LLC, Ukraine) according to V. Drobot (2019). Gas-forming ability of the dough – by volumetric method on the AG-1M device, which is described in the paper by G. Munteanu *et al.* (2019). The gas retention capacity of the dough from flour mixtures was based on the change in the volume of samples from the beginning of fermentation to the moment when the dough falls off in measuring cylinders at a temperature of 30°C, which is described by A. Shevchenko *et al.* (2023). The shape-holding capacity of the dough was determined by the method of spreading the dough ball, by changing its diameter during fermentation at a temperature of 30°C for 180 minutes, which was described in the paper by C. Verheyen *et al.* (2015). The lifting force of the dough was determined by the surfacing of the dough ball, the titrated acidity of the dough was determined by the titrimetric method, according to I. Hetman *et al*. (2021).

Determination of organoleptic and physico-chemical indicators of the quality of finished bread (mass fraction of moisture, acidity, specific volume, shape stability, porosity) was carried out 4 hours after baking in accordance with DSTU 7045-2009 (2010). The moisture content of bread was determined by the standard method of drying the suspension in a drying cabinet SESH-3M (LLC "UkrAnalityka", Ukraine) at a temperature of 130°C, described in DSTU 7045-2009 (2010). Porosity was studied using the Zhuravlev device (LLC NVF "Standard-M", Ukraine), described by C. Verheyen *et al*. (2015). Shape stability (ratio of the height of the loaf (H) to its diameter (D) was measured on the IFC device; the volume of bread was determined using the OHL brand device, according to the methods described by I. Hetman *et al*. (2021). The acidity of titrated bread was determined by the titrimetric method according to DSTU 7045-2009 (2010). The duration of preservation of bread freshness was evaluated during its storage of 24, 48, 72 hours by changes in the fragility of bread and the amount of water absorbed by the crumb (water absorption capacity). These indicators characterise the freshness of bread or the degree of staleness.

To assess the crumbiness of bread, two samples were taken in the form of parallelepipeds, each weighing 5 g. These pieces were placed in a conical flask with a volume of 250 cm^3 and stirred on a vibrating mixer for 5 minutes. Crumbs formed as a result of mutual friction of the samples were carefully collected and weighed with an accuracy of 0.01 g. The final calculations were performed according to the method described by V. Drobot (2019). Analysis of the water absorption capacity of the crumb began with its preliminary grinding. A sample weighing 3 g was selected from the crushed mass, which was transferred to a special sieve (with 12 holes per 1 cm^2). Within five minutes, 17 cm^3 of distilled water was added to the sample using a pipette. The moistened crumb was collected from a sieve and re-weighed for further calculations. Statistical processing of the obtained data was performed using Microsoft Excel 2016 software suite. The number of repetitions for each experiment was $n = 3$. The results obtained were considered reliable at the significance level of $p \leq 0.05$.

Results and Discussion

According to V. Drobot (2019), the composition of gluten fractions plays an important role in determining its strength and effectiveness in ensuring the necessary rheological characteristics of dough. Prolamine fractions, in particular, gliadin protein, and glutelins (glutenin protein) are involved in the development of the gluten framework. The fractional protein composition of 4 wheat gluten samples was studied, the results are presented in Table 2.

Table 2. Fractional composition of wheat gluten

Indicator, unit of measurement	Wheat gluten			
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Albumins (water fraction), g	3.20±0.02	0.08±0.02	0.17±0.02	1.14±0.02
Prolamins (alcohol fraction), g	47.20±0.95	69.20±0.95	53.44±0.1	67.59±0.05
Globulins (salt fraction), g	1.20±0.02	8.81±0.02	2.02±0.02	0.82±0.02
Glutelins (alkaline fraction), g	48.50±0.95	21.91±0.05	44.38±0.05	30.45±0.02
"Prolamins/glutelins" ratio	0.97	3.2	1.2	2.2

Note: sample No. 1 – WG "BeneoPro VWG 75" (Belgium); sample No. 2 – WG "Viten-Vital" (France); sample No. 3 – WG "NVG-Vital" (Hungary); sample No. 4 – WG "Gluvital 21020" (Poland)
Source: compiled by the authors

It was found that in samples No. 2 and No. 4, the determining fraction was prolamins (69.20 g and 67.59 g, respectively) and a smaller amount of glutelins (21.91 g and 30.45 g). As a result, the "prolamine/glutelin" ratios for these samples had the highest values, 3.2 and 2.2, respectively (Table 2). That is, such gluten, due to the dominant prolamins, will work perfectly in a dough system with elastic gluten to weaken it or for categories of products in which the dough needs greater stretchability (for example, for pita bread). In samples No. 1 and No. 3, there was no significant predominance of any of the fractions, in general, the distribution of gluten fractions was 50:50 with minimal values of the "prolamine/glutelin" ratio, respectively, 0.97 and 1.2. This means the equilibrium effect of such gluten on the stretchability and elasticity of the dough, it is more suitable for a dough system with low elasticity, medium or long gluten stretchability, which needs to be increased. It should be noted that researchers and manufacturers have not sufficiently substantiated what the ratio of "prolamins/glutelins" should be for the best effectiveness of gluten. M. Schopf & K. Scherf (2020) reported in their studies that "ideal gluten" should contain 60-70% prolamins and 40-30% glutelins. According to V. Drobot *et al*. (2005), gluten quality determines the "prolamins/glutelins" ratio, which should have a minimum value that ensures high gluten quality. However, a stable correlation between quality and the "prolamine/glutelin" ratio has not been established, since V. Dhaka & B. Khatkar (2015) suggest that this is also directly affected by the nature of the gluten proteins glutenin and gliadin.

Based on the results of the fractional composition of WG from different manufacturers, it was established that for a wheat-hemp dough system, which is characterised by stretchy, weak gluten with low elasticity, it is better to add gluten No. 1 or No. 3. According to C. Verheyen *et al*. (2015), wheat dough is a complex system in which processes such as hydration, swelling, structure formation, and protein peptisation occur continuously. These dynamic changes are crucial for the development of its structural and mechanical characteristics. Flour proteins have the ability to absorb a significant amount of water, mainly by an osmotic mechanism. This leads to their intense swelling and, as a result, to the establishment of an internal gluten framework in the dough. The strength of this protein structure directly depends on the amount and quality of gluten, which ultimately affects the elastic properties of the dough, its consistency, and ability to retain gas. It is the gas-retaining function, together with the gas-forming one, that is critical for the volume of finished bread and the porosity of its crumb. To determine the effectiveness of WG from different manufacturers, its effect on the quantity and quality of gluten was determined. Table 3 shows the results of the conducted studies.

Table 3. *Effect of wheat gluten on the quantity and quality of gluten in the dough*

Indicator, unit of measurement	Samples of wheat-hemp dough				
	Control	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Raw gluten content, %	25.4±0.5	35.1±0.5	34.1±0.5	34.2±0.5	35.0±0.5
Hydration capacity, %	168.1±2.0	162.0±2.0	169.8±2.0	164.6±2.0	170.5±2.0
Dry gluten content, %	10.2±0.2	11.1±0.2	11.1±0.2	12.9±0.2	13.3±0.2
Stretchability, cm	13±0.5	10±0.5	14±0.5	11±0.5	14±0.5
IDC (quality index), conventional units	80.9±2.0	68.6±2.0	70.5±2.0	67.0±2.0	78.1±2.0

Note: control – without WG; sample No. 1 – WG "BeneoPro VWG 75" (Belgium); sample No. 2 – WG "Viten-Vital" (France); sample No. 3 – WG "NVG-Vital" (Hungary); sample No. 4 – WG "Gluvital 21020" (Poland)
Source: compiled by the authors

It was found that the addition of WG significantly affected the state of gluten in the dough in all samples of wheat-hemp dough. The amount of raw gluten increased by 25.5-27.6%, depending on the sample, and was 34-35% compared to 25.4% in the control. In samples No. 2 and No. 4, an increase in the hydration capacity of gluten was observed, which made the dough more stretchable and less elastic (Table 3). This is not suitable for the wheat-hemp dough system under investigation, as it may impair the quality of the finished products. Samples No. 1 and No. 3 by stretchability and elasticity (quality index), gluten can be characterised as a quality group "Good" according to classification by V. Drobot (2019). The use of WG in these samples resulted in a 15.4-23.0% reduction in gluten stretchability. This should have a positive impact on the quality of finished products. The results obtained are consistent with the previous ones (Table 2) and indicate that gluten samples No. 1 and No. 3 are the most suitable for use in the formulation of wheat-hemp bread. R. Kaushik *et al.* (2015) made similar conclusions that the use of WG in the amount of 1 to 3% gluten by weight of wheat flour allows controlling the level of stretchability of the dough, improve other rheological characteristics of wheat dough, obtaining flour of a given quality, and enhancing the ability of the dough to absorb water. To finally determine the effect of WG on the dough system, trial laboratory baking of wheat-hemp bread was carried out with a gluten dosage of 3% of the flour weight. Table 4 shows the results of studies of wheat-hemp bread from WG of various manufacturers.

Table 4. *Influence of wheat gluten on the technological process, bread quality*

Indicator, unit of measurement	Samples of wheat-hemp dough, bread				
	Control	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Dough					
Fermentation time, min.	100±2				
Proofing time, min.	36±2				
Baking time, min.	32±2				
Mass fraction of moisture, %	43.8±0.2	44.3±0.2	43.9±0.2	44.3±0.2	43.7±0.2
Accumulation of CO_2, cm^3	1,088.0±5.0	1,098.0±5.0	1,080.0±5.0	1,070.0±5.0	1,080.0±5.0
Gas retention capacity, cm^3	138±1.0	130±1.0	136±1.0	131±1.0	133±1.0
Shape-holding capacity, mm	72±1.0	67±1.0	74±1.0	68±1.0	74±1.0

Table 4. Continued

Indicator, unit of measurement	Samples of wheat-hemp dough, bread				
	Control	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Bread					
Mass fraction of moisture, %	43.4 ± 0.2	43.8 ± 0.2	43.2 ± 0.2	43.8 ± 0.2	43.1 ± 0.2
Specific volume, g/cm^3	2.6 ± 0.1	2.9 ± 0.1	2.4 ± 0.1	2.9 ± 0.1	2.8 ± 0.1
Porosity, %	66.0 ± 1.0	72.0 ± 1.0	74.0 ± 1.0	70.0 ± 1.0	67.0 ± 1.0
Shape stability (H/D)	0.64 ± 0.1	0.62 ± 0.1	0.66 ± 0.1	0.61 ± 0.1	0.65 ± 0.1
Acidity, deg	2.4 ± 0.2	2.4 ± 0.2	2.5 ± 0.2	2.4 ± 0.2	2.4 ± 0.2

Note: control – without WG; sample No. 1 – WG “BeneoPro VWG 75” (Belgium); sample No. 2 – WG “Viten-Vital” (France); sample No. 3 – WG “NVG-Vital” (Hungary); sample No. 4 – WG “Gluvital 21020” (Poland)
Source: compiled by the authors

The data in Table 4 show that in all samples with the introduction of WG, the gas retention capacity of the dough improved by 1.4-5.8% compared to the control. The shape-holding capacity improved only in samples No. 1 and No. 3 – by 5.6-7.0%, compared to the control. In dough samples No. 2 and No. 4, shape retention worsened by 2.8%. This is probably conditioned by differences in the fractional composition of proteins of different types of gluten and the specifics of the effect of fractions on the gluten framework of wheat-hemp dough. In terms of gas formation, no significant differences were recorded between the samples. Analysis of finished products showed that bread with gluten sample No. 1 had a specific volume increased by 11.5%, porosity by 9.0% compared to the gluten-free control. The shape stability of bread with gluten No. 1 and No. 3 was better by 3.1-4.8% compared to the control. Gluten-free bread sample No. 2 had a high porosity index – 6% more than in the control, but had a lower volume and shape stability of 8% and 3.2%, respectively. Bread sample No. 4 had a high volume, 7.7% more than in the control, but the porosity increased slightly and did not meet the regulatory requirements of DSTU 7517:2024 (2025). Overall, bread with gluten samples No. 1 and No. 3 had the best quality among all the products under study. It should be noted that samples No. 1 and No. 2 differed from other bread samples with a better porosity structure. It was uniform, the pores were small, which is consistent with higher porosity indicators compared to other samples. All bread samples with WG had a more elastic crumb compared to the control bread sample without WG addition.

The results obtained are consistent with the data provided by S. Li *et al*. (2020), concluding that if there is a need to improve the porosity and increase the volume of the finished product from low-quality flour, the amount of WG can be increased from 2% to 4%, in some cases up to 6%. M. Zhang *et al*. (2022) proved that the inclusion of WG in the recipe of bakery products in the amount of up to 3% can not only improve the rheological properties of the dough, but also enrich the products with protein, reduce the content of easily digestible carbohydrates. According to data by I. Pohorielov & L. Mykonik (2021), to improve the quality of both the flour itself and bread, it is necessary to use no more than 2% WG by weight of flour; V. Drobot *et al*. (2005) suggest that the best quality indicators of bakery products are achieved if 4% WG to the weight of flour is added. However, the conducted studies show that the introduction of WG in the amount of 3% by weight of flour allows fully compensating for the lack of wheat flour in the recipe, preventing the spread of dough, and simultaneously not making the gluten strong and short-lived. The results obtained regarding the quality of the finished bread are consistent with the indicators of rheological properties of the dough with WG (gas-holding and shape-holding capacity) (Table 4). Along with the analysis of structural and mechanical properties, changes in crumb fragility and changes in the hydrophilic properties of bread during 72 hours of storage were studied (Table 5).

Table 5. *Effect of wheat gluten on the fragility of bread crumb*

Duration of storage	Fragility, % by weight of the crumb				
	Control	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
24 hours	0.7 ± 0.05	0.6 ± 0.06	0.7 ± 0.05	0.5 ± 0.05	0.5 ± 0.05
48 hours	0.98 ± 0.10	0.96 ± 0.10	0.99 ± 0.11	0.95 ± 0.10	0.94 ± 0.10
72 hours	1.4 ± 0.12	1.1 ± 0.11	1.2 ± 0.12	1.3 ± 0.12	1.2 ± 0.12

Note: control – without WG; sample No. 1 – WG "BeneoPro VWG 75" (Belgium); sample No. 2 – WG "Viten-Vital" (France); sample No. 3 – WG "NVG-Vital" (Hungary); sample No. 4 – WG "Gluvital 21020" (Poland)
Source: compiled by the authors

It was found that during storage, due to a decrease in the strength of the bread pore walls, the brittleness index increased evenly in all samples, which is explained by a gradual decrease in the mass fraction of moisture. Bread samples with different WG after 72 hours of storage had a lower brittleness by 7.1-21.4% compared to the control. The best indicator was characterised by bread sample No. 1 (Table 5). Determination of the hydrophilic properties of bread crumb showed that after 72 hours of storage, bread with WG absorbed more water compared to the control (Table 6).

Table 6. *Effect of wheat gluten on the water absorption capacity of bread crumb*

Duration of storage	Water absorption capacity of the crumb, % of water absorbed by crumb				
	Control	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
24 hours	460.8 ± 2.0	500.3 ± 2.0	505.0 ± 2.2	500.4 ± 2.1	498.2 ± 2.0
48 hours	404.8 ± 2.0	484.6 ± 2.2	420.9 ± 2.0	473.0 ± 2.0	456.2 ± 2.1
72 hours	360.5 ± 1.5	365.3 ± 1.5	383.6 ± 1.7	376.3 ± 1.6	370.0 ± 1.5

Note: control – without WG; sample No. 1 – WG "BeneoPro VWG 75" (Belgium); sample No. 2 – WG "Viten-Vital" (France); sample No. 3 – WG "NVG-Vital" (Hungary); sample No. 4 – WG "Gluvital 21020" (Poland)
Source: compiled by the authors

The obtained data indicate a decrease in staling of products with the addition of WG. All samples with gluten absorbed 2.2-5.2% more water compared to the control. The best indicator among all the samples under study was characterised by bread sample No. 1 (Table 6). Thus, based on the results of the study of the effect of each type of gluten on the dough system and the quality of bread made from a mixture of wheat and hemp flour, it was concluded that gluten samples No. 1 and No. 3 are best suited for adjusting the quality indicators of this bread. The technology of wheat-hemp bread was tested in the bakery workshop of "Pravo" LLC, Kyiv region. The effectiveness of the developed technological solutions for obtaining high-quality wheat and hemp bread has been established (Approval Certificate No. 1 dated 16.10.2023). Regulatory documentation for wheat-hemp bread TU 00419880.068:2023 was approved by the specialised tasting Commission of "Ukrhlibprom" (Act No. 5 of 31.10.2023). Scientific data on the use of WG in bakery products technologies were implemented at "Azelis" LLC in Kyiv; agreement No. 08/24/1 of 01.02.2024.

Conclusions

It was established that the use of WG tends to increase against the background of climatic and technological challenges in the bakery industry. Gluten is not produced by Ukrainian manufacturers, but there are samples of foreign manufacturers on the Ukrainian market, which causes interest in studying their properties. An analysis of the quality and impact on the dough system of WG from different manufacturers was carried out: sample No. 1 – "BeneoPro VWG 75" (Belgium); sample No. 2 – "Viten-Vital" (France); sample No. 3 – "NVG-Vital" (Hungary); sample No. 4 – "Gluvital 21020" (Poland). It was found that in samples No. 2 and No. 4, the largest fraction was prolamins – 69.2 and 68.59 g, respectively. In smaller amounts, samples No. 2 and No. 4 contained glutelins, 21.91 and 30.45 g, respectively, and the "prolamins/glutelins" ratio had the highest values among all the samples presented. In samples No. 1 and No. 3, there was no significant predominance of any of the fractions, in general, the distribution of gluten fractions was 50:50.

It was found that with the addition of WG, the amount of raw gluten in the dough samples increased by 25.5-27.6%, depending on the sample, and amounted to 34-35% against 25.4% in the control. Samples No. 1 and No. 3 for the elasticity and stretchability of gluten can be described as the quality group "Good". Due to the introduction of gluten No. 1 and No. 3, the stretchability of gluten decreased by 15.4-23.0% compared to the control, and the elasticity increased by 15.2-17.2%, respectively. Bread with gluten sample No. 1 had a higher volume of 11.5%, porosity was better by 9% compared to the gluten-free control. Bread sample No. 2 with gluten had a high porosity index – 6% higher than in the control, but the remaining indicators were low. Sample No. 4 had a high volume, 7.7% larger than in the control, but porosity did not increase significantly. All bread samples with added WG retained freshness longer in terms of water absorption and brittleness, but bread with gluten No. 1 was best preserved. Thus, it was found that gluten samples No. 1 and No. 3 are best suited for correcting the quality indicators of wheat-hemp bread. The results obtained can be used in research papers, and in industrial conditions of bakeries, bakeries, in particular, in the technological process of production of wheat bread varieties with the addition of hemp flour and hemp seeds. They will help flour milling technologists to adjust the quality of wheat flour, and technologists at bread factories and bakeries to model recipe compositions and the technological process of producing wheat bread varieties. The prospect of further research is to find other technological ways to improve dough systems with a weak gluten system and low technological properties.

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Conflict of Interest

None.

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Дослідження властивостей глютену пшеничного та його впливу на формування якості хліба

Інна Гетьман

Доктор філософії, старший науковий співробітник
Інститут продовольчих ресурсів Національної академії аграрних наук України
02002, вул. Є. Сверстюка, 4-А, м. Київ, Україна
https://orcid.org/0000-0002-9448-9956

Іванна Лук'янчук

Аспірант
Інститут продовольчих ресурсів Національної академії аграрних наук України
02002, вул. Є. Сверстюка, 4-А, м. Київ, Україна
https://orcid.org/0009-0007-4876-0470

Оксана Науменко

Доктор технічних наук, професор
Інститут продовольчих ресурсів Національної академії аграрних наук України
02002, вул. Є. Сверстюка, 4-А, м. Київ, Україна
https://orcid.org/0000-0002-1691-1381

Володимир Ковбаса

Доктор технічних наук, професор
Національний університет харчових технологій
01033, вул. Володимирська, 68, м. Київ, Україна
https://orcid.org/0009-0001-8876-3373

Любов Ткаченко

Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-2731-1178

Анотація. Збагачення хлібобулочних виробів конопляним борошном підвищує їхню харчову цінність, проте відсутність у ньому клейковини вимагає додавання структуроутворюючих добавок, наприклад, пшеничного глютену. Водночас технологічні показники та вплив на тістову систему різних зразків глютену пшеничного, представлених на ринку України, залишаються недослідженими. Мета досліджень – проаналізувати ефективність глютену пшеничного різних виробників для покращення реологічних властивостей тіста та якості пшенично-конопляного хліба. Показано, що у зразках глютену «Viten-Vital» та «Gluvital 21020» найбільшою фракцією були проламіни, відповідно, 69,2 та 68,59 %, і в меншій кількості містились глютеліни: відповідно, 21,91 та 30,45 %. У зразках «BeneoPro VWG 75» та «NVG-Vital» усереднений розподіл цих фракцій становив близько 50:50. Досліджено, що внесення глютену пшеничного в кількості 3 % до маси борошна збільшувало кількість сирої клейковини на 25,5-27,6 %, залежно від зразка. За результатами пробних лабораторних випікань встановлено, що найкращою якістю за сукупністю показників: об'єм, пористість та збереження свіжості характеризувався хліб пшенично-конопляний з глютеном «BeneoPro VWG 75» або «NVG-Vital». Хліб зі зразком глютену «Gluvital 21020» характеризувався на 7,7 % вищим питомим об’ємом, ніж у контролі, але пористість його збільшилась несуттєво. Встановлені відмінності у технологічних показниках глютену пшеничного різних виробників можуть допомогти у правильному виборі даної сировини для використання у виробництві пшеничних сортів хліба, зокрема з додаванням борошна конопляного

Ключові слова: борошно конопляне; закваска; показники якості; харчова цінність; хлібобулочні вироби