UDC 664.66.022.39

METHODS OF REGULATING PHYSICAL PROPERTIES OF DOUGH USING PHYTOEXTRACTS

T. Lebedenko, D.Sc., Associate Professor[1], *E-mail*: tatyanalebedenko27@gmail.com
H. Korkach, Ph.D., Associate Professor[1], *E-mail*: kor2007@ukr.net
V. Kozhevnikova, Ph.D., Senior Lecturer[2], *E-mail*: kozhevnikova-viktoriya@ukr.net
T. Novichkova, Ph.D., Associate Professor[2], *E-mail*: vicnov@ukr.net
[1]Department of bread, confectionery, macaroni products and food concentrates technology
[2]Department of hotel and catering business
Odessa National Academy of Food Technologies, 112, Kanatna St., Odessa, Ukraine, 65039

Abstract. This paper considers the prospects of using phytomaterials to solve the problems of baking industry, caused by the instability and defects of wheat flour, and analyses the main methods of regulating structural and mechanical properties of wheat dough and improving the quality of products made from weak flour. The prospects of using phytomaterials as natural alternatives to synthetic additives and baking improvers are presented. The chemical composition and the content of active substances in rosehips (the dogrose fruit) and hawthorn fruit are analyzed as to their effect on increasing the nutritional value and improving the protective properties of products as well as their effect on the course of the technological process, the quality of semi-finished and finished products. The methods of processing the phytomaterials have been suggested, and the optimum parameters of their extraction have been determined as to their effect on the protein-proteinase complex. Water and milk whey are suggested as extractants with the 1:10 ratio between the raw materials and the extractant, while the optimal temperature (100°C) and duration (60 minutes) of extraction were determined experimentally. Rational doses of phytoextracts have been found on the basis of their influence on gluten elasticity and the physical properties of wheat dough during its mixing and fermentation (30% of the rosehip water extract, 45% of hawthorn water extract, and 15% of whey extracts to the weight of flour). It has been established that proposed phytoextracts can increase the water absorption capacity of flour with weak and medium-strength gluten during dough mixing, improve its formation, stability, and elasticity, and decrease the degree of dilution according to the study of rheological properties of the dough using farinograph and extensograph. The mechanism of interactions and conformational changes in the structure of gluten proteins with the active substances of phytoextracts, especially pectins, polyphenols, and organic acids, has been suggested. It has been proven that fruit phytoextracts can be used as alternatives to synthetic improvers to process weak flour. Their usage allows solving the problems of regulating the properties of the gluten network and obtaining baked products with high physical, chemical, and sensory qualities. The proposed methods are effective and relatively easy to implement, which is important for small bakeries and restaurant establishments.

Key words: rosehips, hawthorn, phytomaterials, extract, gluten, structural and mechanical properties, weak flour.

СПОСОБИ РЕГУЛЮВАННЯ ФІЗИЧНИХ ВЛАСТИВОСТЕЙ ТІСТА З ВИКОРИСТАННЯМ ФІТОЕКСТРАКТІВ

Т.Є. Лебеденко, доктор технічних наук, доцент[1], *E-mail*: tatyanalebedenko27@gmail.com
Г.В. Коркач, кандидат технічних наук доцент[1], *E-mail*: kor2007@ukr.net
В.О. Кожевнікова, кандидат технічних наук, старший викладач[2], *E-mail*: kozhevnikova-viktoriya@ukr.net
Т.П. Новічкова, кандидат технічних наук, доцент[2], *E-mail*: vicnov@ukr.net
[1]Кафедра технології хліба, кондитерських, макаронних виробів і харчоконцентратів
[2]Кафедра готельно-ресторанного бізнесу
Одеська національна академія харчових технологій, вул. Канатна, 112, м. Одеса, Україна, 65039

Анотація. У представленій роботі розглянуто проблеми виробництва хлібопекарської продукції, спричинені коливанням якості та дефектами борошна, та проаналізовано основні заходи регулювання структурно-механічних властивостей пшеничного тіста і підвищення якості продукції зі слабкого борошна. Показано перспективність використання фітосировини як альтернативи синтетичним добавкам та хлібопекарським поліпшувачам. Проаналізовано хімічний склад, вміст діючих речовин плодів шипшини та глоду з точки зору підвищення харчової цінності та посилення у продукції захисних властивостей, а також їх впливу на перебіг технологічного процесу, якість напівфабрикатів і готових виробів. Розглянуто способи переробки фітосировини і визначено оптимальні параметри її екстрагування з точки зору впливу на білково-протеїназний комплекс. В якості екстрагентів запропоновано використання питної води і молочної сироватки зі співвідношенням сировини до екстрагенту 1:10, оптимальні температуру (100°C) та тривалість екстрагування (60 хв) встановлювали дослідним шляхом. Встановлено раціональні дозування фітоекстрактів за їх впливом на пружність клейковини та фізичні властивості пшеничного тіста при замісі і ферментації (водні екстракти глоду – 45%, шипшини – 30%, сироваткові екстракти – 15% до маси борошна). Дослідження водопоглинальної здатності борошна зі слабкою та середньою за силою клейковиною, реологічних властивостей напівфабрикатів за даними екстенсографа і фаринографа показали, що тісто з запропонованими фітоекстрактами краще зберігає фізичні властивості протягом замісу і ферментації. Запропоновано механізм взаємодій і конформаційних змін в будові клейковинних білків за участю діючих речовин фітоекстрактів, насамперед пектинів, поліфенолів, органічних кислот. Доведено, що плодові фітоекстракти можуть бути альтернативою синтетичним поліпшувачам при переробці слабкого борошна, а їх використання дозволяє вирішити комплекс проблем по регулюванню властивостей клейковинного каркасу тіста та отримати хлібобулочні вироби з високими фізико-хімічними та органолептичними властивостями. При цьому запропоновані заходи відрізняються ефективністю та відносною простотою використання, що є актуальним як для дрібних пекарень, так і для підприємств ресторанного господарства.

Ключові слова: шипшина, глід, фітосировина, екстракт, клейковина, структурно-механічні властивості, слабке борошно.

DOI: http://dx.doi.org/10.15673/fst.v12i4.1182

Introduction. Formulation of the problem

Bread products are staple, mass-consumption ones. They belong to the most affordable sources of energy and biologically active substances (BAS) for people. Depending on the recipe, technology, and thus their chemical composition and their nutrient and micronutrient content, bread products can have different lipotropic, detoxifying, antioxidant or other valuable therapeutic and prophylactic properties. Bread can motivate and signal, its flavor and taste are among the most effective factors in arousing appetite and improving the emotional state. Besides, some specific features of the content and state of biopolymers and the porous texture allow bread products to impart the required consistency and structure to the food consumed along with them. This contributes to the effectiveness of gastrointestinal tract functioning, allowing fuller digestion of different types of food. To preserve the special value of bread in human life and its functions so important for the organism, its quality (taste, aroma, appearance, porosity, acidity, chemical composition, state of biopolymers, and BAS content) must comply with certain requirements. The formation of the above characteristics depends on the baking properties of the raw materials (especially of the flour), the recipes, the organization of the technological process, the duration, intensity and direction of the physical, chemical, colloidal, biochemical, microbiological, and thermophysical modifications of the components of the dough systems [1].

Analysis of recent research and publications

In recent years, instability and reduction of the baking quality of wheat flour have become one of the major problems of domestic baking industry [2]. Bakeries more and more often face the problem of being provided with defective wheat flour – low in gluten (24.0 to 28.0%), of insufficient elasticity and excessive resilience (47 to 63 units of gluten strain meter with 11.0–12.5 cm of elongation), or too diluted after the processing. The defects can also include significant fluctuations in the falling number (285 to 556 s), in gas production (1070–1490 cm^3 of CO_2), and in other technological and biochemical characteristics. All this hinders the formation of a continuous sponge-like gluten structure of the wheat dough, its structural and mechanical properties and elasticity-resilience balance during the technological process, the gas-forming, gas-retaining and shape-keeping capabilities of the dough, – thus, it prevents the dough from taking the required shape, volume, porosity, and other product quality characteristics. Fluctuations of flour properties along with the manufacturers' desire to improve the range of products, to form their special sensory characteristics, to strengthen the prophylactic, therapeutic, and preventive properties of the products by using new raw materials and introducing intensive technologies – all this has made the problems of baking products quality and their stability in storage really acute. The insufficient intensity of colloidal, biochemical and microbiological processes during the preparation of wheat dough negatively affects, first of all, the taste and aroma of bread, its shelf-life, and increases the risk of microbiological damage, which reduces the consumer demand [1-3].

Most of the activities aimed at solving these problems are implemented at the stage of dough preparation – its mixing and fermentation. The decisive factor in the regulation of rheological properties of wheat dough is considered to be the modification of the composition, structure, and properties of gluten proteins due to updating the recipes, including reactive compounds, changing the medium (pH, humidity, temperature) and the parameters of mechanical loading during the doughing process. This provides chemical, physical, mechanical, and biochemical effects on the state of proteins, on intermolecular and intramolecular protein-protein, protein-lipid, and protein-polysaccharide interactions of covalent and nonvalent nature, causes changes in the quality of gluten, its degree of hydration, aggregation ability of glutenin, gliadin and other biopolymers of flour systems, activity of proteolytic enzymes, etc.

Baking improvers are commonly used, during both the production of flour and the dough preparation, to regulate the technological properties of flour, and thus the physical characteristics of the dough, and to improve the products quality both in Ukraine and abroad. These improvers are, first of all, enzymes, dry wheat gluten, as well as redox supplements, emulsifiers, modified starches, hydrocolloids, mineral salts, etc. [4-9]. The versatility and interrelation of the processes of forming the necessary consumer characteristics of bread and the complexity of baking problems predetermine the usage of combined approaches and complex improvers (mostly of foreign production), capable of multifunctional effect on the technological process and product quality. The wide spread of baking improvers is due to their effectiveness in forming the main characteristics of product quality, controlled by regulatory documents, and the ease of their usage in dynamic industrial conditions. However, since baking improvers are largely synthetic additives, their wide usage alarms a lot of consumers (according to surveys, it is the reason why 35% of consumers choose not to buy such products) and nutritionists (who link them to the spread of allergies and other diseases), both in Ukraine and abroad [10-13].

That is why it is becoming relevant to search for natural alternatives to synthetic additives that combine safety, complexity, the polyvalent effect, the possibility of solving the problems of the industry and improving the nutritional value of baked goods and their physiological properties. The products of processing plant and animal raw materials (legumes, fruit powders, dairy products, etc.) are used in baking industry. Their benefits include the complex composition, the balance of their individual components, the presence of compounds in the most easily digested form [1,14,15]. In recent years, special importance worldwide has been given to medicinal and aromatic plants, both in terms of their usage in phytotherapy and in the production of dietary supplements, food, cosmetics, natural dyes, flavors, preservatives, etc. [16-18].

The value of phytomaterials, as applied to baking, consists in their diversity, high content of biologically active substances with relevant physiological effects, reactive to the components of flour systems. Particularly, the composition of BAS in hawthorn fruit (*Crataegus sanguinea*) includes mono- and disaccharides (up to 15%), pectins (up to 1.8%), and 2.1% of organic acids (citric, malic, caffeic), polyphenols and tannins (anthocyanins, catechins, flavonols, etc.), up to 24 micro- and macroelements [19-21]. Hips of the dogrose (*Rosa canina*) contain up to 18% of mono- and disaccharides, up to 2.8% of organic acids (mainly citric and malic) and 1.8–2.7% of pectin. Rosehips mostly contain such BAS as vitamin C, β-carotene, and phenolic compounds (anthocyanins, flavonols, etc.). Fruit pulp also contains vitamins PP, B_1, B_2, B_9, E, essential oils, and a significant amount of salts (Ca, Na, Fe, Mn, P, K, Mg, etc.) [22,23].

This chemical composition allows us to view rosehips and hawthorn fruit as promising additives to increase the nutritional value, improve the protective properties of products, and enrich semi-finished flour products with nutrients, important for fermentative microflora (saccharides, amino acids, vitamins, macro- and microelements), including using them as components of the nutrient medium for yeast activation [24]. The presence of pectins, tannins, organic acids that can shift the pH of the medium, interact with proteins, affect the activity of proteases allows us to consider whether they can regulate the structural and mechanical properties of wheat dough, neutralize the negative effects of fluctuations in the baking properties of flour [1,25]. However, the use of medicinal and aromatic plants to solve the problems of baking industry is hindered by the instability of their quality. Besides, it is necessary to deepen the theory and, basing on it, standardize the requirements for their quality, methods of determining their technological properties, the profile of their main active substances, and recommendations about rational methods of their preparation.

Thus, **the purpose** of this work was to develop practical measures supposed to stabilize the quality of bakery products by using the products of processing hawthorn fruit and rosehips to regulate the dough preparation processes and its structural and mechanical properties.

Research tasks.

1. To determine the optimum extraction parameters for rosehips and hawthorn fruit by their influence on the state of gluten in wheat flour.
2. To investigate the effect of phytoextracts on the structural and mechanical properties of wheat dough, and to establish their rational doses.
3. To determine the physical, chemical, and organoleptic properties of wheat dough and bakery products made from normal and weak flour with phytoextracts.

Research materials and methods

In this research, first grade wheat flour was used. To assess the state of the protein-proteinase complex of the flour, such parameters were determined as the 'raw' gluten content according to GOST 27839-88, its elasticity (measured on the gluten strain meter), and elongation [26]. The selected samples of flour had the following baking properties: 1st – weak gluten with a content of 28.2%, 105 units of elasticity, and 20 cm of elongation; 2nd – good quality gluten with a content of 26.8%, 75 units of elasticity, and 15 cm of elongation. The following phytomaterials were used: hawthorn fruit and rosehips, whose quality (average particle size, bulk density, degree of swelling) was evaluated according to the recommendations of the State Pharmacopoeia of Ukraine [27].

A Brabender farinograph and extensograph were used to evaluate the effect of phytomaterials and the products of their processing on the progress of wheat dough preparation, its structural and mechanical properties during mixing and fermentation, according to DSTU 4111.1-2002, DSTU 4111.2-2002. Other characteristics determined were dough running (during 180 min. of fermentation), shape stability, volume and porosity of the test-baked bread according to GOST 27669-88 [26].

Results of the research and their discussion

A comparison of the sensory, physical, and chemical characteristics of powdered phytomaterials with first grade wheat flour (Table 1) has shown that the particle size of the former is much larger, they can be sensed while chewing, have a darker color, and swell much more slowly. This means that measures should be developed for the preliminary preparation of phytomaterials so as to eliminate these flaws and retain valuable properties.

Table 1 – Comparative analysis of powdered fruit phytomaterials and flour

Physical characteristics	Hawthorn and rosehip phytomaterials	1st grade wheat flour
- average particle size, μ	325–464	40-60
- bulk density, kg/m^3	380–450	550
- degree of swelling, cm^3/g	3.60–4.47	1.78–2.05

One of the oldest and most widespread methods of isolating BAS from plant materials is extraction, which removes unwanted fractions that can adversely affect the sensory properties of the product. The main goal when organizing a phytomaterial extracting process is to determine its optimum parameters (type of extractant, material-to-extractant ratio, dispersion, extraction temperature and duration, etc.) to isolate the technologically significant compounds and preserve their physiological properties with the least possible energy consumption [28-30].

Water and milk whey (OST 10-02-02-3-87) are suggested as extractants, since they are widely used in baking. The ratio between the raw materials and the extractant was chosen as 1:10, according to the recommendations of the State Pharmacopoeia of Ukraine and preliminary studies [31], and the optimum temperature and duration of extraction were established experimentally. The effectiveness of the process was determined by the effect of rosehip and hawthorn extracts on the gluten network. The effect was evaluated by measuring gluten elasticity with a gluten strain meter (Fig. 1).

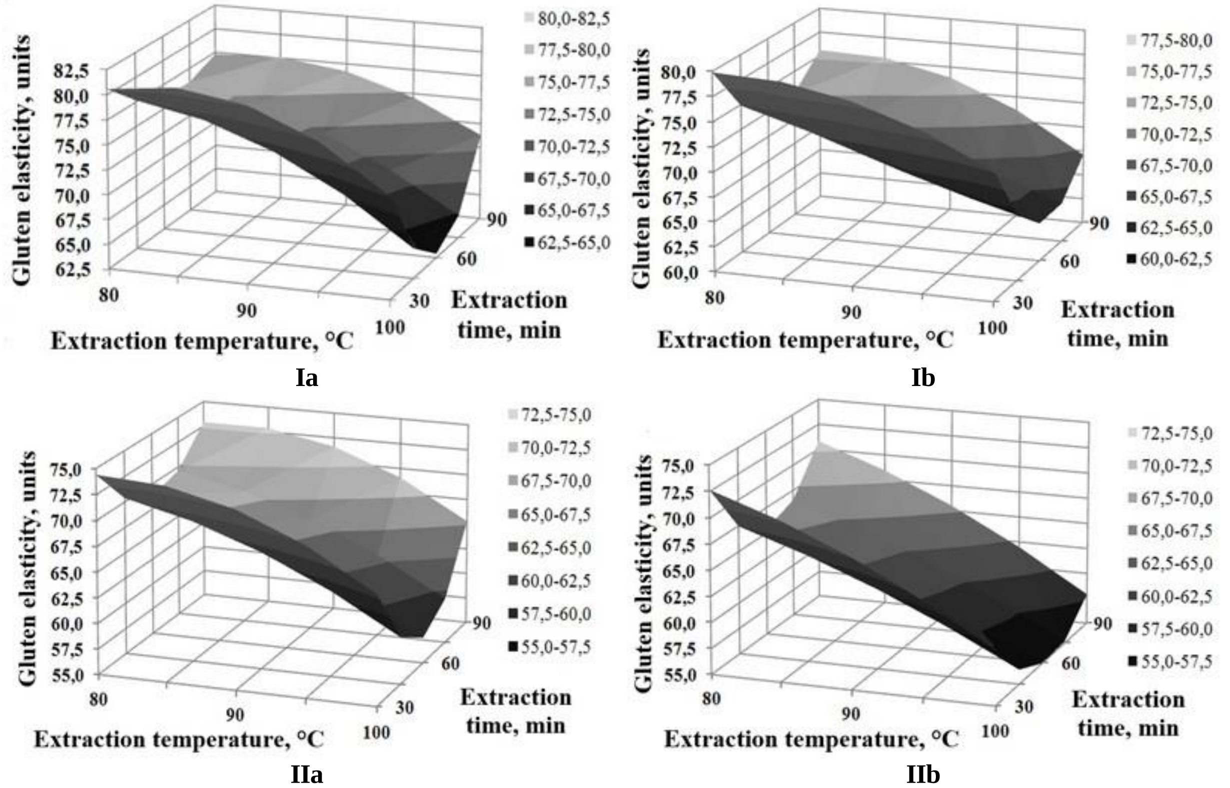

Fig. 1. Effect of water (I) and whey (II) extracts of hawthorn (a) and rosehips (b) on the elasticity of weak flour gluten

The above results show that phytoextracts strengthen the gluten, increase its elasticity, and reduce its running and elongation. In this case, the most significant factor of extraction is its duration, the optimum value of which is 60 minutes. Obviously, such extracts contain higher concentrations of pectin, other polysaccharides, polyphenols, and organic acids that can interact with gluten-free proteins of the dough, affect the number of intra- and intermolecular hydrogen, disulphide, and ionic bonds between gliadin and glutenin fractions. They can become embedded into the structure of gluten, and this effects on the density of their packaging and on their properties. Increasing the extraction time adversely affects the effectiveness of phytoextracts strengthening the gluten network. This, apparently, results from the changes in the state of active substances, in particular, from hydrolysis and polymerization of pectins and polyphenols, and from an increase in acidity.

To check the hypothesis that fruit phytoextracts are effective for strengthening the gluten network of wheat dough, the dough was made with addition of different doses of hawthorn and rosehips that had been extracted with water or milk whey for over 30 min (a) and 60 min (b), and then, the quality of its gluten was determined (Fig. 2).

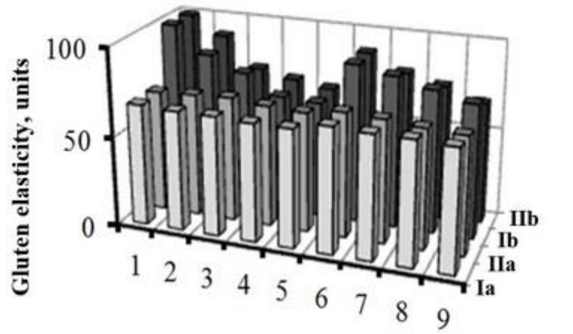

Fig. 2. Effect of hawthorn (I) and rosehip (II) phytoextracts on the gluten resilience: 1 – control (water); 2–5 – water extract dosage to the mass of flour: 2 – 15 %; 3 – 30 %; 4 – 45 %; 5 – 60 %; 6 – control (15 % of milk whey); 7–9 – whey extract dosage to the mass of flour: 7 – 5 %; 8 – 10 %; 9 – 15 %

It has been confirmed that addition of up to 30% of the rosehip water extract, up to 45% of hawthorn water extract, and up to 15% of whey extracts (with the extraction time of 60 minutes) to the dough while mixing it has a positive effect on the formation of the gluten network. The gluten from the samples with hawthorn and rosehip water extracts added had higher resilience (by 23 and 27%, respectively) and lower elongation (by 22.5 and 20.0%). In the samples with whey phytoextracts added, the gluten resilience increased by 15.7 and 23.5%, and elongation was reduced by 11.8 and 23.2%, as compared to the control sample. Using the extracts with the extraction time of 30 min. resulted in a slightly increased gluten resilience (by 1.5–2.9% for water extracts, 2.8–5.7% for whey extracts) and decreased elongation (by 1.8–3.7% and 3.3–6.7%, respectively), compared to the control sample.

This is, evidently, due to faster extraction of saccharides, amino acids, organic acids, vitamins, minerals with low molecular weight, valuable when intensifying dough fermentation, but ineffective for strengthening the gluten. Besides, this is due to slower extraction of pectins, polyphenols, and other substances active as to the protein-proteinase complex.

At the same time, higher doses of phytoextracts lead to further strengthening of gluten, but also to unwanted reduction of its yield, loss of elasticity, and higher crumbling, which can be the result of excessively dense packing of protein macromolecules.

To determine the relationship between the chemical composition of the extracts, the physical properties of the dough, and the quality of bread, the main characteristics and content of active substances in the hawthorn and rosehip extracts were determined (Table 2).

For a more detailed study of the effect these fruit phytoextracts have on the properties of the dough during its mixing and fermentation, farinograph and extensograph were used, respectively. The results of processing the farinograms are presented in Fig. 3

Table 2 – Characteristics of phytoextracts likely to be effective in regulating the physical properties of wheat dough made from weak flour

Extract	Extraction parameters	Extract quality characteristics				
		Dry matter content, %	*pH*	Content of the main active substances		
				pectins, mg/100 g	polyphenols, mg/100 g	organic acids, % of dry matter
Rosehip extract (water)	Water duty (material-to-extractant ratio – 1:10; extraction time – 60±2 min.; temperature – 100±2 °C	3.6±0.2	5.7±0.1	585±5	74.9±3	0.114±0.001 (citric, mallic)
Rosehip extract (whey)		10.0±0.2	4.7±0.1	624±5	154.5±3	0.118±0.001 (lactic, citric, mallic)
Hawthorn extract (water)		3.2±0.2	6.1±0.1	498±5	50.4±3	0.118±0.001 (citric, mallic)
Hawthorn extract (whey)		9.2±0.2	4.8±0.1	595±5	98.9±3	0.120±0.001 (citric, mallic)

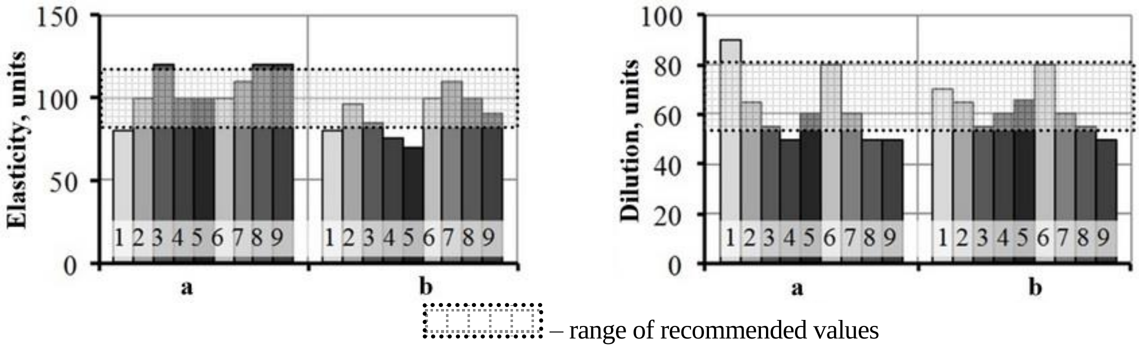

Fig. 3. Structural and mechanical properties of wheat dough with hawthorn (a) and rosehip (b) extracts added: 1 – control (water); 2–5 – water extract dosage to the mass of flour: 2 – 15 %; 3 – 30 %; 4 – 45 %; 5 – 60 %; 6 – control (15 % of milk whey); 7–9 – whey extract dosage to the mass of flour: 7 – 5 %; 8 – 10 %; 9 – 15 %

The experimental data shows a 2.0–3.5 min. increase in dough formation time and a 3.0–4.5 min. increase in its stability, improved elasticity and reduced dilution when using hawthorn (up to 45%) and rosehip (up to 30%) water extracts. At the same time, all samples with whey extracts added in an amount of up to 15 % to the mass of the flour improved the physical properties of the dough. Hawthorn extracts increased its elasticity by 27.7–44.4%, rosehip extracts by 14.3–31.3%. Exceeding these doses resulted in drastic loss of dough elasticity, decreased stability, and increased dilution caused by the destruction of the gluten network. This is confirmed by a reduced gluten yield and its high crumbling.

Differences in the effects of extracts on the physical properties of wheat dough are more pronounced in the course of the technological process, which is characterized by continuous colloidal and biochemical transformations of flour biopolymers. They determine the dough fermentation and, to a large extent, the formation of quality bread products. But they can also lead to the loss of required characteristics due to deviations in their intensity and direction caused by the baking properties of the flour, the specific features of mechanical treatment, and other factors. To assess the influence of phytoextracts on the speed and direction of changes in the structural and mechanical properties of the dough during 45, 90, and 135 minutes of fermentation, the dough's ability to resist tensile deformation was analyzed. The results of decoding the extensograms are presented in Fig. 4.

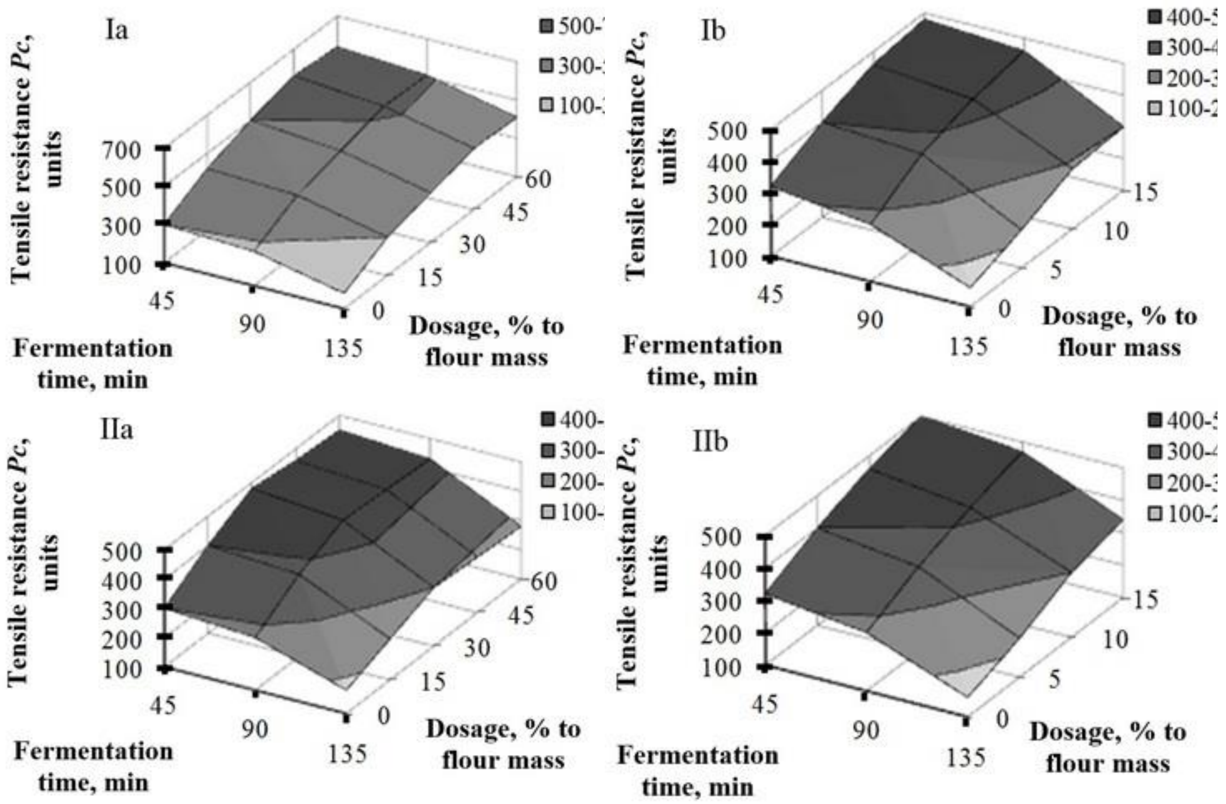

Fig. 4. Changes in the structural and mechanical properties of the dough with hawthorn (I) and rosehip (II) extracts obtained using water (a) and whey (b)

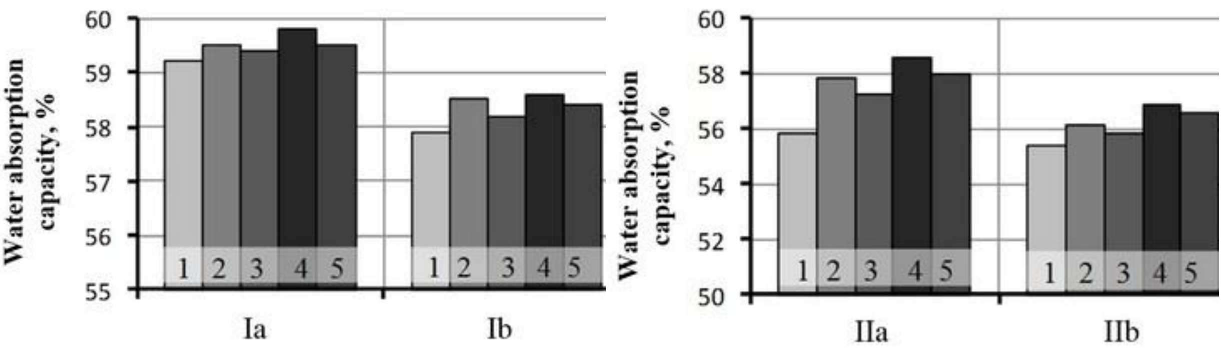

Fig. 5. Water absorption capacity of normal (I) and weak (II) wheat flour with water (a) and whey (b) extracts: 1 – control; 2 – hawthorn (30 min. extraction); 3 – rosehips (30 min. extraction); 4 – hawthorn (60 min. extraction); 5 – rosehips (60 min. extraction)

The data demonstrates the positive influence of rosehip and hawthorn extracts on the structural and mechanical properties of wheat dough, the dough's increased resistance to tensile deformation, the reduced rate and degree of dough dilution during fermentation due to slowing down the disaggregation of the gluten network. A better balance between the elasticity and resilience of wheat dough is observed when introducing 45% of hawthorn water extracts, 30 % of rosehip water extracts, and 15% of whey extracts to the mass of flour.

To confirm the effectiveness of using rosehip and hawthorn extracts as regulators of dough's structural properties, it is necessary to investigate their effect on the physical properties of semi-finished products made from wheat flour with reduced baking properties. At the same time, despite the fact that the best characteristics were obtained using phytoextracts with extraction time of 60 min, it is also advisable to study less effective extracts with extraction time of 30 min, taking into account the recommendations for their use to intensify microbiological processes.

An integral indicator that allows us to assess the properties and balance of the solid and liquid phases of wheat dough and its constituents (primarily proteins, but also other biopolymers, hydrophilic compounds) is the water absorption capacity of the flour. It affects the yield of bread products and thus has economic and technological significance. Fig. 5 presents the changes in the water absorption capacity of wheat flour with normal and weak gluten under the influence of hawthorn and rosehip water phytoextracts (45 and 30% of the mass of the flour, respectively) and whey extracts (15%).

It has been observed that both flour with normal and that with weak gluten require more water (mixed with extracts) to form wheat dough with a specified consistency (500 farinograph units). Using rosehip and hawthorn extracts with 60 min extraction time increases this parameter by 1.2–5.0%, with 30 min extraction time – by 0.5–3.6 %. This is, evidently, due to the introduction of pectins, polyphenols, and other biopolymers that have hydrophilic properties, can polymerize and form complexes with protein macromolecules, other biopolymers, which increases their swelling and the amount of bound moisture.

A comparative analysis of the effect of phytoextracts on the physical properties of wheat dough during mixing (Fig. 6) indicates that dough stability increases by 1.9–2.2 min for weak flour, and 0.7–1.3 min for normal flour. The dilution of wheat dough with gluten of normal strength decreases by 4.0–6.7% when using rosehip and hawthorn extracts with 30 min extraction time, and by 6.8–10.7% with 60 minutes' extraction time. The dilution decreases by 2.3–22.2% and 12.5–33.3%, respectively, for flour with weak gluten.

To study the intensity of colloidal and biochemical processes, occurring at the subsequent stages of dough preparation (its fermentation and maturation), the changes in the physical properties of the wheat dough were evaluated during the 135 minutes of fermentation with the Brabender extensograph (Fig. 7), and the running of the dough pieces in 180 min was determined (Fig. 8).

The extensograms having been analyzed, the dough's increased resistance to elongation was observed during the whole period of fermentation when using water and whey phytoextracts, especially those with 60 min. extraction time. Using water and whey phytoextracts with 30 and 60 min. extraction time results in improvement of the physical properties of weak dough by 6.2–9.5% and 11.3–19.0%, respectively, and normal dough by 4.2–6.3% and 12.7–15.3%.

To determine the effect of phytoextracts on the bread quality characteristics that depend primarily on the state of the gluten network, a baking test was carried out, the results of which, particularly, the loaf's shape stability, are presented in Fig. 8, and the outer appearance of the bread obtained – in Fig. 9.

It has been established that the introduction of fruit phytoextracts with 30 min. extraction time into the dough made from normal flour allows increasing the uniformity of bread loaf by 6.8–11.3%, and of those with 60 min. extraction time – by 20.4–35.5%. The shape stability of the loaf made from weak flour increases by 33.3–41.9% and 60.0–67.7%, respectively, under the influence of active substances of phytoextracts, which also improve the volume and porosity (Fig. 9). This is due to the formation, during dough mixing with pectins, polyphenols, and other components of phytoextracts, of a gluten network that is more stable, has a better balance between elasticity and resilience, is more resistant to different types of loading and to the proteolytic activity of enzymes, which leads to its less disaggregation in the course of the technological process. Saccharides, vitamins, minerals, organic acids of phytoextracts intensify alcoholic and lactic acid fermentation. Together with improved gas formation and retention capacity of dough, this results in the increased volume and porosity of the products.

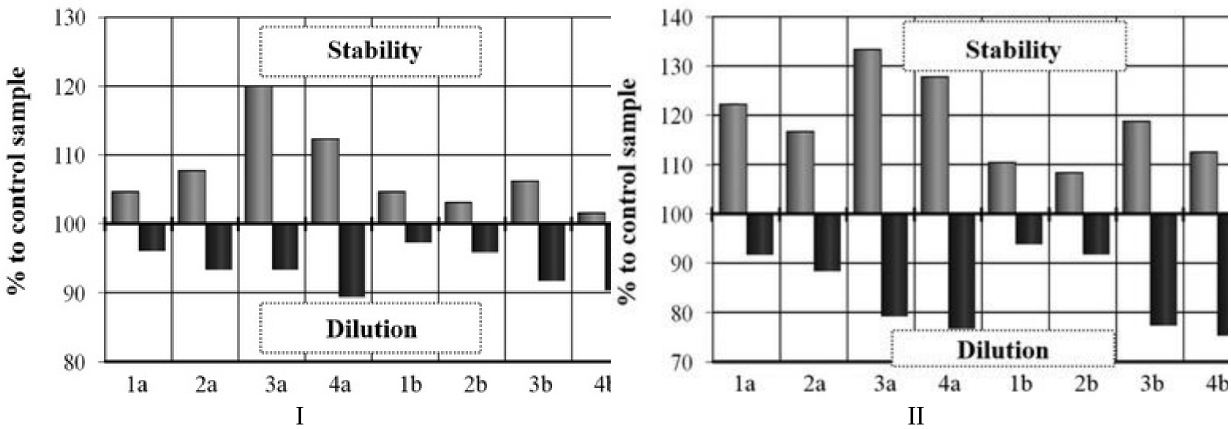

Fig. 6. Changes in the stability and dilution of dough made from normal (I) and weak (II) wheat flour with water (a) and whey (b) phytoextracts: 1 – hawthorn (30 min. extraction); 2 – rosehips (30 min. extraction); 3 – hawthorn (60 min. extraction); 4 – rosehips (60 min. extraction)

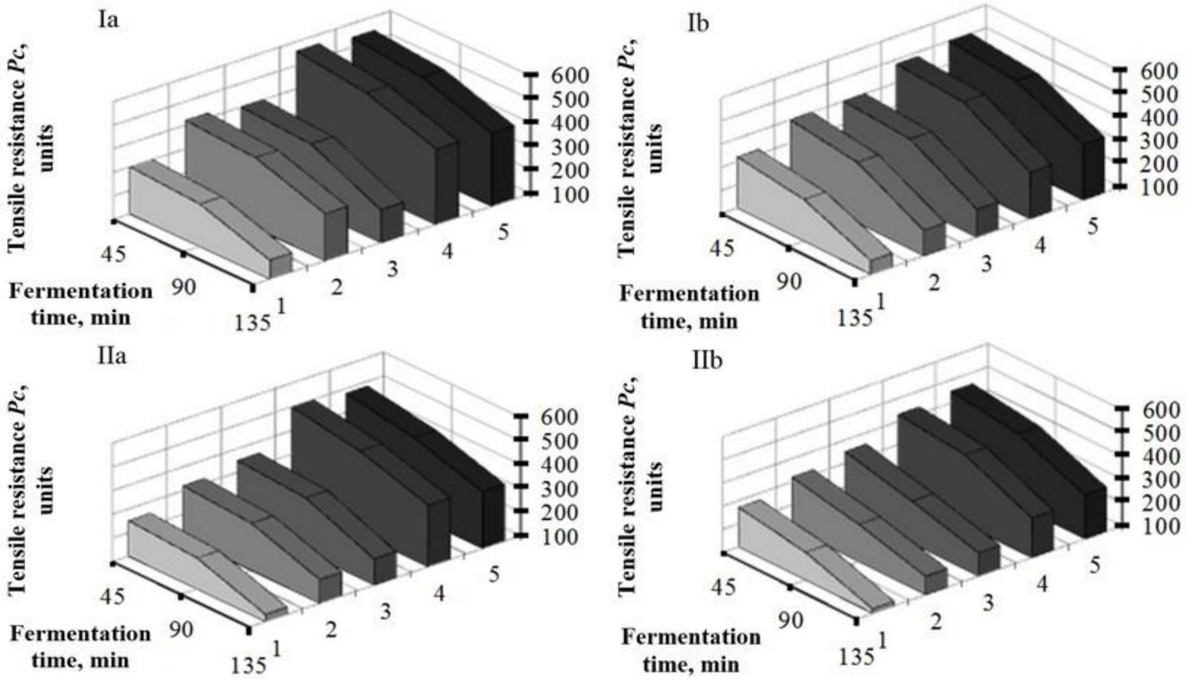

Fig. 7. Changes in the physical properties of dough made from normal (I) and weak (II) wheat flour with water (a) and whey (b) phytoextracts: 1 – control; 2 – hawthorn (30 min. extraction); 3 – rosehips (30 min. extraction); 4 – hawthorn (60 min. extraction); 5 – rosehips (60 min. extraction)

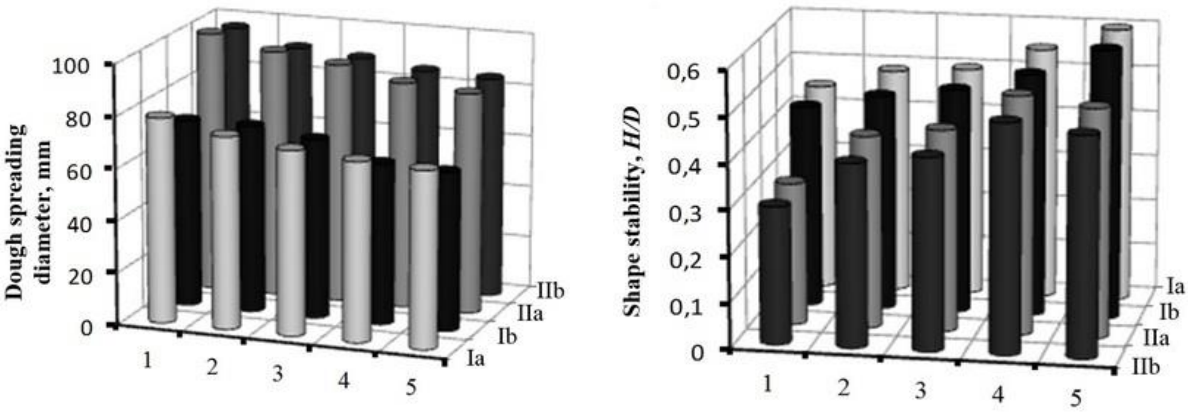

Fig. 8. Running and shape stability of dough made from normal (I) and weak (II) wheat flour with water (a) and whey (b) phytoextracts: 1 – control; 2 – hawthorn (30 min. extraction); 3 – rosehips (30 min. extraction); 4 – hawthorn (60 min. extraction); 5 – rosehips (60 min. extraction)

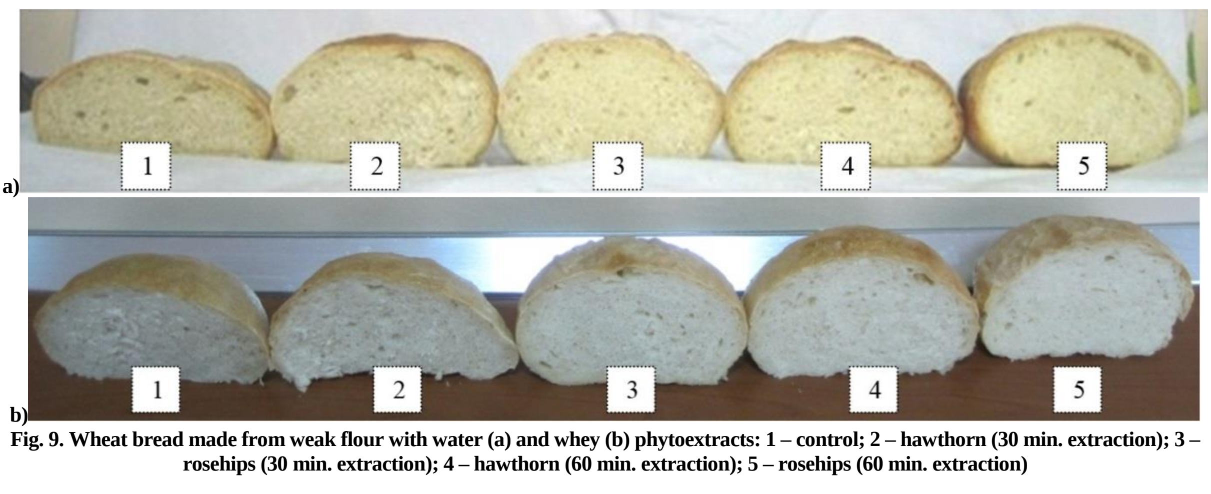

Fig. 9. Wheat bread made from weak flour with water (a) and whey (b) phytoextracts: 1 – control; 2 – hawthorn (30 min. extraction); 3 – rosehips (30 min. extraction); 4 – hawthorn (60 min. extraction); 5 – rosehips (60 min. extraction)

The results of the research confirm that there is a correlation between the effect of phytoextracts on the physical properties of wheat dough during mixing and fermentation and the structural properties of bread. Rosehip and hawthorn extracts, particularly those with 60 min. extraction time, have a positive effect on the physical properties of dough, and those with 30 min. extraction time have a less pronounced effect.

Considering the structure and properties of gluten proteins of wheat flour and active substances of phytoextracts (pectin, polyphenols, organic acids, etc.), it is possible to suggest the following mechanisms of their interaction and dough quality regulation. Firstly, when organic acids make the *pH* phytoadditives of the liquid phase shift into the acidic medium, the proteins' amphoteric properties make the surface charge of macromolecules change (they acquire a positive charge by transforming bipolar ion amino acids into their ammonium cations). This intensifies the unfolding of globules and α-helices of proteins, causes repulsion between similarly charged portions of polypeptides, initiates the formation of new interactions of the functional groups of previously inaccessible amino acids with water, and establishes a contact with the active groups of compounds in phytoextracts. Secondly, a high amount of reactive groups in pectins (which are acidic polysaccharides) and in polyphenols that are contained in phytoextracts creates the conditions for their interaction with proteins, the formation of additional cross-interactions, and their integration into the gluten network. Thirdly, phytoextract compounds enhance the stability of intermolecular disulfide bonds. All this leads to an increase of bound intermolecular interactions, the formation of new, more orderly conformations of gluten proteins with high density and strength of hydrogen bonds, forces of Van der Waals electrostatic interaction, and disulfide bridges in order to form stable structures of dough where elasticity and resilience are combined.

Conclusion

The theoretical and experimental research has proved that using rosehip and hawthorn extracts is a relevant and expedient method of improving the structural and mechanical properties of wheat dough and bread products made from normal and weak flour, particularly those with extraction time of 60 minutes and temperature of 100°C, using water or milk whey as extractants. It has been established that phytoextracts can increase the water absorption capacity of flour during dough mixing, improve its formation, stability, and elasticity, and decrease the degree of dilution. It has been demonstrated that adding hawthorn (45% of the mass of the flour) and rosehip (30%) water extracts or whey extracts (15%) to the dough made from normal or weak flour can improve its physical properties, particularly, its elasticity during fermentation for 135 and 180 min. It has been proven that fruit phytoextracts can be used as alternatives to synthetic improvers to process weak flour. Their usage allows solving the problems of regulating the properties of the gluten network, intensifying alcoholic and lactic acid fermentation, and obtaining baked goods with a brightly colored crust, sufficient volume, porosity, and shape stability.

The mechanism of interactions and conformational changes in the structure of gluten proteins with the active substances of phytoextracts, especially pectins, polyphenols, and organic acids, has been suggested.

List of references:

1. Іоргачова К.Г., Лебеденко Т.Є. Хлібобулочні вироби оздоровчого призначення з використанням фітодобавок. Київ: К-Прес, 2015. 464с.
2. Жигунов Д.О., Ковальова В.П., Жиронкіна Д.С. Аналіз якості борошна з різних регіонів України // Наукові праці ОНАХТ. 2017. Т. 81, вип. 2. С. 35-43.
3. Research of efficiency of using the complex baking improver "Svizhist" in order to prolong freshness of bran crispbreads / Halikova E., et al. // Eastern-European Journal of Enterprise Technologies. 2017. Vol. 3/11 (81). P. 32-41. DOI: 10.15587/1729-4061.2017.103860
4. Дзюбинський А.В., Дзюбинська О.В., Шегинський О.В. Проблеми забезпечення якості пшеничного борошна // Товарознавчий вісник. 2017. Вип. 10. С. 23-29.
5. Байрамов Э.Э. Улучшители, влияющие на свойства хлебопекарного теста из пшеничной муки // Research in: Agricultural & Veterinary Sciences. 2017. №3(1). С.172-182.
6. Zhygunov D., Mardar M., Kovalyova V. Use of enzyme preparations for improvement of the flour baking properties // Food Science and Applied Biotechnology. 2018. №1(1). P. 26-32. DOI: 10.30721/fsab2018.v1.i1.21
7. New challenges of flour quality fluctuations and enzymatic flour standardization // International Association of Operative Millers. 2017. URL: https://www.iaom.info/wp-content/uploads/07abenzymessea17.pdf (viewed on 20.07.2018).
8. Paucean A., Man S.M., Socaci S.A. Wheat germ bread quality and dough rheology as influenced by added enzymes and ascorbic acid // Studia Universitatis Babes-Bolyai, Chemia. 2016. Vol. 2(61). P. 103-118.
9. Influence of enzymes and ascorbic acid on dough rheology and wheat bread quality / Baratto C.M., et al. // African Journal of Biotechnology. 2015. Vol. 46. P. 3124-3130. DOI: 10.5897/AJB2015.14931
10. Clean Labels: Public Relations or Public Health? // Center for Science in the Public Interest. 2017. URL: https://cspinet.org/sites/default/files/attachment/Clean%20Label%20report.pdf (viewed on 20.07.2018).
11. Haen D. The Paradox of E-Numbers: ethical, aesthetic, and cultural concerns in the Dutch discourse on food additives // Journal of Agricultural and Environmental Ethics. 2014. Vol. 27, Issue 1. P. 27-42. DOI: 10.1007/s10806-013-9440-4
12. Колесник В.М., Розкладай М.І. Маркетингові дослідження споживчих мотивацій на ринку хлібопродуктів в регіоні // Наукові праці Полтавської державної аграрної академії. Серія: Економічні науки. 2013. Вип. 6, Т. 1. С. 133-139.
13. Харчові добавки: віддалена загроза / Кобзар А.Я. та ін. // Environment & Health. 2013. №1. С. 70-74.
14. Аспекти технології хліба з використанням сушеної рослинної сировини / Нємірiч О.В. та ін. // Восточно-Европейский журнал передовых технологий. 2014. №2/12(68). С. 95-101. DOI: 10.15587/1729-4061.2014.23146

15. Kochubei-Lytvynenko O., Bilyk E. The prospects of using milk whey enriched with Mg and Mn in the technology of bakery products // Food Science and Technology. 2017. Vol. 11, Issue. 4. P. 55-63. DOI: 10.15673/fst.v11i4.731
16. Філенко С.В., Середа Л.О. Актуальність використання пряно-ароматичної лікарської рослинної сировини у харчовій промисловості // Лікарське рослинництво: від минулого до новітніх технологій: мат-ли V Міжн. наук.-пр. інтернет-конф., Полтава, 27-28 грудня 2016 р. / Полт. держ. аграр. акад. Полтава, 2016. С. 269-272.
17. Importance of Medicinal and Aromatic Plants in Human Life quality / Ghorbanpour M., et al. // Medicinal Plants and Environmental Challenges / Ghorbanpour M., Varma A. (editors). Switzerland, 2017. – P. 1-25.
18. Jamshidi-Kia F., Lorigooini Z., Amini-Khoei H. Medicinal plants: Past history and future perspective // Journal of Herbmed Pharmacology. 2018. Vol. 7(1). – P. 1-7. DOI: 10.15171/jhp.2018.01
19. Hawthorn Crataegus spp. fruit some physical and chemical properties / Ozcan M., et al. // Journal of Food Engineering. 2005. Vol. 69(4). P. 409-413.
20. Phytochemical characterization of several hawthorn (Crataegus spp.) species sampled from the Eastern Mediterranean region of Turkey / Caliskan O., et al. // Pharmacognosy Magazine. 2012. Vol. 8(29). P. 16-21. DOI: 10.4103/0973-1296.93305
21. Determination of active ingredients in hawthorn and hawthorn piece by capillary electrophoresis with electrochemical detection / Geng C. H., et al. // Journal of Analytical Chemistry. 2008. Vol. 63(1). P. 75-81.
22. Ercisli S. Chemical composition of fruits in some rose (Rosa spp.) species // Food Chemistry. 2007. Vol. 104(4). P. 1379-1384. DOI: 10.1016/j.foodchem.2007.01.053
23. A systematic review on the Rosa canina effect and efficacy profiles / Chrubasik C., et al. // Phytotherapy Research. 2008. Vol. 22(6). P. 725-733.
24. Лебеденко Т. Є., Кожевнікова В. О., Соколова Н. Ю. Удосконалення процесу активації дріжджів шляхом використання фітодобавок // Харчова наука і технологія. 2015. №2 (31). С. 25-34.
25. Correa M.J., Pérez G.T., Ferrero C. Pectins as Breadmaking Additives: Effect on Dough Rheology and Bread Quality // Food and Bioprocess Technology. 2012. Vol. 5(7). P. 2889-2898.
26. Лебеденко Т.Є., Пшенишнюк Г.Ф., Соколова Н.Ю. Технологія хлібопекарського виробництва. Практикум: навч. посібник. – Одеса: Освіта України, 2014. 392 с.
27. Державна Фармакопея України. Доповнення 1. 2-е вид. Харків: ДП "Український науковий фармакопейний центр якості лікарських засобів", 2016. 360 с.
28. Altiok E. Recovery of phytochemicals (having antimicrobial and antioxidant characteristics) from local plants: thesis. Izmir: Izmir Institute of Technology, 2010. 246 p.
29. Technologies for Extraction and Production of Bioactive Compounds to be Used as Nutraceuticals and Food Ingredients: An Overview / Gil-Chavez G.J., et al. // Comprehensive Reviews in Food Science and Food Safety. 2013. Vol. 12. P. 5-20. DOI: 10.1111/1541-4337.12005
30. Бабенко Ю.И., Иванов Е.В. Экстрагирование. Теория и практические приложения. СПб.: Профессионал, 2009. 334 с.
31. Лебеденко Т.Е., Иоргачева Е.Г., Кожевникова В.О. Перспективы использования плодовых фитодобавок в хлебопечении. Обоснование рациональных способов подготовки к производству // Хлебопечение России. 2014. №5. С. 32-36.

References:

1. Iorhachova KH, Lebedenko TYe. Khlibobulochni vyroby ozdorovchoho pryznachennia z vykorystanniam fito-dobavok. Kyiv: K-Pres; 2015.
2. Zhyhunov DO, Kovalova VP, Zhyronkina DS. Analiz yakosti boroshna z riznykh rehioniv Ukrainy. Scientific Works. ONAFT. 2017. Vol. 81, Issue. 2. P. 35-43.
3. Halikova E, et al. Research of efficiency of using the complex baking improver "Svizhist" in order to prolong freshness of bran crispbreads. Eastern-European Journal of Enterprise Technologies. 2017; 3/11(87): 32-41. DOI: 10.15587/1729-4061.2017.103860
4. Dziubynskyi AV, Dziubynska OV, Shehynskyi OV. Problemy zabezpechennia yakosti pshenychnoho boroshna. Tovaroznavchyi visnyk. 2017; 10: 23-29.
5. Bairamov EE. Uluchshytely, vlyiaiushchye na svoistva khlebopekarnoho testa yz pshenychnoi muky. Research in: Agricultural & Veterinary Sciences. 2017; 3(1): 172-182.
6. Zhygunov D, Mardar M, Kovalyova V. Use of enzyme preparations for improvement of the flour baking properties. Food Science and Applied Biotechnology. 2018; 1(1): 26-32. DOI: 10.30721/fsab2018.v1.i1.21
7. New challenges of flour quality fluctuations and enzymatic flour standardization. International Association of Operative Millers [Internet]. 2017 [cited 2018 June 20]. Available from: https://www.iaom.info/wp-content/uploads/07abenzymessea17.pdf
8. Paucean A, Man SM, Socaci SA. Wheat germ bread quality and dough rheology as influenced by added enzymes and ascorbic acid. Studia Universitatis Babes-Bolyai, Chemia. 2016; 2(61): 103-118.
9. Baratto CM, et al. Influence of enzymes and ascorbic acid on dough rheology and wheat bread quality. African Journal of Biotechnology. 2015; 46: 3124-3130. DOI: 10.5897/AJB2015.14931
10. Clean Labels: Public Relations or Public Health? Center for Science in the Public Interest [Internet]. 2017 [cited 2018 June 20]. Available from: https://cspinet.org/sites/default/files/attachment/Clean%20Label%20report.pdf
11. Haen D. The Paradox of E-Numbers: ethical, aesthetic, and cultural concerns in the Dutch discourse on food additives. Journal of Agricultural and Environmental Ethics. 2014; 27(1): 27-42. DOI: 10.1007/s10806-013-9440-4
12. Kolesnyk VM, Rozkladai MI. Marketynhovi doslidzhennia spozhyvchykh motyvatsii na rynku khliboprodu-ktiv v rehioni. Scientific Works of Poltava State Agrarian University. Economical Sciences. 2013; 6(1): 133-139.
13. Kobzar AIa, et al. Kharchovi dobavky: viddalena zahroza. Environment & Health. 2013; 1: 70-74.
14. Niemirich OV, et al. Aspekty tekhnolohii khliba z vykorystanniam sushenoi roslynnoi syrovyny. Eastern-European Journal of Enterprise Technologies. 2014; 2/12(68): 95-101. DOI: 10.15587/1729-4061.2014.23146
15. Kochubei-Lytvynenko O, Bilyk E. The prospects of using milk whey enriched with Mg and Mn in the technology of bakery products. Food Science and Technology. 2017; 11(4): 55-63. DOI: 10.15673/fst.v11i4.731

16. Filenko SV, Sereda LO. Aktualnist vykorystannia priano-aromatychnoi likarskoi roslynnoi syrovyny u kharchovii promyslovosti. In: Likarske roslynnytstvo: vid mynuloho do novitnikh tekhnolohii: proceedings of V International scientific internet-conference, Poltava, 27-28 December 2016. Poltava: Poltava State Agrarian University; 2016.
17. Ghorbanpour M, et al. Importance of Medicinal and Aromatic Plants in Human Life quality. In: Ghorbanpour M, Varma A, editors. Medicinal Plants and Environmental Challenges. Switzerland; 2017.
18. Jamshidi-Kia F, Lorigooini Z, Amini-Khoei H. Medicinal plants: Past history and future perspective. Journal of Herbmed Pharmacology. 2018; 7(1): 1-7. DOI: 10.15171/jhp.2018.01
19. Ozcan M, et al. Hawthorn Crataegus spp. fruit some physical and chemical properties. Journal of Food Engineering. 2005; 69(4): 409-413.
20. Caliskan O, et al. Phytochemical characterization of several hawthorn (Crataegus spp.) species sampled from the Eastern Mediterranean region of Turkey. Pharmacognosy Magazine. 2012; 8(29): 16-21. DOI: 10.4103/0973-1296.93305
21. Geng CH, et al. Determination of active ingredients in hawthorn and hawthorn piece by capillary electrophoresis with electrochemical detection. Journal of Analytical Chemistry. 2008; 63(1): 75-81.
22. Ercisli S. Chemical composition of fruits in some rose (Rosa spp.) species. Food Chemistry. 2007; 104(4): 1379-1384. DOI: 10.1016/j.foodchem.2007.01.053
23. Chrubasik C, et al. A systematic review on the Rosa canina effect and efficacy profiles. Phytotherapy Research. 2008; 22(6): 725-733.
24. Lebedenko TYe, Kozhevnikova VO, Sokolova NYu. Udoskonalennia protsesu aktyvatsii drizhdzhiv shliakhom vykorystannia fitodobavok. Food Science and Technology. 2015; 2 (31): 25-34.
25. Correa MJ, Pérez GT, Ferrero C. Pectins as Breadmaking Additives: Effect on Dough Rheology and Bread Quality. Food and Bioprocess Technology. 2012; 5(7): 2889-2898.
26. Lebedenko TYe, Pshenyshniuk HF, Sokolova NYu. Tekhnolohiia khlibopekarskoho vyrobnytstva. Prakty-kum. Odesa: Osvita Ukrainy; 2014.
27. Derzhavna Farmakopeia Ukrainy. Dopovnennia 1. 2nd ed. Kharkiv: DP "Ukrainskyi naukovyi farmakopeinyi tsentr yakosti likarskykh zasobiv"; 2016.
28. Altiok E. Recovery of phytochemicals (having antimicrobial and antioxidant characteristics) from local plants: thesis. Izmir: Izmir Institute of Technology; 2010.
29. Gil-Chavez GJ, et al. Technologies for Extraction and Production of Bioactive Compounds to be Used as Nutraceuticals and Food Ingredients: An Overview. Comprehensive Reviews in Food Science and Food Safety. 2013; 12: 5-20. DOI: 10.1111/1541-4337.12005
30. Babenko YuI, Yvanov YeV. Ekstrahyrovanye. Teoryia y praktycheskye prylozhenyia. Saint Petersburg: Professyonal: 2009.
31. Lebedenko TYe, Yorhacheva YeH, Kozhevnykova VO. Perspektivy ispolzovaniia plodovykh fitodobavok v khlebopechenii. Obosnovanie ratsyionalnykh sposobov podhotovki k proyzvodstvu. Khlebopechenie Rossii. 2014; 5: 32-36.

Отримано в редакцію 12.07.2018 | Received 12.07.2018
Прийнято до друку 06.11.2018 | Approved 06.11.2018

Цитування згідно ДСТУ 8302:2015

Lebedenko T. Korkach H. Kozhevnikova V. Novichkova T. Methods of regulating physical properties of dough using phytoextracts // Food science and technology. 2018. Vol. 12, Issue 4. P. 52-62. DOI: http://dx.doi.org/10.15673/fst.v12i4.1182

Cite as Vancuver style citation

Lebedenko T, Korkach H, Kozhevnikova V, Novichkova T. Methods of regulating physical properties of dough using phytoextracts. Food science and technology. 2018; 12(4): 52-62. DOI: http://dx.doi.org/10.15673/fst.v12i4.1182