25. Jinab, Z. Impacts of Combination of Foliar Iron and Boron Application on Iron Biofortification and Nutritional Quality of Rice Grain [Text] / Z. Jinab et al. // Journal of Plant Nutrition. – 2008. – Vol. 31, Issue 9. – P. 1599–1611. doi: 10.1080/01904160802244803
26. Ježek, P. Effect of foliar application of selenium on the content of se-lected amino acids in potato tubers (Solanum tuberosum L.) [Text] / P. Ježek et al. // Plant soil environ. – 2011. – Vol. 57, Issue 7. – P. 315–320.
27. Kozak, V. V. Printsipy ekologicheski bezopasnogo zemledeliia [Text] / V. V. Kozak. – Kyi: MEF «AQUA-VITAE», 2009. – 38 p.
28. Yudicheva, O. Study of zinc content in biofortified tomato vegetables [Text] / O. Yudicheva // The advanced science journal. – 2014. – Vol. 2014, Issue 7. – P. 15–18. doi: 10.15550/asj.2014.07.015
29. Dejnychenko, G. V. Study of possibilities to grow biofortified vegetables as a source of carotenoids [Text] / G. V. Dejnychenko, O. P. Judicheva // Eastern-European Journal of Enterprise Technologies. – 2015. – Vol. 2, Issue 10 (74). – P. 36–40. doi: 10.15587/1729-4061.2015.39763
30. Yudicheva, O. P. Zavisimost khimicheskogo sostava ot sorta biofortifitsirovannykh tykvennykh ovoshchey [Text] / O. P. Yudicheva // Vestnik Sibirskogo universiteta potrebitelskoy kooperatsii. – 2015. – Vol. 4, Issue 11. – P. 68–72.

UDC 644.641

DOI: 10.15587/1729-4061.2016.70984

RESEARCH INTO THE IMPACT OF ENZYME PREPARATIONS ON THE PROCESSES OF GRAIN DOUGH FERMENTATION AND BREAD QUALITY

S. Oliinyk
PhD, Associate Professor*
E-mail: svitlana.oliinyk@gmail.com

O. Samokhvalova
PhD, Professor, Head of Department*
E-mail: sam55ov@gmail.ru

A. Zaparenko
Postgraduate student*
E-mail: kindeducation@gmail.com

E. Shidakova-Kamenyuka
PhD, Associate Professor*
E-mail: shidakova_99@mail.ru

M. Chekanov
PhD, Associate Professor**
E-mail: m.chekanov@hduht.edu.ua

*Department of the technology of bakery, confectionary, pasta and food concentrates production***

Department of physical and mathematical and engineering-technical disciplines*

***Kharkiv State University of Food Technology and Trade
Klochkivska str., 333, Kharkiv, Ukraine, 61051

Досліджено вплив ферментних препаратів целюлази, ксиланази та глюкозооксидази на процеси дозрівання зернового тіста та якість зернового хліба. Встановлено, що внесення дослідних ферментних препаратів у зернове тісто під час його приготування сприяє інтенсифікації біохімічних і мікробіологічних процесів дозрівання. У результаті покращуються реологічні властивості тіста та підвищуються показники якості готових виробів

Ключові слова: ферментні препарати, зерновий хліб, приготування тіста, целюлаза, ксиланаза, глюкозооксидаза

Исследовано влияние ферментных препаратов целлюлазы, ксиланазы и глюкозооксидазы на процессы созревания зернового теста и качество зернового хлеба. Установлено, что внесение исследуемых ферментных препаратов в зерновое тесто при его приготовлении способствует интенсификации биохимических и микробиологических процессов созревания, улучшению его реологических свойств и повышению показателей качества готовых изделий

Ключевые слова: ферментные препараты, зерновой хлеб, приготовление теста, целлюлаза, ксиланаза, глюкозооксидаза

1. Introduction

One of the most acute problems of society today is a significant spread of diseases of alimentary origin, associated with deficiencies of essential nutrients in food rations, in particular dietary fibers. It is known that an efficient way of solving this problem is using the products of everyday consumption, rich in essential substances, including bakery products. From this perspective, very promising is expanding the range of bread made of whole grains, which, along with high content of dietary fibers, contains a significant amount of vitamins, minerals and other physiologically-functional ingredients [1]. However, due to the features of the technology and the high content of non-starch polysaccharides, grain bread has lower organoleptic, physical-chemical and structural-mechanical properties in comparison with bakery products of the white flour, which negatively affects demand. In this regard, the search for ways to improve the technology of grain bread is an actual task.

2. Analysis of scientific literature and the problem statement

The ways of improving the technology of grain bread are widely discussed in scientific literature, and most of them cover the processes of regulation of soaking the grains and ensuring microbiological purity, since this stage is the longest-lasting, and it also largely affects the formation of the products quality. The proposed approaches aim at solving the tasks of reducing the duration of this stage by steeping the grains at higher temperatures, its previous humid heat processing and exfoliation [2]. The important task of improving the technology of grain bread is to ensure sanitary-hygienic security of grain semi-finished products that is possible to achieve by preliminary treatment of grain by gaseous preservatives [3, 4], or grain wash using disinfectants of chemical nature, as well as soaking the grains by adding organic acids or their salts [3, 5], extracts of medicinal plants [3, 5], etc.

From the point of view of the formation of quality grain bread, not less important is the stage of preparing the dough. It is known that due to high content of non-starch polysaccharides, as well as high enzymatic activity, grain dough is characterized by unstable rheological properties, reduced gas-retaining capacity [6], which leads to obtaining bread with low indicators of specific volume, porosity, structural-mechanical characteristics. Currently proposed solutions to this problem are implemented through the preparation of grain dough by using concentrated lactic acid starter [7], frozen dispersed grain mass and structure-forming agents [8], dry wheat gluten [9], the use of heat traiting of part of the hydrated grain [10] and others. However, the task of improving the quality of grain and bread cannot be considered solved.

In our view, to adjust the rheological characteristics of grain dough, it is expedient to use the experience of application of enzymes for the technology of bread, obtained from flour [11, 12]. Taking into consideration significant content of non-starch polysaccharides in the grain raw material, in order to improve the quality of grain bread, it is reasonable to use hemicellulases and cellulases, which, while performing moderate hydrolysis of grain shells, raise the viscosity of the dough, increase its water-retaining and gas-retaining capacities, which positively influence formation of quality products [11]. Thus, the study [13] shows that it is possible to purposefully change the content of water-soluble and insoluble fractions of arabinoxylans in the dough and influence its structural-mechanical properties through the use of enzyme preparation of xylanase. The use of fungal xylanase in the technology of bread made of ground whole-wheat flour [14] contributes to the increase in the specific volume of the products, improvement of rheological properties of dough and slowing down the processes of their staling. In the technology of grain bread hemicellulases and cellulases have already been applied at the stage of soaking the grains in order to remove ions of heavy metals out of their shells [3]. Additional effect of their use is reducing the duration of steeping the grain and improving rheological properties of dough and bread. However, implementation of this technical solution implies the application of higher temperatures of steeping the grain that is connected to the necessity of creation of favorable conditions for the action of enzymes and requires special equipment, which causes the rise in the cost of production. At the same time, the use of enzymes at the stage of grain dough mixing may be justified, as the temperature of its fermentation (30±2 °C) is more favorable for the action of enzymes than the temperature of steeping, which is usually 20±2 °C.

During steeping of the grain, the content of gluten in it decreases and its properties deteriorate due to proteolysis [15]. One of the efficient ways of adjusting the properties of gluten is applying oxidoreductases [16] during dough preparation, which is accompanied by the improvement of rheological properties of dough, increase in its gas-retaining capacity, improving the quality of bread [11]. Among the enzymes of this group, the most promising includes glucose oxidase, under the influence of which oxidation of glucose occurs with the formation of hydrogen peroxide and its further inclusion in the processes of oxidation of thiol groups of protein protease complex, which allows using this enzyme during the processing of flour with weak gluten [17]. In addition, many modern studies [18–20] discuss the feasibility of joint application of enzyme preparations of xylanase and glucose oxidase due to the synergy of their actions.

Thus, the performed analysis of the scientific sources made it possible to discover the prospects of applying cellulases, hemicellulases and oxidoreductases at the stage of preparation of grain dough that requires systematic study of their impact on the formation of the properties of grain and bread.

3. The purpose and objectives of the study

The purpose of the research is to define the influence of cellulases, hemicellulases and oxidoreductases on the patterns of the processes of grain dough fermentation and quality indicators of the finished products.

To achieve the set goal, the following tasks are formulated:

– to set the patterns of change in the content of non-starch polysaccharides and the properties of gluten of grain dough under the influence of the studied enzymes;

– to research into the progress of microbiological processes, occurring in grain dough with enzymes, during its fermentation;

– to determine the effect of enzymes on the rheological properties of grain dough and the indicators of the quality of finished products.

4. Materials and methods of the study

4. 1. Materials of the study

In the research we used grain of wheat, grade Kharkivska 30 (the wheat) and emmer of new grade Golikovska (the emmer), which was created at the Institute of Crop Production named after V.Ya. Yuriev, of National Academy of Agricultural Science of Ukraine (Kharkiv, Ukraine), and it is a hybrid of emmer *Triticum diccocum* and durum wheat *Triticum durum* with high protein content (19.0 % CP) [21].

In the research we used enzyme preparations of celluloitic, hemicelluloitic and redox action Xylolad, Celulad and Glucose Oxidase (Table 1).

Table 1

Characteristics of enzymes

Indicators	Celulad	Xylolad	Glucose Oxidase
Classification number	EC 3.2.1.4	EC 3.2.1.8	EC 1.1.3.4
Systematic name	cellulase	endo-1,4-xylanase	glucose oxidase
Producer	Tr. reeseii	P.canescens	P.canescens
Activity, U/g	300	200	2000
The range of action by pH	4,5...6,5	4,6...6,5	4,5...7,5
The range of action by temperature, °C	30...60	28...55	20...50

These enzyme preparations are produced by DP "Enzyme" (Ladyzhyn, Ukraine).

4. 2. Methods for the preparation of semi-finished grain products and grain dough

Grain of emmer and wheat were soaked in water using parameters set earlier [22], namely temperature of 20 °C, hydrological module 1:1.5 for 15 and 18 h according to reaching the moisture content of 40...41 % [23]. Hydrated grain of the emmer and the wheat differed in the content and properties of gluten, as well as in the activity of enzymes (Tables 2, 3).

Table 2

The content and properties of gluten in hydrated grain

Hydrated grain	The contents of crude gluten, %	The content of dry gluten, %	Hydration capacity, %	Compressibility, units of IDK	Extensibility, cm
Emmer	29,0	9,6	202	88	18
Wheat	21,8	7,4	194	78	14

Table 3

The activity of the enzymes of hydrated grain

Hydrated grain	The activity of enzymes			
	Proteolytic, mg of nitrogen/100 g DM	Amylolytic, mg starch per hour		
		Total	α-amylase	β-amylase
Emmer	52,4	161,0	27,9	133,1
Wheat	45,3	150,3	23,9	126,4

After steeping, the grain was washed and ground on the laboratory grinder that is equipped with one four-blade knife and one matrix with a hole of diameter 2 mm.

Using shredded grain mass, the dough of humidity 47.0 % was mixed. Enzyme preparations Ksylolad, Tseliulad and Gliukosooksidasa were added in the form of suspensions at the stage of mixing the dough, in the previously specified dosages, which for the emmer dough reached 0.036, 0.078 and 0.001 %, and for the wheat – 0.034, 0.065 and 0.0007 %, respectively.

To determine the effect of enzyme preparations on the biochemical processes and rheological properties of the dough, we prepared non-yeast dough, and to study the microbiological processes – yeast dough with addition of 3.0 % of baking yeast and 1.5 % salt to the mass of the grain. The experiments were conducted at the temperature of 30 °C.

To study the progress in the grain dough, 3.0 % of pressed baking yeast and 1.5 % of the salt were added to the mass of the grain in the model systems.

To determine the quality of bread with enzymes, fermented yeast dough was divided in pieces, which were subjected to rounding, the dough pieces were laid in forms and kept for 30...40 min at temperature of 38 °C and then baked for 30 min at temperature of 180...220 °C.

4. 3. Methods of evaluation of grain semi-finished products

Cellulose content was determined by the method, described in [24]. Contents of hemicelluloses were defined by the method based on combination of the scheme of distribution of carbohydrates by Bailey and the modified spectrophotometric method of Dreywood, described in [25]. Assessment of the effects of enzyme preparations on the gluten-forming proteins was carried out by the change in the content and properties of gluten that are determined by GOST 27839-2013 and GOST 28796-90. The effect of enzymes on the process of alcohol fermentation was determined by the total volume of emitted carbon dioxide during dough ripening, determined by the method shown in [26]. Titratable acidity of the grain dough was defined, by the method, described in [24]. Gas-retaining capacity of the grain dough was assessed by the indirect method of the change in the volume of the dough during fermentation. In this case, 50 g of dough was placed in a cylinder with a volume of 250 cm^3 and kept in the thermostat at temperature 30 °C during fermentation. Structural and mechanical properties of grain dough were defined by the method of planar shearing on the Tolstoy elastoplastometer [27].

4. 4. Methods of evaluation of grain bread

Organoleptic characteristics of grain bread quality (physical appearance, colour and crisp, state of the crumb, taste, smell) were assessed by the requirements of DSTU-P 4588:2006 «Bakery products for special dietary consumption". Physical-chemical parameters of the grain bread quality, such as moisture content, titratable acidity, porosity and specific volume were defined by the methods, described in [24].

4. 5. Methods of processing experimental data

The processing of the obtained experimental data was carried out by using MS Office Excel spreadsheets.

5. Results of the studies of the impact of enzymes on the processes of grain dough fermentation and the quality of grain bread

To get an idea about the effect of xylanase, cellulase and glucose oxidase on the regularities of formation of properties of grain dough, we thought it appropriate to investigate in dynamics the changes in the content of fiber, hemicelluloses, including soluble and insoluble, that are able to bind substantial amounts of moisture in the system and affect the rheological properties of the dough [18]. Results of the study are presented in Fig. 1 and in Tables 4, 5.

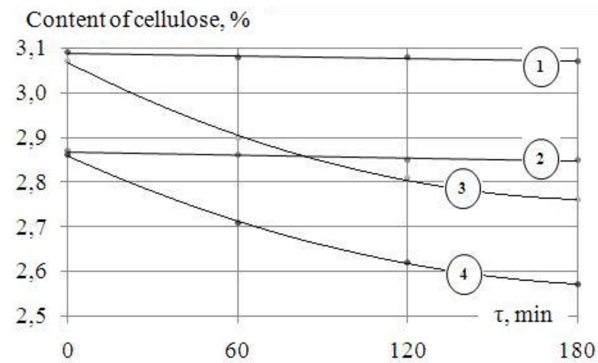

Fig. 1. Change in the content of cellulose when softened in grain dough: 1, 2 — the emmer and the wheat, without adding enzymes (control samples); 3, 4 — the emmer and the wheat with added enzymes

Table 4

Effect of enzyme preparations on the change in the content of hemicelluloses in the emmer grain dough n=3; P≤0,05

Duration of softening, min	Content of hemicelluloses in samples of dough, % DM					
	without enzymes (control)			with enzymes		
	total	insoluble	soluble	total	insoluble	soluble
0	10,5±0,5	6,3±0,2	4,2±0,1	10,4±0,5	6,2±0,3	4,2±0,2
60	10,4±0,4	6,1±0,2	4,3±0,2	10,4±0,5	5,9±0,2	4,5±0,2
120	10,2±0,4	5,7±0,2	4,5±0,2	9,7±0,3	4,5±0,2	5,2±0,2
180	9,8±0,4	5,2±0,2	4,6±0,2	9,0±0,3	4,0±0,1	5,0±0,2

Table 5

Effect of enzyme preparations on the change in the content of hemicelluloses in the wheat grain dough n=3; P≤0,05

Duration of softening, min	Content of hemicelluloses in reference samples of dough, % DM					
	without enzymes (control)			with enzymes		
	total	insoluble	soluble	total	insoluble	soluble
0	7,7±0,2	5,1±0,2	2,6±0,1	7,6±0,2	5,0±0,2	2,6±0,1
60	7,6±0,2	4,9±0,2	2,7±0,1	7,5±0,3	4,5±0,1	3,0±0,1
120	7,4±0,2	4,5±0,1	2,9±0,1	7,1±0,3	3,6±0,1	3,5±0,1
180	7,1±0,2	4,2±0,1	2,9±0,1	6,3±0,2	2,9±0,1	3,4±0,1

Analysis of the data presented in Fig. 1 and in Tables 4, 5 proves that the emmer dough contains more cellulose and hemicelluloses than the wheat. During the autolysis of the control samples of grain dough, no significant changes occur in cellulose, while the total content of hemicelluloses in both samples of the dough reduces – by 6.7 % in the emmer dough and by 7.8 % in the wheat. Along with the decrease in the total content of hemicelluloses, the changes in their fraction compositions occur in both samples of the dough: the content of insoluble fraction decreases, while that of the soluble – increases, which might be linked to the activity of the grain's own enzymes.

Adding enzyme preparations of hemicellulolytic and cellulolytic action contributes to more intensive, when compared with the reference samples, reduction in the content of both cellulose (approximately by 11 % in both samples) and hemicelluloses (by 14.3 % in the emmer dough and by 13.0 % in the wheat). In this case there is a noticeable reduction of the content of insoluble hemicelluloses – by 36.5 and 43.1 % in the emmer and wheat dough, accordingly, and increase in the content of soluble fraction – by 33.3 and 30.8 %.

The effect of enzyme preparations on the gluten-forming proteins was studied by the change in the content and properties of gluten (Table 6).

Table 6

Content and properties of gluten of grain dough with addition of enzyme preparations n=3; P≤0,05

Indicator	The emmer dough		The wheat dough	
	Without enzymes (control)	With enzymes	Without enzymes (control)	With enzymes
The content of crude gluten, % after (min.) of softening				
0	29,0±0,3	31,1±0,5	21,8±0,4	23,3±0,3
60	29,4±0,4	31,4±0,4	22,1±0,3	23,7±0,3
120	30,0±0,5	31,9±0,5	22,5±0,3	23,9±0,5
180	30,4±0,3	32,4±0,3	22,7±0,5	24,1±0,4
The content of dry gluten, % after (min.) of softening				
0	9,6±0,2	10,4±0,3	7,4±0,1	8,0±0,2
60	9,2±0,3	10,3±0,1	7,2±0,2	7,9±0,2
120	8,9±0,2	10,1±0,2	7,0±0,3	7,8±0,2
180	8,4±0,2	9,9±0,3	6,9±0,3	7,7±0,1
Hydration capacity, % after (min.) of softening				
0	202±4,0	196±5,0	194±5,0	193±5,0
60	219±5,0	204±7,0	206±4,0	200±5,0
120	237±6,0	215±5,0	221±5,0	206±4,0
180	264±5,0	227±6,0	229±6,0	211±5,0
Gluten compressibility, units of IDK after (min.) of softening				
0	88±1,0	86±1,0	78±1,0	75±2,0
60	92±2,0	88±2,0	80±1,0	76±2,0
120	97±1,0	91±3,0	85±2,0	79±1,0
180	105±3,0	95±2,0	91±3,0	82±2,0
Extensibility, cm after (min.) of softening				
0	18±1,0	16±0,5	14±0,3	12±0,5
60	19±1,0	17±1,0	15±0,5	12±0,5
120	21±1,5	18±0,5	16±0,5	13±0,3
180	23±2,0	18±0,3	17±1,0	15±0,5

The data in Table 6 show that the content of raw gluten in the reference sample of the emmer dough is by 36.6 % (and of the dry is by 29.7 %) larger than that of the reference sample of the wheat that is typical for this grain culture. During the experiment, a slight increase (by 4.8 and 4.1 %) in the contents of crude gluten in these samples of the emmer and wheat dough occurs, which is caused by the increase in the dehydration capacity of gluten and attests to its weakening under the action of proteolytic enzymes. In this case, increasing the content of crude gluten in the emmer dough is slightly greater than that in the wheat and corresponds to the data about the change in rheological properties of gluten. The content of dry gluten reduces – by 12.5 and 7.2 %, respectively.

Adding the studied enzyme preparations to the emmer and wheat grain dough helps to increase the content of crude gluten by 7.2 and 6.9 %, of dry – by 8.3 and 8.1 %, respectively, as well as to reduce its hydration capacity and tensile strength, elasticity. It should be noted that during the experiment these indicators of the studied samples vary less intensively than in the control samples, and in 180 minutes the studied emmer and wheat dough was characterized by a 6.6...6.2 % and 17.9 and 11.6 % larger content of raw and dry gluten, respectively, in comparison to the reference samples, lower hydration capacity and tensile strength with better elastic properties.

Essential role in the formation of quality bakery products is played by microbiological processes, the patterns of progress of which in the dough are mostly defined by the state of carbohydrate-amylase complex of grain and the activity of lactic acid bacteria and yeast. In this regard, the influence of enzyme preparations on the progress of microbiological processes in grain dough during its fermentation was assessed by the change in the titratable acidity and the volume of carbon dioxide released during fermentation. Results of the research into dynamics of titratable acidity of the dough during fermentation are presented in Fig. 2.

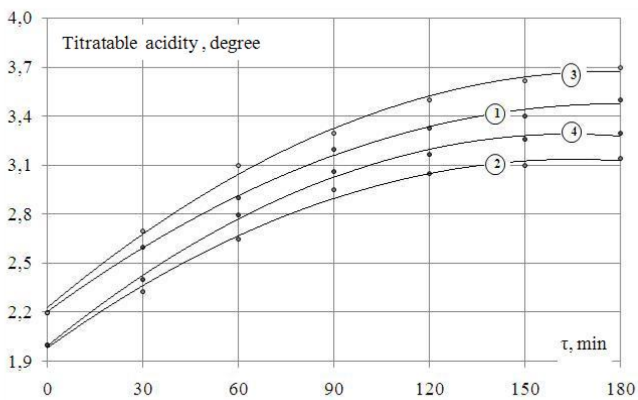

Fig. 2. Change in titratable acidity of the grain dough during the fermentation: 1, 2 – the emmer and the wheat without adding enzymes (control samples); 3, 4 – the emmer and the wheat with added enzymes

Analysis of the data in Fig. 2 shows that the titratable acidity of the emmer dough without added enzymes the beginning of the experiment is higher than that of the wheat and this trend persists for the duration of the dough fermentation. In 180 min. of fermentation, the acidity of both emmer and wheat dough increases by 1,1...1,3 degrees. The addition of enzymes to both samples of grain dough contributes to the intensification of its accumulation of titratable acidity, which at the end of the experiment is larger than the original by 1.3...1.5 degrees, which is higher than in the reference samples by 6.8 and 6.5 %.

Adding the enzyme preparations to the grain emmer and wheat dough affects the intensity of gas release, which is confirmed by a 16.9 and 16.4 % greater volume of the carbon dioxide, released by the studied samples during 180 minutes of fermentation, compared to the reference samples (Fig. 3).

Essential part in the formation of specific volume of grain bread, along with the gas–forming, is played by the gas-retaining capacity of dough (Fig. 4).

The data in Fig. 4 show that the reference samples of grain dough rapidly increase in volume at early fermentation and reach the maximum in about 90 minutes, after which the dough is stable for some time and then subsides. In this case the maximum volume of wheat grain dough is 9.4 % lower than that of the emmer that can be caused by a lower content of gluten in it, able to hold the gas that is produced, and fewer carbon dioxide amount released during dough fermentation. The addition of enzyme preparations to grain emmer and wheat dough helps to increase the maximum volume of the dough, compared to reference samples, by 25.5 % for the emmer and by 26.2 % for the wheat.

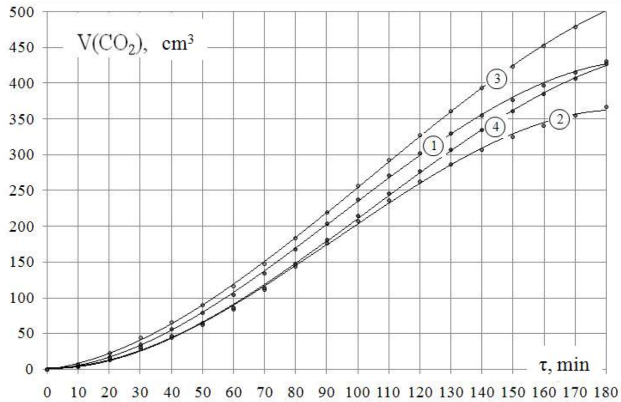

Fig. 3. The amount of carbon dioxide released in the process of fermentation of grain dough: 1, 2 – the emmer and the wheat without adding enzymes (control samples); 3, 4 – the emmer and the wheat with added enzymes (studied samples)

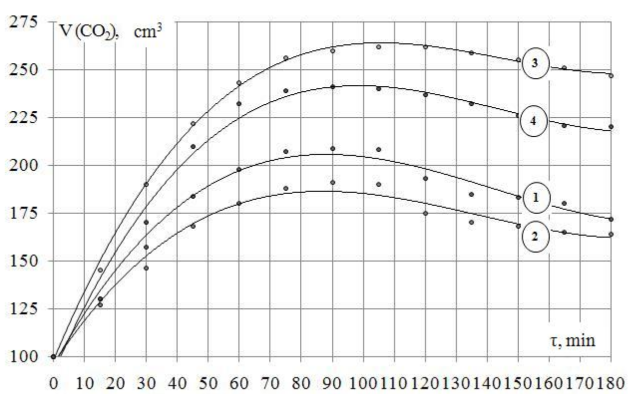

Fig. 4. Change in the volume of the dough during grain dough fermentation: 1, 2 – the emmer and wheat without adding enzymes (control samples); 3, 4 – the emmer and wheat with added enzymes (studied samples)

The patterns of the progress of the above–described biochemical and microbiological processes in grain dough influence its rheological properties (Table 7) and the quality of the finished products (Table 8).

As the result of the analysis of the obtained experimental data presented in Table 7, we found that a reference sample of the emmer grain dough is characterized by more expressed plastic properties than the sample of the wheat, as evidenced by the lower indicators of module instant elasticity and the elasticity module. Adding proposed enzymes contributes to the increase of indicator of plastic viscosity by more than 3 times in both samples, as well as to the increase in the instant modulus of elasticity by 8.4 and 8.0 % and in module of elasticity by 29.6 % and 29.8 in the samples of the emmer and wheat dough, respectively. That is, the presence of the studied enzyme preparations in grain dough provides resilience of the system to applied external tension shear that can be associated both with a change in fractional composition of hemicelluloses (Tables 4, 5) and with a change in the properties of gluten (Table 6).

Table 7

Rheological characteristics of grain dough n=3, $P \leq 0,05$

Indicators	Emmer dough		Wheat dough	
	Without enzymes (control)	With enzymes	Without enzymes (control)	With enzymes
Instant module of elasticity, 10^4 Pa	2,26±0,10	2,45±0,11	2,38±0,10	2,57±0,12
Modulus of elasticity, 10^3 Pa	0,84±0,03	0,92±0,04	1,04±0,04	1,35±0,05
Plastic viscosity, 10^5 Pa·s	1,92±0,07	6,36±0,22	1,78±0,08	5,74±0,15

By the organoleptic indicators, the reference samples of the emmer and wheat bread differed in: the emmer bread had better state of the surface and the crumb and more intensive coloring of the crust. Adding proposed enzyme preparations to the formulations of grain bread has a positive effect on the change in its organoleptic parameters. Products with added enzymes differed by a greater volume compared to the control, either in the case of baking grain bread of emmer or wheat. If the reference samples of bread had rough surface, then in the case of using proposed enzymes, the surface appeared more convex and smooth and had no cracks. The biggest effect of adding enzyme preparations was observed during the evaluation of the condition of the crumb of the emmer and wheat bread: it was more elastic and better loosened, had a more uniform and well-developed porosity. The taste and flavor of the reference and studied samples did not differ and were inherent to grain bread.

Positive effect of enzyme preparations on bread quality proved to be true during the defining of the physical-chemical parameters of quality products (Table 8).

Table 8

Physical-chemical parameters of grain bread quality

Indicator	Grain emmer bread		Grain wheat bread	
	Without enzymes (control)	With enzymes	Without enzymes (control)	With enzymes
Moisture content, %	45,8±0,3	46,4±0,2	45,2±0,2	46,0±0,1
Titratable acidity, degree	2,7±0,1	2,8±0,1	2,5±0,1	2,6±0,1
Porosity ,%	58±2	65±2	56±2	62±3
Specific volume, cm^3/g	2,0±0,12	2,6±0,11	1,8±0,11	2,3±0,11

The data in Table 8 show that the humidity of the reference sample of the emmer dough is higher by 0.6 % compared to that of the wheat grain that is caused by different content of non-starch polysaccharides in the grain of emmer and wheat (Fig. 1, Tables 4, 5), which are characterized by high water-absorbing capacity [28]. When adding the studied enzyme during preparation of the grain dough, moisture content of the samples of bread increases by 0.6 and 0.8 % in the emmer and wheat bread, respectively. Indicator of specific volume of the emmer grain bread exceeds that of wheat by 11.1 %. Adding enzyme preparations to formulations of grain bread contributes to a significant increase of the indicators of specific volume and porosity – by 30.0 % and by 12.1 % for emmer bread and by 27.8 % and by 10.7 % for wheat bread, respectively.

6. Discussion of the results of the studies of the impact of enzymes on the processes of grain dough fermentation and grain bread quality

The obtained results suggest that the inclusion of xylanase, cellulase and glucose oxidase to grain dough contributes to intensification of biochemical and microbiological processes in it while it is fermentation, and as a result the improvement of rheological properties of dough and quality of grain bread.

Intensive reduction of cellulose and hemicelluloses content in grain dough under the influence of enzymes (Fig. 1, Tables 4, 5) is explained by the catalytic action of xylanase and cellulase on hemicelluloses and cellulose [11, 12, 29]. Less significant hydrolysis of cellulose, compared to hemicelluloses, can be associated with low compliance of cellulose to the action of enzymes, which is consistent with the data given in [29]. It is known that during hydrolysis of non-starch polysaccharides under the influence of xylanase and cellulose, the compounds with high water-absorbing capacity are formed, which increase the viscosity of dough, which provides improving effect from the application of enzyme preparations [18].

Inhibition of weakening of the gluten of grain dough during its autolysis (Table 6) with adding enzyme preparations is related to the fact that under the action of hydrogen peroxide, the oxidation of thiol groups of gluten occurs that provides its strengthening, and, additionally, to the decrease in the activity of proteolytic enzymes and proteolysis activators. In the scientific literature there are data available on the beneficial effect of the products of hydrolysis of hemicelluloses on the properties of gluten, which can form protein-polysaccharide complexes, promoting the improvement of rheological properties of gluten and dough [18]. At the same time, as a result of the destruction of the protein-polysaccharide bonds in grain under the influence of cellulolases and hemicellulases, the availability of gluten-forming proteins that form the structure of the dough may increase [18], which contributes to the improvement of rheological properties of dough.

Intensification of microbiological processes in grain dough under the action of enzymes (Fig. 2, 3) may be caused by a number of factors and is probably a result of their mutual influence. Thus, as a result of the action of the enzyme preparations of cellulases and hemicellulases, the polysaccharide-polysaccharide bonds between starch and non-starch polysaccharides are destroyed [16], which leads to the increase in the exposure of starch to amylases action and as a result, the increase in the activity of yeast, for which the products of hydrolysis of starch are the nutrients.

Growth of the titratable acidity indicator of dough may be linked to the presence of gluconic acid in the system, which is formed in a series of redox processes involving glucose oxidase.

Described effect of enzymes on the biochemical and microbiological processes in grain dough predetermines the increase of its viscosity (Table 7), that depends on the content of gluten-forming proteins and the quantitative and qualitative composition of non-starch polysaccharides in it. Increasing the viscosity of the dough, affecting the increase of its gas-retaining capacity (Fig. 4), along with the increase in gas-forming capacity (Fig. 3) provides for the improvement of the quality of grain bread (Table 8).

Increase in the moisture content of the samples of grain bread that is baked with the use of enzymes, compared to the reference samples, is explained by an increase of hemicelluloses with a high water-absorbing and water-retaining capacity in the system. Possibly this will help to prolong the terms of bread freshness, which needs further research. Increasing the acidity of the studied samples of grain bread, compared to control samples, corresponds to the data obtained when defining titratable acidity of grain dough (Fig. 2). Increase in the indicators of specific volume and porosity of grain bread under the influence of enzyme preparations is caused by an increase in the gas-forming and gas-retaining capacity of dough.

7. Conclusions

1. It is proved that under the influence of enzyme preparations of Xylolad, Celulad and Glucose Oxidase in the grain emmer and wheat dough, reduction of the content of non-starch polysaccharides takes place, the content of water-soluble hemicelluloses increases, structural-mechanical properties of gluten improve, which leads to the improvement of rheological properties of grain dough.

2. The research revealed that the studied enzymes promote a more intensive course of microbiological processes in the dough, which testifies itself in accelerating acid and gas generation. This is due to an increase in the amount of nutritious for fermenting microflora substances in the dough, by increased pliability of starch to amilase action as a result of the destruction of bonds between starch and non-starch polysaccharides under the action of the studied enzymes.

3. By adding the enzyme preparations, plastic viscosity of the emmer and wheat dough increases by 3 times, an instant elasticity module – by 8.4 and 8.0 % and the module of elasticity by 29.6 and 29.8 %, which contributes to the increase in the volume of grain dough by 25.5 % and 26.2 %, respectively. The resulting effect is the increase in specific volume and porosity of the emmer bread by 30.0 % and 12.1 %, and the wheat – by 27.8 % and 10–7 %, accordingly, as well as the improvement of the organoleptic properties of finished products.

References

1. Mofidi, A. The Acute Impact of Ingestion of Sourdough and Whole-Grain Breads on Blood Glucose, Insulin, and Incretins in Overweight and Obese Men [Text] / A. Mofidi, Z. M. Ferraro, K. A. Stewart, H. M. F. Tulk, L. E. Robinson, A. M. Duncan, T. E. Graham // Journal of Nutrition and Metabolism. – 2012. – Vol. 2012. – P. 1–9. doi: 10.1155/2012/184710
2. Shkapov, E. I. Sovershenstvovaniye technologii dispergirovaniya zerna dlia proizvodstva khlebobulochnykh izdeliy [Text] / E. I. Shkapov. – Moskovskij gosudarstvennyj universtitet pishhevyh proizvodstv, 2002. – 18 p.
3. Koriachkina, S. Ya. Technologiya khleba iz tselogo zerna triticale [Text] / S. Ya. Koriachkina, E. A. Kuznetsova, L. V. Cherepnina, S. Ya. Koriachkina, E. A. Kuznetsova, L. V. Cherepnina. – Orel: FGBOU VPO «Gosuniversitet – UNPK», 2012. – 177 p.
4. Balanov, P. E., Smotrayeva, I. V. (2014). Technologiya soloda [Text] / P. E. Balanov, I. V. Smotrayeva. – SPb.: NIU ITMO; IHiBT, 82.
5. Pshenyshniuk, G. F. Innovatsiyni zahody pidvyshtschennia yakosti zernovogo khliba [Text] / G. F. Pshenyshniuk, O. V. Makarova, G. S. Ivanova // Kharchova nauka i technologiya. – 2010. – Vol. 1. – P. 73–77.
6. Koriachkina, S. Ya. Povysheniye mikrobiologicheskoy chistoty rzhy I pshenitsy na stadii zamachivaniya v rastvorakh chimicheskikh sredstv pri proizvodstve zernovogo khleba [Text] / S. Ya. Koriachkina, E. A. Kuznetsova, O. M. Prigarina // Prioritety i nauchnoye obespecheniye realizatsyi gosudarstvennoy politiki zdorovogo pataniya, 2006. – P. 25–28.
7. Ivanova, G. S. Vplyv sposobiv tistoprygotuvannia na yakist zernovogo khliba na osnovi sumishi [Text] / G. S. Ivanova, O. V. Leschuk // Naukovi zdobutky molodi – vyrishenniu problem kharchuvannia liudstva u XXI st. – 2012. – Vol. 1. – P. 88.
8. Novikova, A. N. Sovremennaya technologiya khleba iz tselogo zerna pshenitsy [Text] / Novikova, A. N. – Moskovskij gosudarstvennyj universitet pishhevyh proizvodstv, 2004. – 25 p.
9. Kalina, M. A. Razrabotka zernovogo khleba iz triticale i otsenka yego potrebitelskikh svoystv [Text] / M. A. Kalina. – FGBOU VPO «Rossijskij ekonomicheskij universitet im. G. V. Plehanova», 2012. – 22 p.
10. Makarova, O. V. Vliyaniye vlagoteplovoy obrabotki pshenitsy na pokazateli kachestva zernovogo khleba [Text] / O. V. Makarova, G. F. Pshenyshniuk, G. S. Ivanova // Kharchova nauka i technologiya. – 2011. – Vol. 1. – P. 69–72.
11. Kapreliyants, L. V. Phermenty v piashevykh technologiyzkh [Text] / L. V. Kapreliyants. – Odessa, 2009. – 468 p.
12. Melim Miguel, A. S. Enzymes in Bakery: Current and Future Trends [Text] / A. S. Melim Miguel, T. Souza, E. V. da Costa Figueiredo, B. W. Paulo Lobo, G. Maria // Food Industry. doi: 10.5772/53168
13. Ogneana, M. Rheological Effects of Some Xylanase on Doughs from High and Low Extraction Flours [Text] / M. Ogneana, C. F. Ogneana, A. Bucurb // Procedia Food Science. – 2011. – Vol. 1. – P. 308–314. doi: 10.1016/j.profoo.2011.09.048
14. Shah, A. R. Improvement of the quality of whole wheat bread by supplementation of xylanase from Aspergillus foetidus [Text] / A. R. Shah, R. K. Shah, D. Madamwar // Bioresource Technology. – 2006. – Vol. 97, Issue 16. – P. 2047–2053. doi: 10.1016/j.biortech.2005.10.006

15. Sanina, T. V. Intensifikatsyya protsessa bioaktivatsyi zerna i snizheniye yego mikrobilogicheskoy obsemenennosti v technologii zernovogo khleba [Text] / T. V. Sanina, G. P. Shuvayeva, N. N. Aliokhina // Hranenye y pererabotka sel'hozsyr'ja. – 2003. – Vol. 1. – P. 15–17.
16. Renzetti, S. Role of enzymes in improving the functionality of proteins in nonwheat dough systems [Text] / S. Renzetti, C. M. Rosell // Journal of Cereal Science. – 2016. – Vol. 67. – P. 35–45. doi: 10.1016/j.jcs.2015.09.008
17. Bonet, A. Rebuilding gluten network of damaged wheat by means of glucose oxidase treatment [Text] / A. Bonet, C. M. Rosell, I. Perez-Munuera, I. Hernando // Journal of the Science of Food and Agriculture. – 2007. – Vol. 87, Issue 7. – P. 1301–1307. doi: 10.1002/jsfa.2846
18. Primo-Martın, C. An explanation for the combined effect of xylanase–glucose oxidase in dough systems [Text] / C. Primo-Martın, M. Wang, W. J. Lichtendonk, J. J. Plijter, R. J. Hamer // Journal of the Science of Food and Agriculture. – 2005. – Vol. 85, Issue 7. – P. 1186–1196. doi: 10.1002/jsfa.2107
19. Primo-Martin, C. Influence of pentosanase and oxidases on water-extractable pentosans during a straight breadmaking process [Text] / C. Primo-Martin, M. A. Martinez-Anaya // Journal of Food Science. – 2003. – Vol. 68, Issue 1. – P. 31–41. doi: 10.1111/j.1365-2621.2003.tb14110.x
20. Hilhorst, R. Baking performance, rheology andchemical composition of wheat dough and gluten affected cross-linking by xylanase and oxidative enzymes [Text] / R. Hilhorst, B. Dunnewind, R. Orsel, R. Stegeman, T. V. Vliet, H. Gruppen, H. A. Schols // Journal of Food Science. – 1999. – Vol. 64, Issue 5. – P. 808–813. doi: 10.1111/j.1365-2621.1999.tb15917.x
21. Lysyuk, G. M. The technological aspects of emmer breed Golikovska [Text] / G. M. Lysyuk, S. G. Oliynyk, G. V. Zaparenko, S. Y. Didenko, O. V. Golik, T. S. Geyko // Scientific Letters of Academic Society of Michal Baludansky. – 2014. – Vol. 2, Issue 5. – P. 54–56.
22. Oleynik, S. G. Obosnovaniye technologicheskikh parametrov zamachivaniya zerna polby [Text] / S. G. Oleynik, G. M. Lysyuk, A. V. Zaparenko // Sovremennye technologii selskokhoziaystvennogo proizvodstva, 2015. – P. 304–306.
23. Pogozhykh, M. I., Pak, A. O., Chekanov, M. A., Ishtvan, Ye. O., Pavliuk, I. M. (2014). Researches of system water of food raw materials by thermodynamic and molecular-kinetic methods [Text] / M. I. Pogozhykh, A. O. Pak, M. A. Chekanov, Ye. O. Ishtvan, I. M. Pavliuk // Eastern-European Journal of Enterprise Technologies. – Vol. 5, Issue 11 (71). – P. 42–46. doi: 10.15587/1729-4061.2014.27790
24. Tecknockimichnyi control syrovyny ta khlibobulochnykh i makaronnykh vyrobiv [Text] : navchalnyi posibnyk / za red. V. I. Drobot. – K. : Kondor-Vydavnytstvo, 2015. – 972 p.
25. Olennikov, D. N. Metodika kolichestvennogo opredeleniya gruppovogo sostava uglevodnogo kompleksa rastitelnykh obyektov [Text] / D. N. Olennikov, L. M. Tankhaeva // Khimiya rastitelnogo syrya. – 2006. – Vol. 4. – P. 29–33.
26. Matveeva, I. V. Biotechnologicheskiye osnovy prigotovleniya khleba [Text] / I. V. Matveeva, I. G. Beliavskaya. – Moskow: DeLi print, 2001. – 150 p.
27. Horalchuk, A. B. Rheologichni metody doslidzhennia syrovyny I kharchovykh produktiv ta avtomatyzatsiya rozrakhunkiv rheologichnykh kharakterystyk [Text] / A. B. Horalchuk, P. P. Pivovarov, O. O. Grinchenko, M. I. Pogozhykh, V. V. Polevich, P. V. Gurskyi. – Kharkiv: KhDUHT, 2006. – 63 p.
28. Hemdane, S. Wheat (Triticum aestivum L.) Bran in Bread Making: A Critical Review [Text] / S. Hemdane, P. J. Jacobs, E. Dornez, J. Verspreet, J. A. Delcour, C. M. Courtin // Comprehensive Reviews in Food Science and Food Safety. – 2015. – Vol. 15, Issue 1. – P. 28–42. doi: 10.1111/1541-4337.12176
29. Gracheva, I. M. Technologiya fermentnykh preparatov [Text] / I. M. Gracheva, A. Yu. Krivkova. – Moscow: «Elevar», 2000. – 512 p.