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WHEAT FLOUR QUALITY CORRECTION BY USING ENZYME PREPARATIONS

Abstract

Over the past decade, the flour milling industry has been undergoing active development, with the reconstruction of existing enterprises and increased construction of new flour mills under conditions of declining quality of incoming raw materials, high competition and low profitability of bakery enterprises and flour mills. Therefore, such enterprises should be able to produce not only standard flour but also flour with specified quality indicators. One example is flour with enhanced baking properties intended for special product groups such as loaves, baguettes, buns, etc. Standard Ukrainian flour, produced due to its low protein and gluten content, cannot always be used for these products. The aim of the study was to investigate the effect of a protease-acting enzyme preparation on the gluten network of flour and to develop a complex-acting technological additive. To study the quality of flour, both conventional and innovative evaluation methods were used with the help of the Mixolab device, and trial laboratory baking of samples was carried out. To improve the protein-proteinase complex, the enzyme preparation Neutrase 15 BG was used in three dosages: minimum (0.02 g/kg), medium (0.06 g/kg) and maximum (0.1 g/kg). For complex action, a mixture of enzyme preparations Neutrase 15 BG and Fungamyl 2500 SG in the following dosages: 0.02 g/kg + 0.002 g/kg; 0.02 g/kg + 0.005 g/kg; 0.02 g/kg + 0.01 g/kg. The paper analyses the quality of flour produced by Ukrainian producers, determines the effect of a proteolytic enzyme on the quality characteristics of gluten, evaluates the baking properties of graded flour with a proteolytic enzyme, and develops a technological additive to adjust the protein-proteinase complex of flour. The analysis of previous studies has shown that high-grade flour from the Southern region is characterised by low quality, namely a low gluten content of 24.0-25.2% with excessively resistant gluten properties of 47-60 units, and low amylolytic activity – the falling number is above 460-480 s. It has been established that at the minimum and average dosage of Neutrase 15 BG, the specific volume of bread increased by 0.5% and at the maximum – by 0.2%, with a clear deterioration in organoleptic characteristics. Therefore, it makes sense to use this enzyme in low dosages to prevent stickiness of the dough. According to the results of the influence of the technological additive on bread quality indicators, it has been found that in the sample with the following dosage of Neutrase 15 BG and Fungamyl 2500 SG – 0.02 g/kg + 0.01 g/kg, respectively, the volume and porosity of bread increased by 1.3 times and 1.1 times, respectively.

Keywords: wheat flour, graded milling, rheological properties, protein-proteinase complex, carbohydrate-amylase complex, enzyme preparation, technological additive.

Introduction

Over the past five years, the profitability of flour mills in the grain processing industry has been gradually declining due to the constant increase in competition and the decrease in capacity utilisation due to martial law [1].

Such a high level of competition is due to the availability of production facilities with identical technical equipment and the production of the same range of products manufactured by leading enterprises. In such conditions, traditional methods of reducing costs to increase profitability become ineffective, and the only possible way to improve the economic performance of an enterprise is to produce products with fundamentally new properties [2]. One of the types of innovative products of flour mills is special types of wheat flour that meet the needs of the baking industry [3]. Targeted correction of properties and production of flour with specified quality indicators allows for the most efficient use of grain resources with different properties, increases the profitability of flour mills, reduces the cost of transporting grain raw materials, meets the growing requirements for the initial quality of flour from baking enterprises, and stabilise the quality of finished products [4].

Previous studies [5, 6] have shown the effectiveness of using enzyme preparations with amylolytic and xylanase efficiency. Therefore, there is a need to study the effect of enzymes with proteolytic activity on the protein-proteinase complex of wheat flour.

Enzyme preparations have a number of advantages over other food additives. The main ones are their natural origin and high specificity of action, which allow us to ensure the absolute environmental friendliness of finished products. In addition, in practice, enzymes allow bakers to expand the range of their products and save both raw materials and energy [7].

The current trend of replacing chemical additives in flour with analogues from natural sources is determined mainly by the need to enrich food products with components that have a beneficial effect on human health. Numerous studies have highlighted the need to use enzymes to produce fibre-enriched bread, develop gluten-free products, and products with a higher content of arabinoxylans, which have a high prebiotic potential [6].

Tabl 1 – General properties of enzyme preparations

Enzymes	Improved gluten network	Increased gas-retaining capacity of dough and bread volume	Improved colour, taste, smell	Improved crumb structure	Increased shelf life
Amylase		x	x	x	x
Protease	x				
Xylanase	x	x		x	
Lipase	x	x	x	x	

The rapid development of biotechnology in the field of enzymology has made enzyme preparations an indispensable part of many food technologies. The use of enzymes can increase the speed of technological processes, significantly increase the yield of finished products and improve their quality. For the industrial production of enzyme preparations for food use, sources of animal, plant and microbiological origin are used. The different genesis of enzymes determines the conditions for their use. The modern enzyme market is largely represented by enzymes of bacterial origin, as the speed and volume of production of enzyme preparations of bacterial origin is much higher compared to enzymes of fungal origin [8].

Literary review

Щонайменше 50 % ферментних препаратів, що представлені на світовому ринку, отримують з генетично модифікованих організмів з використанням генетичної та білкової інженерії. Харчові ферменти є найбільш широко використовуваними (табл.1) на ринку виробництва усіх ферментів [9].

There are two areas of enzyme use: enzymes used to convert raw materials into the main product and enzymes used as additives to change the functional characteristics of the product. In the first case, the enzymatic process is carried out under optimised and controlled conditions to increase the catalytic potential of the enzyme, while in the second case, it is more difficult to ensure optimal conditions and control the enzymatic reaction.

Enzymes are an important ingredient used in most flour products. In recent years, enzymes have become even more important due to restrictions on the use of chemical additives, especially in bread production. However, the main reason for the use of enzymes is the steady downward trend in wheat grain quality [10].

Wheat flour is the most important ingredient for the production of bakery products. When the dough is kneaded, complex biochemical and biophysical processes are initiated, catalysed by enzymes and yeast. These processes continue during the baking phase, leading to the bread formation [9]. Additional enzymes added to the dough improve the baking process, reduce the duration of the process, slow down staling, compensate for variability in flour quality and replace chemical additives.

Enzymes are typically added to change the rheological properties of dough, increase gas production and improve crumb porosity in bread production. Enzymes can be added individually or in complex mixtures that can act synergistically in the production of flour products [10].

Several types of enzymes are used to improve the baking properties of wheat flour: amylase to convert starch into sugar and produce dextrins, oxidase to increase the strength and whiten the dough, hemicellulase and xylanase to increase the elasticity of the gluten network, and protease to strengthen and relax the gluten, respectively [8]. All of these enzymes play an important role in providing bread volume and improving the condition of the crumb and crust.

Amylolytic enzymes are the main group of enzymes used to intensify the dough preparation process and improve bread quality. α-Amylases are endoenzymes that catalyse the cleavage of α-1,4-glycosidic bonds in the internal part of the amylose or amylopectin chain. The end products of α-amylase action are oligosaccharides with an α-configuration and different lengths, dextrins, which are branched oligosaccharides. These enzymes can be derived from grain, fungal, bacterial and biotechnologically modified bacterial sources. α-Amylases break down damaged starch in wheat flour into small dextrins, creating conditions for yeast action during the fermentation, proofing and initial baking stages. The result is a high-volume bread with a good porous crumb [11].

Undamaged starch granules begin to gel at a temperature of +55°C leading to amylose 'leakage' from the granules and the start of melting of amylopectin crystallites. The viscosity of the dough increases sharply, and the dough stops rising in the oven. When α-amylases attack the gelatinised starch, the dough rising in the oven lasts longer and the volume of the bread increases. The amount of damaged starch granules depends on the type of flour and the specifics of its milling [10].

Typical enzymes include β-amylase and amyloglucoamylase, which cleave α-1,4-glycosidic bonds at the non-reducing end of the linear chains of the starch molecule, thereby catalysing the subsequent release of β-maltose and β-glucose, respectively. β-Amylases cannot cleave α-1,6-linkages, and the final products consist of maltose and β-limit dextrin. Therefore, the hydrolysis of amylopectin is incomplete, resulting in only 50-60% of its conversion to maltose. In the case of amylose, the maximum degree of hydrolysis is 75-90% due to the weakly branched structure of this polysaccharide [9].

Malt and microbial α-amylases are widely used in the baking industry. Fungal α-amylases or malt are usually added to optimise flour amylase activity, initially aimed at increasing fermentable and reducing sugar levels. Due to their low thermostability, fungal α-amylases are more suitable than malt amylases for flour stabilisation. α-Amylases and β-amylases have different but complementary functions in the bread production pro-

cess. Added α-amylases break down damaged starch particles into low molecular weight dextrins during the dough production stage, while endogenous β-amylase converts these oligosaccharides into maltose, which is used as a fermentable sugar by yeast or sourdough microorganisms [11]. The increased content of reducing sugars leads to the formation of Maillard reaction products, enhancing the taste of bread and the colour of the crust. In addition, these enzymes can improve the gas-retaining capacity of yeast dough and reduce its viscosity during starch gelatinisation, with subsequent improvements in product volume and softness [10].

Amylases play an important role in slowing down the staling of bread. Fungal amylases have little effect on staling, as they are already inactivated at the temperatures at which the gelatinisation process begins and do not interact with starch. Bacterial amylases are much more thermostable and, therefore, are able to affect amorphous gelatinised starch. Its modification significantly slows down staling, but due to their very high thermal stability, these enzymes retain some activity after baking, which leads to excessive starch breakdown and a sharp decrease in bread volume during storage after baking. Bacterial amylases can only be used in very low concentrations, but even then, there is still a risk of overdose [10].

Maltogenic amylase (glucan 1,4-α-maltohydrolase) produces maltose (and some maltodextrins) in the α-configuration. This enzyme is most active at +60-70°C and breaks down amylopectin more strongly than fungal amylases or β-amylase. In terms of thermostability, maltogenic amylase occupies an intermediate position between fungal and bacterial amylases, which is why the enzyme can reduce amylopectin retrogradation – it hydrolyses glucosidic bonds in gelatinised starch before it is inactivated during baking.

Furthermore, since this enzyme is inactivated at the end of baking, excessive hydrolysis of the starch does not occur. In addition to optimal thermal stability, maltogenic amylase has other advantages over fungal and bacterial amylases. It breaks down amylose and amylopectin into maltose and maltodextrin. However, there is one drawback to using maltogenic amylase, which is a significant increase in the cost of flour [12].

Proteases are used on a large commercial scale in the production of bread, bakery products, crackers, and waffles [13]. These enzymes can reduce kneading time, reduce dough consistency, ensure dough homogeneity, regulate gluten content in bread and improve flavour [14]. In addition, proteases have largely replaced the use of bisulfite previously added to flour to control consistency by reducing the disulfide bonds of the gluten protein, while proteolysis breaks down peptide bonds. In both cases, the end effect is a similar weakening of the gluten network.

Proteases are also used to produce cakes, biscuits, and cookies. They act on wheat flour proteins to reduce the elasticity of the gluten and thus reduce the shrinkage of the dough or pastry after shaping and puffing [15]; for example, hydrolysis of glutenin proteins, which are responsible for the elasticity of dough, significantly improves the flow factor of biscuits.

Hemicellulases are used to regulate the physical properties of gluten. They are a diverse class of enzymes that hydrolyse hemicelluloses, a group of polysaccharides that include xylan, xylobiose, arabinoxylan, and arabinogalactan [16].

In cereal crops, the predominant hemicelluloses are pentosans, which make up 2.5-4.0% of wheat flour. The most common are xylans. They are represented by water-soluble (0.5%) and insoluble (1.9%) fractions of wheat flour. Pentosans affect the rheological properties of the dough, making it resistant to stretching. Insoluble pentosans form cross-links with gluten proteins, thereby negatively affecting the elastic properties of the dough and bread quality. Soluble pentosans have a high moisture-binding capacity and can absorb 10-15 times more water than their weight. Therefore, they have a significant impact on the water absorption capacity of the dough [15].

The hydrolysis of insoluble pentosans by hemicellulases (xylanases) prevents the formation of pentosan complexes with gluten. The products of partial hydrolysis of pentosans have a high water-retaining capacity, which contributes to coagulation processes – the formation of the gluten network. Hydrolysis products (xylo-oligosaccharides) prevent starch from interacting with proteins, which slows down the staling of bread. The hydrolysis of pentosans produces arabinose and xylose, which are involved in melanoid formation [16].

Lipolytic enzymes were used much later than other enzymes. Lipases hydrolyse the ester bonds of acylglycerols to form mono- and diacylglycerols, free fatty acids and glycerol. Lipases usually act on the surface of the fat-air interface, and their activity increases significantly in the presence of organised lipid structures, usually located on such surfaces [15].

The positive effect of lipases is attributed to the breakdown of non-polar lipids (e.g. triglycerides) and, consequently, the removal of undesirable components from the dough. It is known that triglycerides do not form stable monolayers at the fat-air interface, and therefore, their breakdown has a positive effect. It is believed that 1,3-specific lipases do not attack polar lipids, which also has a positive effect on quality. The first generation of lipases used in baking was represented exclusively by lipases of this type. It was believed that they would replace chemical emulsifiers and leavening agents, but the technical and economic benefits of such a replacement were negligible. Second-generation enzymes had much greater specificity, acting also on polar lipids, and exhibited phospholipase and lipase activity [17].

Lipases directly affect the gluten network. This is partly due to the formation of free fatty acids, oxidised by endogenous lipoxygenase, which leads to an increase in their ability to oxidise and a positive effect on the formation of the gluten network. In addition, lipases can affect the interaction of lipids with gluten proteins [10].

Formulation of the problem

Enzyme preparations are used not only to improve flour quality but also to produce flour with certain technological properties to meet the needs of bakery enterprises. Therefore, it is necessary to analyse the effect

of enzyme preparations with different principles of action on the quality characteristics of flour.

Purpose and objectives of the study

The aim of the study is to investigate the effect of a protease-acting enzyme preparation on the gluten network and to develop a complex-acting technological additive.

To achieve this aim, the following tasks need to be solved:

- to analyse the quality of flour from Ukrainian producers;
- to determine the effect of proteolytic enzyme on the quality characteristics of gluten;
- to evaluate the baking properties of graded flour with a proteolytic enzyme;
- to develop a technological additive to adjust the protein-proteinase complex of flour

Materials and methods

To conduct the study, we analysed the data on Ukrainian flour quality and identified the indicators that need to be adjusted. Flour samples with low proteolytic activity were selected, technological additives were developed, and their quality was determined in accordance with State Standard GSTU 46.004-99 Boroshno pshenychne. Tekhnichni umovy, and the rheological properties of the dough were assessed by analysing them using innovative Mixolab equipment ISO 17718:2013 Wholemeal and flour from wheat (Triticum aestivum L.). The analysis allows for a comprehensive assessment of flour quality indicators, which depend on both the state of the protein-proteinase and carbohydrate-amylase complexes of flour. The data were interpreted by evaluating profilers that show six graphical indices of flour, such as

– water absorption capacity of flour (WAC);
– dough stability during kneading (Kneading);
– gluten quality index (Gluten+);
– viscosity index (Viscosity);
– amylase activity index (Amylase);
– starch retrogradation index during bread storage (Retrogradation).

The baking properties of the flour were also evaluated by trial laboratory baking of bread from the control and the flour samples with the technological additive.

The study was conducted using the following samples:

Sample 1 is a control sample of high-grade flour;

Sample 2 is high-grade flour with the addition of Neutrase 15 BG at a minimum dosage of 0.02 g of the enzyme preparation per 1 kg of flour (0.02 g/kg);

Sample 3 is high-grade flour with the addition of Neutrase 15 BG at an average dosage of 0.06 g of the enzyme preparation per 1 kg of flour (0.06 g/kg);

Sample 4 is high-grade flour with the addition of Neutrase 15 BG at a maximum dosage of 0.1 g of the enzyme preparation per 1 kg of flour (0.1 g/kg);

Sample 5 is high-grade flour with the addition of the mixture: Neutrase 15 BG (0.02 g/kg) and Fungamyl 2500 SG (0.002 g/kg);

Sample 6 is high-grade flour with the addition of a mixture: Neutrase 15 BG (0.02 g/kg) and Fungamyl 2500 SG (0.005 g/kg);

Sample 7 is high-grade flour with the addition of a mixture: Neutrase 15 BG (0.02 g/kg) and Fungamyl 2500 SG (0.01 g/kg).

Results of the study and their discussion

The previous studies [18] show that low baking properties are typical for samples from the southern regions of Ukraine, namely low gluten content – from 24.0% to 25.2% with excessively resistant gluten properties – from 47 units to 60 units, low protein content – from 10.5% to 11.6%, low sedimentation index values – from 34 ml to 38 ml, and low amylolytic activity – the falling number is above 460-480 s.

The study was carried out in samples of high-grade flour with a low gluten content of 24.0% and strong gluten properties of 40 GDI (gluten deformation index) units. The effect of the enzyme Neutrase 15 BG in different dosages on the gluten content and quality, quality indicators of test bread baking (Table 2), and changes in rheological properties according to the Mixolab device (Fig. 1) were determined.

The results of determining the gluten content and quality in the flour samples with the enzyme preparation showed that the quantitative composition of gluten did not change, and the gluten quality indicators increased from 5 units (Sample 2) to 15 units (Sample 4).

The control sample has a uniform golden crust but low volume, clogged porosity and medium elasticity of the crumb, which is explained by the low enzymatic (amylolytic and proteolytic) activity of the original flour sample. With the introduction of the enzyme preparation, with an increase in its dosage, the quality of bread improves, and the specific volume increases, but at a dosage

Tabl 2 – Effect of the proteolytic enzyme Neutrase 15 BG on the test baking parameters

Enzyme	№ зразка	Dosage	Volume of bread, cm^3	Specific volume, cm^3/ g	Porosity, %
Neutraza 15 BG	Sample 1	control	350	2,2	75
	Sample 2	minimum dosage (0,02 g/kg)	420	2,7	78
	Sample 3	average dosage (0,06 g/kg)	430	2,7	77
	Sample 4	maximum dosage (0,1 g/kg)	380	2,4	76

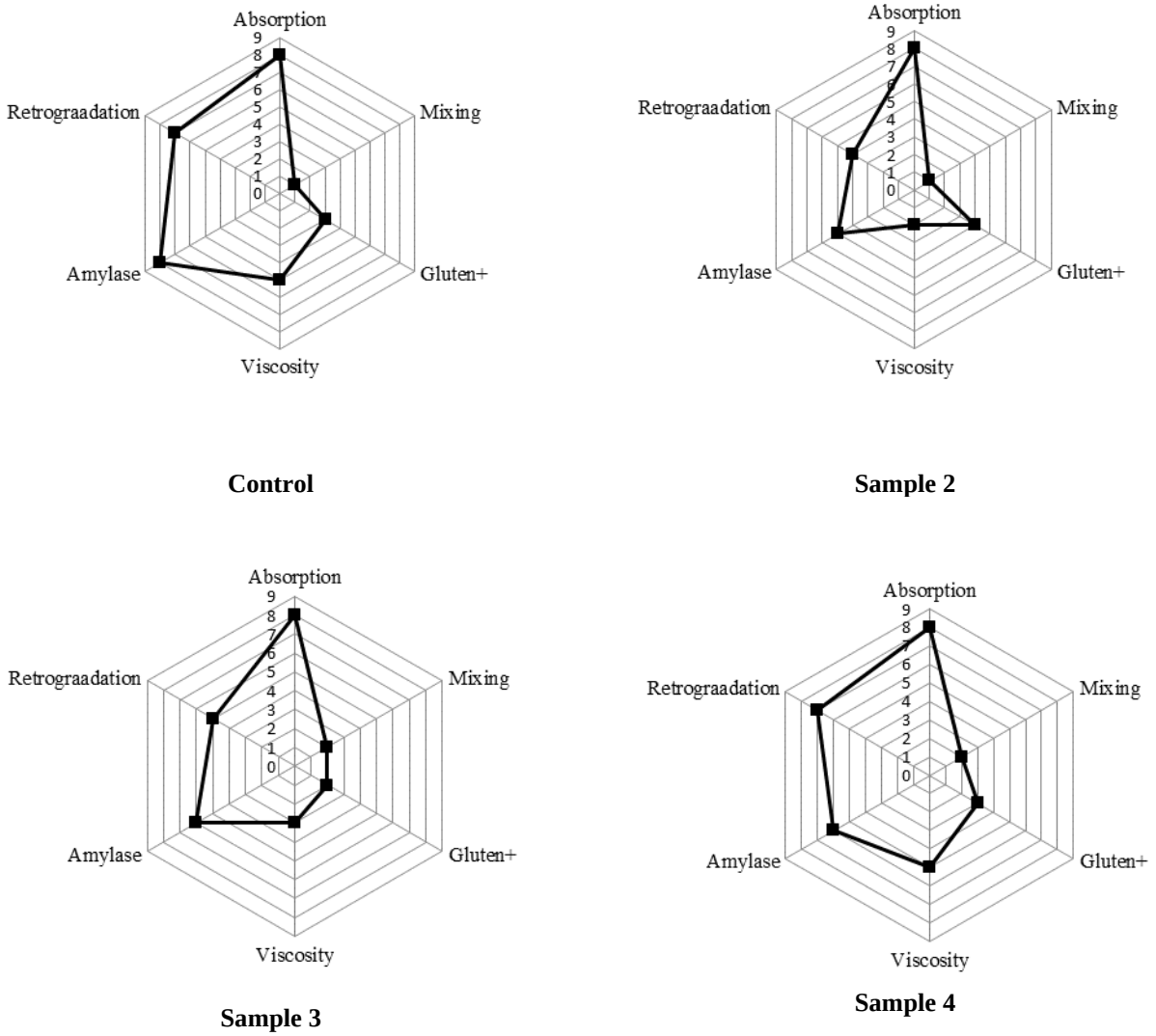

Fig. 1. Mixograms of the control sample and flour samples with different dosages of the enzyme preparation Neutrase 15 BG

of 0.1 g/kg (maximum), a decrease in volume is observed, compared to the average dosage, and the organoleptic characteristics of bread deteriorate. Neutrase 15 BG is an active enzyme that affects the protein complex of the dough, even during bread baking, so information on its addition to flour should be indicated in the accompanying documentation.

The analysis of the Mixograms shows that the WAC Index does not change. The Kneading index has no significant changes; the value in all samples is 1-2 units. Interesting changes are observed in the Gluten+ index. At the minimum dosage (0.02 g/kg), the index increases by 1 unit, but at the average dosage (0.06 g/kg), the index decreases by two units, indicating a slight relaxation of the gluten network. The Viscosity index has approximately the same pattern of change. Thus, at the minimum dosage, the index decreased by three units, with an average of 2 units, indicating a significant dough thinning. For the Amylase and Retrogradation indices, the samples with the minimum and average dosage had the greatest impact, with the indices decreasing by 2-3 units.

Neutrase weakens flour gluten and increases its extensibility, improves the structural and mechanical properties of dough and gluten when processing flour with resistant or short gluten, improves the viscoplastic properties of dough and improves the quality of bakery and confectionery products. However, for flours with low proteolytic activity and, at the same time, low amylolytic activity (400 s and above), a technological additive with enzyme preparations of proteolytic and amylolytic action should be developed.

Three dosage variants were developed (Sample 5, Sample 6, Sample 7), and bread quality was evaluated (Fig. 2). The results of the trial laboratory baking showed that in Samples 5 and 6, the volume of bread increased by 110 cm^3 and the porosity improved by 6%. The best results were observed in Sample 7, with a 130 cm^3 increase in bread volume and an 8% increase in porosity. From the data obtained, it can be concluded that a technological additive consisting of enzyme preparations with proteolytic and amylolytic action should be used for high-grade wheat flour produced in the South of Ukraine, which has a low gluten content with elastic properties and low amylolytic activity. It is mandatory to indicate the content of the technological additive, its composition and dosage in the accompanying documentation, allow

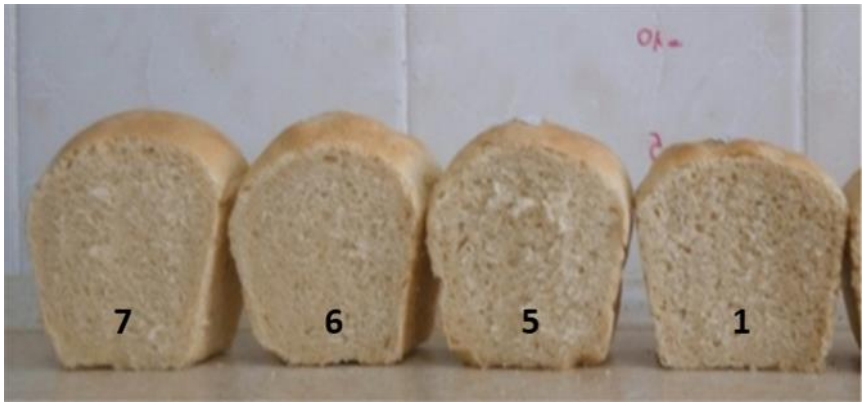

Fig. 2. Results of trial laboratory baking of the control sample and samples with the technological additive

ing bakeries to adjust their technological processes and recipes.

Conclusions

1. The analysis of previous studies has shown that high-grade flour is in great demand, and the requirements for its quality are increasing every year. The Southern region is characterised by the lowest quality of flour, namely low gluten content – from 24.0% to 25.2% with excessively resistant gluten properties – from 47 units to 60 units, low protein content – from 10.5% to 11.6%, low sedimentation values – from 34 ml to 38 ml, as well as low amylolytic activity – the falling number is above 460...480 s;

2. To relax the gluten network, an enzyme preparation with protease activity Neutrase 15 BG was used in three dosages: minimum (0.02 g/kg), average (0.06 g/kg), and maximum (0.1 g/kg). The study found that at the minimum and average dosage, the specific volume of bread increased by 0.5%, and at the maximum dosage – by 0.2%, with a clear deterioration in organoleptic characteristics. Therefore, it makes sense to use this enzyme in low dosages to prevent excessive gluten relaxation.

3. The technological additive has a complex effect on both the gluten network and amylolytic activity. The best bread quality indicators were shown by Sample 7 (0.02 g/kg Neutrase 15 BG + 0.01 g/kg Fungamyl 2500 SG), with an increase in bread volume and porosity by 1.3 times and 1.1 times, respectively.

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КОРИГУВАННЯ ЯКОСТІ ПШЕНИЧНОГО БОРОШНА ЗА РАХУНОК ВИКОРИСТАННЯ ФЕРМЕНТНИХ ПРЕПАРАТІВ

Анотація

За останнє десятиріччя борошномельна промисловість знаходиться в стадії активного розвитку, проводяться реконструкції діючих підприємств та зростає будівництво нових борошномельних заводів в умовах зниження якості вхідної сировини, високої конкуренції і низької рентабельності хлібопекарських підприємств та борошномельних заводів. Тому такі підприємства повинні мати можливість виробляти не тільки стандартне борошно, але й мати змогу виробляти борошно із заданими показниками якості. Одним з прикладів є борошно з підвищеними хлібопекарськими властивостями призначеного для спеціальних груп виробів – батонів, багетів, булок та ін. Стандартне українське борошно, яке виробляється в наслідок низького вмісту білка і клейковини не завжди може бути використане для даних виробів. Мета роботи – вивчити вплив ферментного препарату протезної дії на клейковинний каркас борошна та розробити технологічну добавку комплексної дії. Для дослідження якості борошна були використані як загальноприйняті методи оцінки, так і інноваційні за допомогою приладу Mixolab та проведено пробну лабораторну випічку зразків. Для покращення білково-протеїназного комплексу використовувався ферменний препарат Нейтраза 15 BG в концентрації: мінімальне (0,02 г/кг), середнье (0,06 г/кг) та максимальне (0,1 г/кг). Для комплексної дії суміш ферментних препаратів Нейтраза 15 BG та Фунгаміл 2500 SG при наступному дозуванні: 0,02 г/кг+0,002 г/кг; 0,02 г/кг+0,005 г/кг; 0,02 г/кг+0,01 г/кг. В роботі проаналізовано якість борошна українських виробників; визначено вплив протеолітичного ферменту на якісні характеристики клейковини; оцінено хлібопекарські властивості сортового борошна з протеолітичним ферментом та розроблено технологічну добавку для коригування білково-протеїназного комплексу борошна. Аналіз попередніх досліджень показав, що для борошно вищого сорту Південного регіону характерна невисока якість, а саме невисокий вміст клейковини – 24,0-25,2 % з надмірно міцними властивостями клейковини – 47- 60 од., та занижена амілолітична активність – число падіння вище 460-480 с. Встановлено, що при мінімальному і середньому дозуванні Нейтрази15 BG питомий об'єм хліба збільшився на 0,5 %, а при максимальному – 0,2 % з явним погіршенням органолептичних показників. Тому є сенс використання даного ферменту при невисокому дозуванні задля запобігання липкості тіста. За результатами впливу технологічної добавки на показники якості хліба отримано, що в зразку з наступним дозуванням Нейтраза 15 BG і Фунгаміл 2500 SG – 0,02 г/кг +0,01 г/кг, відповідно, збільшилися показники об'єму і пористості хліба – в 1,3 рази та в 1,1 рази, відповідно.

Ключові слова: пшеничне борошно, сортовий помел, реологічні властивості, білково-протеїназний комплекс, вуглеводно-амілазний комплекс, ферментний препарат, технологічна добавка.

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