При розроблені хлібобулочних виробів, збагачених фізіологічно-активними речовинами нетрадиційних видів сировини, популярністю користуються круп'яні та олійні культури. Актуальним напрямком може бути поєднання використання у виробництві функціонального пшеничного хліба олійної культури у вигляді подрібненого насіння льону світлих сортів та круп'яної культури у вигляді закваски вівсяної спонтанного бродіння.

Під час досліджень використовували сорт льону золотого. У роботі встановлено, що технологічно можливе дозування подрібненого насіння льону становить до 20 % до маси борошна. За такого дозування отримують вироби з розвиненою, тонкостінною пористістю з приємним світло-жовтим забарвленням м'якушки та приємним горіховим присмаком.

Встановлено, що додавання подрібненого насіння льону золотого у тісто зумовлює подовження тривалості його замішування, погіршання еластичності та збільшення його розрідження. В аналізованих зразках відзначено значне зниження кількості клейковини та її якості. Також встановлено, що у тістовій системі з льоном спостерігається погіршення зброджування цукрів, їх накопичення та піддатливість крохмалю амілолізу. Такий вплив подрібненого насіння льону переважно зумовлений впливом водорозчинних харчових волокон, які контактуючи з водою під час замішування тіста, утворюють слизі.

Доведено ефективність застосування попереднього замочування подрібненого насіння льону для поліпшення якісних показників виробів. Замочування подрібненого насіння сприяє утворенню у рідкій фазі тіста більшої кількості слизів. Це зумовлює підвищенню в'язкості тіста, що сприяє покращанню формостійкості готових виробів.

Доведено, що застосування закваски вівсяної спонтанного бродіння у виробництві хліба, збагаченого подрібненим насінням льону, сприяє скороченню бродіння тіста до 60 хв. та покращанню його якості

Ключові слова: насіння льону золотого, хлібобулочні вироби, закваска спонтанного бродіння, в'язкість тіста, харчові волокна, α-ліноленова кислота, клейковина, вівсяне борошно

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THE USE OF GOLDEN FLAX SEEDS AND OATS SOURBREAD IN THE PRODUCTION OF WHEAT BREAD

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1. Introduction

Adverse technogenic and ecological factors of modern living conditions of people determine an increase in their need for micronutrients.

One of the directions of solving the problem of increasing the supply of population with micronutrients is the enrichment of food products, in particular, baked products, with physiologically functional ingredients: unsaturated fatty acids, vitamins-antioxidants, dietary fibers, mineral substances, etc. [1, 2].

When developing baked products, enriched with physiologically active substances of non-traditional types of raw materials, cereal and oil-bearing crops (oats, barley, millet, buckwheat, amaranth, chickpeas, seeds of flax, sunflower, and sesame, etc.) enjoy popularity [3–8].

In the course of development of baked products, enriched with physiologically active substances of non-traditional types of raw materials, cereal and oil crops, such as amaranth [3], barley [4], oats, millet [5, 6], buckwheat, seeds of flax, sunflower [7] and sesame [8] and others enjoy popularity.

Various chemical composition of vegetable raw materials makes it possible to enrich the bakery products with certain nutrients and causes different effect on the formation of rheological properties of dough, flavoring characteristics of finished products.

Considerable interest in flax seeds among oil-bearing crops is caused by the content in it of physiologically active components. Scientists examine flax seeds as a valuable source of protein, fat, rich in α-linolenic acid, dietary fibers (soluble and insoluble) and lignans [9].

Various products of flax seeds processing: flax oil, partially defatted flax flour, fully defatted flax flour, extracts of flax seed mucilage, and flax seed shell are used in the technology of a wide range of food products.

Each of these products has mainly only one of the biologically active components of flax seeds. The whole flax seed is a complex carrier of important physiologically active substances.

Along with this, dieticians recommend the consumers suffering from gastritis and ulcerative diseases to limit the use of whole seed products. That is why it is appropriate to use crushed flax seeds in the formulation in order to develop bakery products with health properties as a result of enriching them with flax.

The market for flax seeds is mostly presented with brown flax, but using the products of its processing in bread making leads to darkening of its crumb. Now there is an increase in croplands of flax of light varieties, which has a higher content of valuable α-linolenic acid, more pleasant flavor characteristics, light yellow seeds that do not give dark shades to the crumb of finished products.

That is why it is relevant to study the use of crushed seeds of light varieties of seeds in bread making with the aim of enriching the products with its physiologically functional ingredients and expansion of the assortment of bakery products with health properties.

Along with the enrichment of bakery products with the products of processing of oil-bearing crops, a promising direction is to introduce it into the formulations of flour and flakes of cereal crops. The products of processing buckwheat and oats are ones of the most valuable when it comes to protein quality, content of vitamins, minerals, and dietary fibers [10–12]. According to the latest tendencies in the production of bakery products, it is appropriate to implement accelerated technologies. The use of enzymes from cereal crops, in particular oatmeal, makes it possible not only to reduce the technological cycle of bread production, but also to enhance its nutritional and biological value.

The relevant direction can be to combine the use of oilseed crop in the form of crushed seeds of flax of light varieties and the cereal crop in the form of oats sourdough of spontaneous fermentation in the production of functional wheat bread.

2. Literature review and problem statement

In paper [13], it was proposed to use crushed flax shells in the formulation of bread. However, it was noted that along with the improvement of the antioxidant properties of the product, a significant decrease in the bread volume and the deterioration of the organoleptic indicators were observed.

In paper [14], the maximum possible dosage of flax seed groats in the amount of 7.5 % of the weight of flour for enrichment of bread with its components was established. Along with this, some deterioration of the quality indicators of products, including crumb darkening, was noticeable. To improve the quality indicators of products in case of adding flax seed groats, scientists proposed to apply a number of technological measures, including adding such formulation ingredients as dry wheat gluten, ascorbic acid, malt extract or fermented malt. However the products always had darkened crumb, which was caused by the use of brown varieties of flax seeds.in the technology of processing.

In paper [15], the authors propose to use raw and fried brown flax seeds for the development of functional bread, enriched with unsaturated fatty acids. The authors are limited to the dosage of crushed flax seed of 10 % to the weight of flour. This may be due to the use of brown flax, which can darken the color of crumb. The use of white varieties of flax can make it possible to increase the dosage in the product, which will facilitate greater enrichment of the product with physiologically functional components of flax. The authors also present the results of its influence on rheological parameters of dough and the quality of bread. However, the basic formulation of the product for enrichment with crushed brown flax seeds contained shortening. It did not make it possible to make objective judgements on the obtained regularities of the influence of only crushed seeds on the obtained results, because shortening is fat-containing raw material that affects the rheological properties of dough and the quality of the finished product.

The authors of paper [16] note that the enrichment of bread with crushed flax seeds, which were previously fried, causes a decrease in digestibility of protein in the product, its glycemic index and an increase in the content of -linolenic acid in the product. However, seeds are not always preliminarily fried in the production of bread products, so it is advisable to investigate the digestibility of products manufactured with use of flax raw material. In addition, the researcher in [17] found that thermal treatment of flax seeds leads to the deterioration of oxidative stability of seeds fat and extraction of its proteins.

In paper [18], the authors propose to enrich Iranian toast with flax flour in the amount of 10, 20, 30 % of the weight of flour. According to the results of their research, it was noted that at the dosage of 30 % of flax flour, the products had the lowest quality in terms of sensory characteristics. The patterns of the influence of flax flour on the dough structure were identified, in particular, it was noted that dough stability decreased. It was experimentally proved that adding flax flour improves the content of phenolic compounds in products. Along with this, it is not clear what flax seed flour exactly was used by the authors (fully fatty, partly defatted or light) and from which flax variety it was obtained (brown or light). It causes doubts that such high dosage of flax flour will make it possible to obtain the porosity structure that is characteristic of toast.

To accelerate the process of preparation of wheat bread and to inhibit the action of alpha-amylase, high-power enterprises use sourdoughs, obtained from pure cultures of lactic acid bacteria and yeast, in the technology of rye and rye-wheat bread. Preparation of these sourdoughs has a continuous character and requires bulky equipment and creation of special conditions. Low-capacity enterprises use sourdough-acidifiers, which include dried flour sourdough, organic acids, lactobacterin, malt extract, etc. [19]. The merit of these sourdough-acidifiers is the ease of their use, the disadvantage is their high cost.

The way of dough preparation with the use of sourdoughs of spontaneous fermentation is common in bakeries today. The periodicity of the process of production of sourdough of spontaneous fermentation and the possibility of its preservation makes it possible to apply it to the alternating operation mode of the enterprise and respond quickly to assortment changes, adjust production volumes depending on the demand in different seasons [20, 21]. Scientific sources mainly contain the research into the use of rye [20, 22, 23] and wheat [24–26] flour for obtaining sourdough of spontaneous fermentation. There are insufficient data on using flour from cereal crops to obtaining sourdough of spontaneous fermentation. Thus, the company "Ernst Böcker GmbH & Co. KG" (Germany) produces dry inactivated sourdough "Böcker Bio Reis 25" from rice flour for the production of gluten-free bread [27]. American and Turkish scientists studied the effect of sourdough from rice flour with the addition of start cultures in the technologies of gluten-free bread [28]. Russian scientists used buckwheat, oatmeal, barley and rye peeled flour for preparation of nutritive mixtures for acidophilic sourdough with the aim of studying its impact on biotechnological properties of sourdough and acid accumulation, as well as microbiological purity of bread [29]. American scientists also developed sourdoughs of spontaneous fermentation from pure cultures of microorganisms with barley flour. It was established that at the end of fermentation the amount of β-glucan in sourdough decreases, which proves its prebiotic properties [30].

In papers [30, 31], studies on the application of sourdoughs of spontaneous fermentation from corn, buckwheat, rice, barley, and oats flour in technologies of health and dietary bread products were conducted.

Thus, most research into the use of sourdoughs from the flour of cereal crops is associated with gluten-free products and with pure cultures of microorganisms. In the case of using flax seeds to enrich bakery products, the existing studies mainly concern brown flax varieties or the products of their processing. Application in the bread production of the variety of golden flax due to the differences in the chemical composition can make a different impact.

The data on the use of sourdough of spontaneous fermentation from oatmeal in the technology of wheat bread with addition of flax seeds were not found.

3. The aim and objectives of the study

The aim of the research was to study the appropriateness of the use of crushed golden flax seeds (CGFS) and oats sourdough of spontaneous fermentation for the production of wheat bread, enriched with basic nutrients of flax for the accelerated technology.

To achieve the aim, the following tasks were set:

– to establish the optimal dosage of CGFS to enrich wheat bread;

– to explore the influence of CGFS on the formation of structural-mechanical properties and progress in biochemical processes in it;

– to explore the influence of CGFS soaking on the quality of finished products;

– to establish the effectiveness of application of oats sourdough of spontaneous fermentation in the production of bread, enriched with CGFS in accelerated technology.

4. Materials and methods to study the influence of golden crushed flax seeds and oats sourdough of spontaneous fermentation on bread quality

4 1. The studied objects and materials that are used in the experiment

Wheat bread with addition of GCFS was produced by the straight method using the formulation:

– wheat flour of first grade – 100 kg;

– pressed baking yeast – 3.0 kg;

– table salt – 1.5 kg.

The variety of golden flax was used in the study. Its characteristic feature is yellow color of seeds. The oil content in seeds is 49.0–51.0 % with high content of linolenic acid (over 70 %).

For the research, golden flax seeds were crushed on the laboratory mill to the size of the particles that pass through the wire sieve with the size of holes of 0.8 mm.

Comparison of the chemical composition of flax seeds and flour wheat (Table 1) showed that flax seeds contain almost twice as much protein.

Table 1

Chemical composition of golden flax seeds and wheat flour of first grade

Components	Wheat flour of first grade	Golden flax seeds
Proteins, %	11.6±0.3	19.5±0.3
General carbohydrates, %	73.3±0.5	21.1±0.5
including mono– and disaccharides, %	1.8±0.05	2.1±0.05
starch, %	68.0±0.5	–
Dietary fibers, %	3.5±0.3	19.0±0.5
Fats, %	1.35±0.1	49±0.1
Ash content, %	0.73±0.05	4.1±0.05
Moisture, %	13.0±0.03	6.3±0.03
Mineral substances, mg/100 g potassium	176	800
calcium	26	267
magnesium	49	400
phosphorus	122	667
iron	1.8	4.8
zinc	1.09	4.0
Vitamins, mg/100 g, thiamine (B_1)	0.16	1.6
riboflavin (B_2)	0.08	0.2
niacin (PP)	2.74	3.0
pyridoxine (B_6)	0.74	0.5
folic acid	0.032	0.08
γ-tocopherol	0.8	19.9

According to literary data [32, 33], it is known that proteins of flax seeds are presented by water-soluble (from 46 % to 65 %), salt-soluble (from 16 % to 28 %) and alkali-soluble (from 13 % to 17 %) factions. There is no alcohol-soluble faction – prolamins – in the composition of flax protein. Flax proteins are characterized by high biological value, since they are balanced in their amino acid composition. Lysine and isoleucine are deficit for flax seeds proteins.

Research of scientists [34] revealed that flax seed proteins have the inhibiting activity towards bacteria, especially towards *Enterococcus faecalis, Salmonella typhimurium* and *Escherichia coli*. Along with this, it was noted that the mucilage composition of carbohydrates of seeds can inhibit the antibacterial activity of flax seeds proteins.

A distinctive feature of flax seeds is a higher content, in comparison with wheat flour, of non-starch polysaccharides that are represented by water-soluble factions – mucilage that has the immune protective and radioprotective properties. Water-soluble fractions in flax seed account on average for 75 % of the total content of dietary fibers. Medical studies proved that flax seed mucilage contributes to the improvement of intestinal microbiota [35].

High ash content of flax seeds correlates with much higher content, in comparison with wheat flour, of potassium – by 4.5 times; calcium and magnesium – by 10 and 9 times; iron – by 2.6; zinc – by 3.7 times.

The inclusion of flax seeds to the formulation of baked goods will contribute to their enrichment with vitamins of B group, as well as folic acid and tocopherol, which are natural bio-antioxidants and which are scarce in wheat flour.

Flax seeds contain almost by 36 times more fat, the fat and acid composition of which, according to the results of chromatographic studies of the developers of the variety, is presented with 70.1 % of linolenic acid, 16 % of linoleic acid, and 9.8 % of oleic acid.

In addition, flax seeds are a source of lignans and phenolic compounds.

In paper [36], it was found that lignans of flax seeds do not decompose when heated even to the temperature of 250 °C.

Given such composition of basic substances, it is appropriate to apply flax seeds to improve the nutritional value of bread and its physiological usefulness.

To implement the accelerated method of bread making from wheat flour with the addition of CGFS, we used oats sourdough of spontaneous fermentation.

To prepare the sourdough of spontaneous fermentation (SSF), the oatmeal of "Organic-Eco-product" brand (Ukraine) according to TU U 15.6-2110615276-002:2010 was used.

Oatmeal has the balanced amino acid composition (amino acid score by lysine makes up 71 %, while wheat protein is 54 %), high content of dietary fibers (8–9 %, including 3–4 % of β-glucan), tocopherols, potassium, magnesium and iron, so it is appropriate to use the sourdough from it in the production of bread that has functional properties [11].

Preparation of SSF consists of the dilution cycle and reduction (production) cycle.

In the dilution cycle, the dough sour was prepared from oatmeal and water of the temperature of 30–32 °C (humidity of 68–70 %). The dilution cycle lasted 72 hours. The nutritious mixture of flour and water was added to the previous portion of mature sour every 24 hours.

The production cycle involved the selection of 50 % of the sourdough and addition of nutrient mixture. Reduction of the sourdough was carried out to accumulate its amount and to wash away all wild flora that gives the sourdough bitter aftertaste and specific sour smell.

The sourdough acquired stable indicators of quality after the fifth reduction and was ready to use in the production cycle. Mature sourdough has a nice "oatmeal" smell with some acid shade, the titrated acidity is 16–18 degrees.

4. 2. Methods to study the quality of dough and bread with the addition of CGFS and the oats sourdough of spontaneous fermentation

To study the indicators of the technological research, biochemical, physical and chemical changes in dough and qualitative indicators of bread, we carried out laboratory bread baking. Dough was kneaded in the direct way at humidity of 42 %. Before mixing the dough, crushed flax seeds were mixed with wheat flour. Dough was kneaded in two-speed dough kneading machine Escher (Italy). The dough was treated manually, ageing of dough pieces was performed in the thermostat at the temperature of (38±2) °C and relative humidity of (78±2) % up to readiness. The products were baked at the desiccator Sveba-Dahlen (Sweden) at the temperature of 220...240 °C.

The quality of semi-finished products for humidity and acidity was controlled according to generally accepted methods [37].

Plastic-elastic characteristics of the dough were studied at the farinograph made by "Brabender" company (Sweden) and the alveograph "Chopin" (France).

The indicators of the gluten quality, autolytic and sugar forming abilities of flour were determined with the use of the standard methods [38].

Viscous-plastic characteristics of the dough were determined by the degree of dough running for 3 hours at the temperature of 30 °C.

To establish the amount of the accumulated and fermented sugars in the dough, yeast-containing and yeast-free dough was prepared in the direct way without crushing flax seeds (control) and with the addition of 20 % of CGSF to the mass of dry and soaked flour. The duration of fermentation of the dough was 120 min. at the temperature of 30 °C.

The content of sugars in the dough was determined by the iodometric (Schorl) method) [38].

The amount of sugars that were formed during the fermentation of dough, were calculated from the difference between their content in yeast-free dough after kneading and after 2 hours of its fermentation. The amount of fermented sugars was calculated from the difference between the sum of the amount of sugars in yeast-containing dough after kneading and the amount of sugars that were formed in yeast-free dough and the amount of sugars that were formed in yeast-containing dough after 2 hours of fermentation.

The finished products were analyzed by organoleptic parameters (appearance, the state of the crust surface, the porosity structure, taste, smell) and the physical and chemical properties (specific volume, shape stability, acidity) [37].

The results of the experimental research were subjected to statistical processing implemented with the use of the standard software Microsoft Office 2010.

5. Results of studying the impact of crushed golden flax seeds and oats sourdough of spontaneous fermentation on the quality of dough and wheat bread

To establish the maximum possible dosage of crushed golden flax seeds (CGFS) for the enrichment of wheat bread, we held trial laboratory baking. We prepared the samples of dough with the dosage of crushed golden flax seed Golden of 10, 15, 20 and 25 % of the weight of flour.

Analysis of organoleptic parameters of bread showed that the products with the addition of CGFS, compared with the control sample, have more intensely colored and thinner crust. The crumb of the studied samples at the dosage of crushed flax seeds of 10–20 % of the weight of flour was close to the control: developed, thin-walled, having a nice light-yellow color. The products had a pleasant nutty taste. In the case of the dosage of 25 % of the weight of CGFS, elasticity of crumb worsened considerably, besides, at this dosage, the products had a very intense oil taste and smell.

To compare the indicators of bread obtained by sensory evaluation, we plotted the profilogram (Fig. 1), assessing each of the indicators based on a five-point scale.

The quality of products by organoleptic indicators was estimated by the sum of points taking into consideration the weight factor, the magnitude of which was established by the method of expert evaluation.

Based on the results of calculation of the comprehensive quality indicator by organoleptic indicators (Fig. 2), it is possible to argue that it is recommended to add crushed flax seeds in the amount of 20 %. An increase in the dosage of CGFS causes a decrease in the quality of the product by the comprehensive indicator by 22 points (control sample scores 93 points, experimental sample scores 71 points), while at the dosage of 20 % of the weight of flour it changes only by 5 points (control sample scores 93 points, experimental sample – 88).

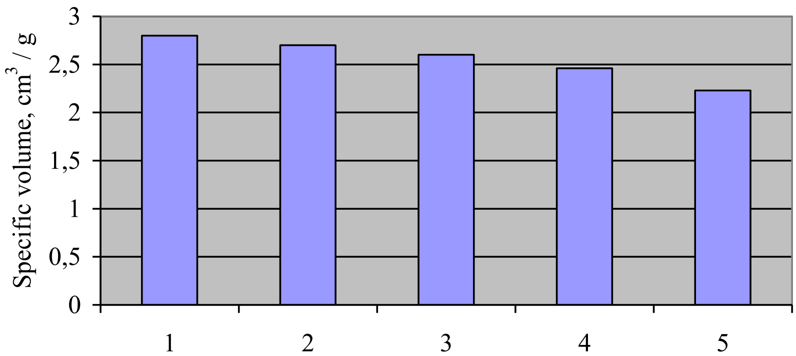

Fig 3. Specific volume of products: 1 – wheat bread from flour of 1 grade; 2 – bread with 10 % CGFS; 3 – bread with 15 % CGFS; 4 – bread with 20 % CGFS; 5 – bread with 25 % CGFS

Specific volume of bread in case of adding the CGFS decreases according to an increase in dosage (Fig. 3).

One of the main factors that determines the formation of volume, porosity, structure of crumb of bakery products, as well as behavior of dough during its treatment, is rheological properties of dough.

Flax is a source of water-soluble dietary fibers (mucilage) that affect the formation of dough structure. It is known that to increase the release of mucilage from seeds, it is pre-soaked. That is why we explored the rheological properties of dough with the addition of dry and soaked GCFS.

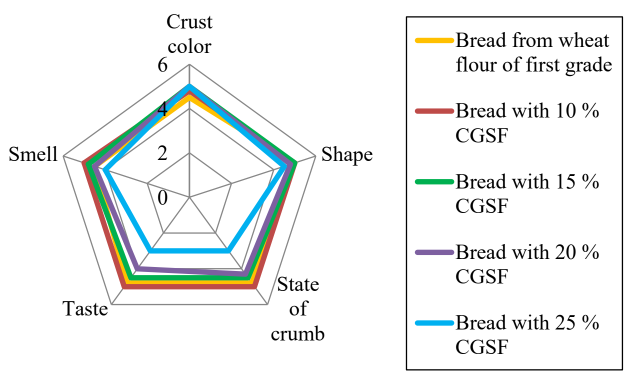

Fig. 1. Profilogram of organoleptic indicators of products

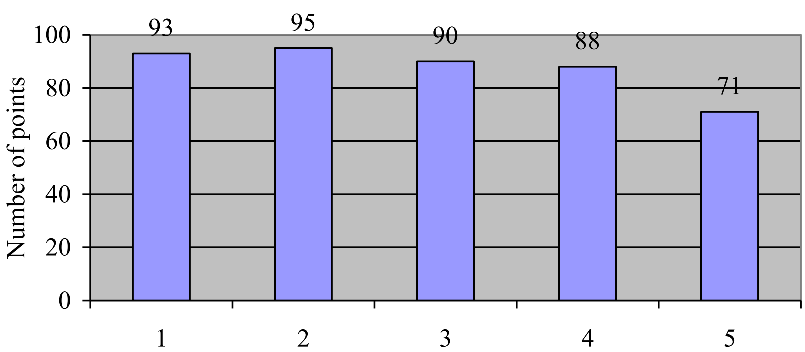

Fig. 2. Comprehensive indicator of quality of products by organoleptic indicators: 1 – wheat bread from flour of 1 grade; 2 – bread with 10 % CGFS; 3 – bread with 15 % CGFS; 4 – bread with 20 % CGFS; 5 – bread with 25 % CGFS

The results of research into plastic-elastic indicators of dough at the farinograph (Table 2) show that the introduction of dry and soaked crushed flax seeds prolongs the duration of dough kneading in comparison with the control sample by 6 and 4 min, respectively. In the case of the use of crushed flax seeds, the duration of dough formation is reduced by 2 min, compared with using the dry one.

Table 2

Indicators of dough quality by farinograph (n=3, p≤0.95)

Indicators	Control	crushed golden flax seeds were added in the amount of 20 % of flour weight	
		dry	soaked
Consistence, units of device	500	500	500
Water absorbing ability, cm³/100 g	59.4	60.8	62.2
Duration of formation, min	1.5	7.5	5.5
Elasticity, units of device	140	110	110
Stability, min	5.5	7.0	9.0
Dilution, units of device	70	140	130

In the case of adding dry and soaked crushed flax seeds, dough elasticity decreases and its dilution increases. This is the consequence of the fact that water-soluble dietary fiber and water-soluble proteins of flax cause an increase in the formation of liquid phase of dough.

A decrease in elasticity of dough was proved by the data obtained with the help of alveograph "Chopin" (France) (Fig. 4, Table 3).

Processing of alveograms showed that the samples of dough with flax have greater elasticity and less extensibility in comparison with the control sample. Probably this is related to the interaction of the constituents of flax and biopolymers of dough, in particular by protein substances. In this case, the ratio P/L increases at the use of both dry and soaked CGSF, but more in the sample with soaked crushed flax seeds.

To understand completely the influence of CGFS on the formation of rheological characteristics of dough, we examined its impact on the indicators of gluten quality.

Table 3

Indicators of dough quality of deciphering alveograms n=3, p≤0.95

Indicators	Con-trol	crushed golden flax seeds were added in the amount of 20 % of flour weight	
		dry	soaked
Elasticity, P, mm	113	106	105
Stretching capacity, L, mm	77	44	40
P/L	1.47	2.41	2.63
Area of alveogram, S, cm^2	19.5	14.8	14.1
Specific work of deformation, W, 10 o.a.	346	176	154

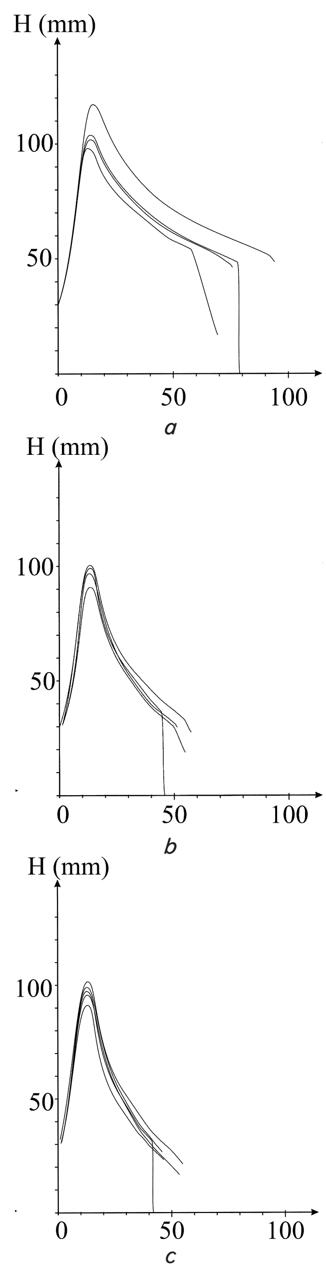

Fig. 4. Alveograms of dough: a — dough from flour of 1 grade; b — dough with addition of 20 % of dry GCSF to the flour weight: c — dough with addition of 20 % of soaked GCSF to the flour weight

It was noted (Table 4) that adding the CGFS in both dry and soaked state causes a significant decrease compared to the reference sample quantity of gluten, 25 % and 59 %, respectively. Along with this, addition of the CGFS leads to loosening of gluten and prevents the aggregation of gluten pieces – it becomes non-viscous, especially in the case of soaking. In the sample with the soaked CGSF, gluten is short by stretching capacity and has satisfactory elasticity.

Table 4

Amount and quality of gluten in dough (n=3, p≤0.95)

Indicator	Con-trol	crushed golden flax seeds were added in the amount of 20 % of flour weight	
		dry	soaked
Amount, %	24.5	18.4	10.0
Stretching capacity, cm	13	11	9
Plasticity, units of device GDM	62	70	80
Elasticity	Good	Good	Satisfactory

Fermentation processes have significant influence of the quality of baked products as well as on their rheological properties.

The intensity of fermentation in semi-finished products is caused by the content of own sugars in flour, as well as the accumulation of sugars, which depends on the activity of amylases and starch susceptibility to amylolysis. That is why the effect of CGFS on these indicators was studied.

The results of Table 5 indicate that as a result of adding 20 % of CGFS to the weight of flour, the autolytic activity increases by 2 % as a result of the fact that there are active amylolytic enzymes in flax seeds. Sugar forming ability is decreased in the presence of flax.

Table 5

Indicators of autolytic activity and sugar forming ability (n=3, p≤0.95)

Indicator	Wheat flour of 1 grade	Wheat flour of 1 grade with the addition of crushed flax seeds in the amount of 20 % to the flour weight
Autolytic activity, %	21	23
Sugar forming ability, mg of maltose/10 g of flour	212	186

Along with the process of accumulation of maltose in the dough as a result hydrolytic splitting of starch, there occurs its fermentation by dough microorganisms.

The content of sugar in the dough before treatment and baking depends on the ratio between the intensity of sugars accumulation in the semi-finished products as a result of starch hydrolysis under the influence of amylolytic enzymes and intensity of their fermentation by micro-organisms.

It was established (Table 6) that in the studied samples, less sugars were fermented with the addition of crushed flax seeds, both dry and soaked. This is probably due to the decreased activity of yeast microflora during fermentation as a result of their wrapping by flax mucilage and oil.

It was established that less sugars were formed in the research sample during fermentation than in the control sample.

Table 6

Accumulation and fermentation of sugars during dough fermentation, % per DS (n=3, $p\leq$0.95)

Indicators	Control	Crushed golden flax seeds were added in the amount of 20 % of flour mass	
		in dry form	in soaked form
Yeast-free dough			
Content of sugars after kneading	1.25	1.24	1.26
After 2 hours of fermentation	2.03	1.84	1.78
Sugars formed	0.78	0.6	0.48
Yeast-containing dough			
After kneading	1.27	1.25	1.24
After 2 hours of fermentation	0.79	0.85	0.92
Fermented sugars	1.26	1.0	0.8

Thus, the addition of flax in the dough causes a decrease in starch susceptibility to amylolysis due to the formation of complexes of starch grains and mucilage. To prove this, a study at the amylograph was carried out (Table 7).

The addition of crushed flax seeds does not affect the temperature of starch pasting and the time of the beginning of pasting. Maximum viscosity of the system with CGSF increases by 16 %. Probably this is due to an increase in viscosity of a suspension due to swelling of dietary fibers of flax along with starch pasting.

During preliminary soaking of CGFS, its water-soluble and insoluble dietary fibers partially swell. That is why during their addition to the system, they immediately take part in the formation of a viscous system. As a result, the formation of the viscous system is accelerated by 1 min and the pasting temperature decreases.

Viscosity of the system with the addition of soaked CGFS is 2 % lower than in the sample with dry crushed flax seeds, probably due to greater thickening of the system by water-soluble dietary fibers of flax.

Under modern production conditions, bakery products are made mainly by accelerated methods, which enable flavor qualities of the product to reveal fully. Enrichment of the product with the CGFS improves the flavor properties of the products, manufactured even by the accelerated methods of production. A promising direction among the accelerated technologies of production of bakery products is the use of sourdoughs of spontaneous fermentation.

Table 7

Indicators of amylograms of the studied suspensions (n=3, $p\leq$0.95)

Water-flour suspensions	Time before the beginning of starch pasting (formation of viscous system), min	Temperature of the beginning of starch pasting (formation of viscous system) °C	Maximum viscosity of the system, units of device
Control	7.5	48.2	605
With the addition, % to flour mass:			
20 % of dry CGFS	7.5	48.2	720
20 % of soaked CGFS	6.5	47.5	712

Table 8

Indicators of quality of products

Indicator	Crushed golden flax seeds were added in the amount of 20 % to the flour weight		
	Control without soaking	Soaked in cold water	Soaked in hot water
Specific volume of bread, cm^3/g	2.4	2.4	2.6
Shape stability, h/d	0.51	0.56	0.58

It the article, it was proposed to make bread enriched with the CGFS using oats sourdough of spontaneous fermentation.

It is known that in contact of flax seeds with water, they actively release mucilage that have good structure forming properties. That is why it was proposed to conduct a trial baking of products with 20 % to the flour weight of the CGSF soaked in hot and cold water.

The results of baking (Table 8, Fig. 5) revealed that it is advisable to apply preliminary soaking of crushed flax seeds for the production of hearth products, because there is a significant improvement of the shape stability of products. Perhaps, in this case, the key role is played by flax mucilage, which when swelling, increase the viscosity of the dough system and increase the surface tension, which contributes to retaining the shape.

This assumption is proven by data on dough running. In accordance with Fig. 6, it was found that compared with the control sample, dough running decreases in the research samples with soaking of CGSF in cold and hot water. This is due to the significant influence of flax mucilage on an increase in viscosity of the dough system.

Fig. 5 Photographs of products (left to right): control with CGFS without their soaking, bread with CGFS soaked in cold water; bread with CGFS soaked in hot water

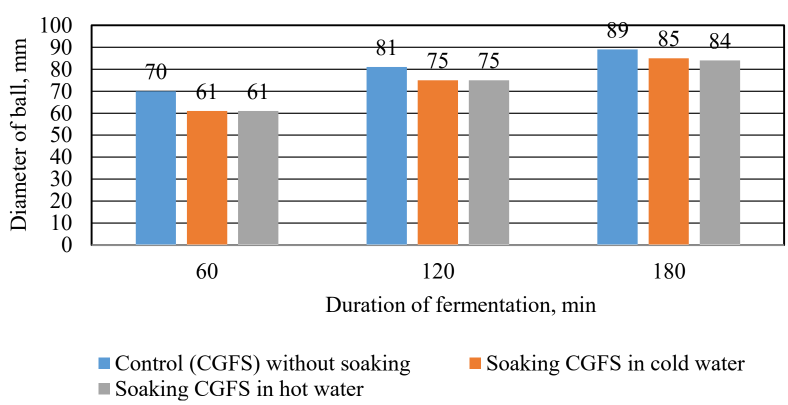

Fig. 6. Running of dough ball

Research results (Table 9) indicate that the introduction of this sourdough in the amount of 12 % to the weight of flour causes the acceleration of dough maturing due to both an increase in initial acidity of dough, and more intensive acid accumulation. Ageing duration decreases by 6 min.

Specific volume and shape stability of products improved compared with the control sample.

Table 9

Indicators of the technological process and bread quality

Indicators	Crushed golden flax seeds were added in the amount of 20 % to the flour weight	
	Control (without adding sourdough)	With adding oats sourdough of spontaneous fermentation
Dough		
Moisture content, %	42.0	42.0
Acidity:		
initial	2.4	3.3
final	3.0	4.3
Duration of fermentation, min	180	60
Duration of ageing, min	46	40
Bread		
Specific volume, cm^3/100 g	280	290
H/D of hearth bread	0.40	0.42
Acidity, degrees	2.3	3.5

Such quality indicators were achieved at reducing the duration of fermentation of the research sample up to 60 min versus 180 min for control.

Thus, according to the comprehensive quality indicator of organoleptic indicators of samples with the CGFS, it was found that it is appropriate to dose it in the formulation of wheat bread up to 20 % to flour weight. It was noted that the introduction of CGFS causes lengthening of dough kneading, the deterioration of its elasticity, a decrease in the content of gluten in it and its loosening along with a decrease in its ability to aggregation. Addition of the CGFS to the dough reduces starch susceptibility to amylolysis and intensity of fermentation of sugars in it. It was proved that addition of crushed flax seeds in the soaked form enables significant improvement of the quality of hearth bread. Application of oats sourdough of spontaneous fermentation contributes to the reduction of the technological process of production of wheat bread, enriched with the CGFS and the improvement of its quality.

6. Discussion of results of studying the influence of crushed golden flax seeds and oats sourdough of spontaneous fermentation on the quality of dough and bread

It was established that to maximally enrich bread with all physiologically functional ingredients of golden flax seed and to ensure good organoleptic indicators of products, it is possible to add it in the crushed state in the amount of up to 20 % to the flour weight. Application of this variety of flax does not cause darkening of the crust of the products and gives it a nice light-yellow color. This makes it possible to use the CGFS in the technology of bakery products and solves the problem discussed in paper [15], specifically, darkening of the crumb of products. It was one of the restrictive factors of research [15] on increasing the dosage of crushed flax seeds for the enrichment of bread with their constituents.

Worsening of the volume of products, enriched with CGFS, is caused by the influence of their components, in particular water-soluble dietary fibers, on the formation of the solid structure of dough. Since, at the stage of kneading of the half-finished product, flax mucilage, along with gluten protein, are active competitors for water, the gluten framework of dough does not develop enough. In addition, the existence of mucilage of flax and oil that get to the dough with the CGFS can affect the formation of a solid gluten frame.

To prove this, we explored the influence of CGFS on the formation of rheological properties and the indicators of gluten quality.

The obtained regularities of extension the duration of kneading dough in case of addition of CGFS, worsening of elasticity and increasing its dilution prove the assumption about the active influence of flax mucilage on the formation of dough. Thus, the extension the duration of dough formation, was probably caused by the fact that at the stage of kneading dough, both flour proteins and mucilage of the GCFS swell, competing for water. That is why it takes more time for proteins to form the solid gluten frame, in this case, the existence of mucilage will interfere with their strong binding.

In case of application of the previously soaked CGFS, mucilage will already partially swell, that is why they will not compete actively with proteins for water, which will contribute to the acceleration of the process of dough formation.

It is due to the fact that when swelling, water-soluble dietary fibers make up mucilage that affect the formation of dough gluten, worsen dough elasticity and increase its dilution. However, as a result of thickening of the dough system, dough stability is extended. Probably, in the sample with the soaked GCFS, more mucilage is formed owing to the previous interaction with water, which contributes to extension of the stability of the dough system.

The same patterns were detected during the analysis of the alveograms.

In paper [18], it was noted that the addition of flax flour also prolongs the duration of dough kneading and worsens its elasticity. In contrast to results [18], it was noted that the addition of CGFS improves the dough stability. This difference of the obtained regularities may be conditioned by the properties of raw materials as a result of different ratio of the components in it.

In the current study, we used CGFS, which contain all the anatomical components of the seeds. It is not clear from paper [18] whether flax flour contains the shell parts of the seeds, which are the main source of water-soluble dietary fibers. Along with this, it was shown in the research that in case of using the CGFS to accelerate kneading, it is advisable to use their previous soaking. It will also contribute to the improvement of dough stability.

The assumption about the influence of CGFS on the rheological characteristics of dough due to the significant influence of their mucilage on the formation of a solid gluten frame was proved by the results of the analysis of gluten. It was found that the content of gluten decreases significantly and its quality worsens, in particularly, low ability for aggregation of its pieces was noted. In the dough system, it does not contribute to the development of the whole gluten framework.

Research results also revealed worsening of the progress of biochemical processes in dough, such as reducing the amount of formed and fermented sugars in the samples of the dough with

CGSF. The reason for this is also the influence of water-soluble dietary fibers that, on the one hand, stick around yeast cells, reducing their fermentation activity. On the other hand, mucilage can reduce susceptibility of starch to the action of amylolytic enzymes due to the probable formation of complexes during their interaction with starch. The state of is also affected by lipids that arrive with flax. They form complexes and by this reduce the solubility of starch. Besides, lipids reduce swelling of starch, which causes a decrease of its susceptibility to fermentative hydrolysis and will influence the course of processes of preparation of semi-finish dough products.

During the analysis of amylograms of the samples with the addition of CGSF, it was noted that in the case of adding crushed flax seed, the following flax components simultaneously influence the system:

– fat that can form a fat layer on the surface of starch grains and thus can slow down their hydration and decrease the speed of achieving maximum viscosity. Fats can also form complexes with starch amylose and thus inhibit swelling of starch grains;

– soluble and insoluble dietary fiber, the process of swelling of which can occur sooner than starch pasting, and it will cause the acceleration in the formation of viscous system.

As in the case of the introduction of dry crushed flax seeds, fat and soluble and insoluble dietary fiber will simultaneously influence the system, the changes in the indicators of pasting temperature and time before the beginning of pasting are not observed.

Thus, an increase in viscosity of the system as a result of the introduction of dry or soaked crushed flax seeds, as well as the possible formation of complexes between starch and mucilage, will cause a decrease in susceptibility of starch to pasting.

Results of the analysis of the conducted studies make it possible to argue that water-soluble dietary fibers of flax seeds have considerable impact on the formation of the properties of dough and baked products. That is why even though flax mucilage exerts an adverse effect on the formation of gluten, it is advisable to increase their content in the dough system, because due to their structure forming properties and the ability to thicken the dough system, the quality of the products can improve. The results of baking products with soaking flax in hot and cold water prove this. Due to soaking CGFS, the amount of mucilage in the dough system increased, which enhanced the strength of dough. This in turn contributed to an increase in surface tension of the dough base at retaining carbon dioxide released during fermentation. The effectiveness of this can be observed in molded products. At this, the best result was observed in the case of soaking in hot water due to better extraction of water-soluble dietary fibers.

During discussion of the results from work [31], it was recommended using the oats sourdough of spontaneous fermentation in the technology of gluten-free bread. This research proved the feasibility of the application of oats sourdough of spontaneous fermentation in the technology of wheat bread enriched with the CGFS. The choice of this sourdough is predetermined, on the one hand, by the implementation of the accelerated technology of preparation of wheat bread, on the other hand, it is also a source of biologically active substances contained in oatmeal. The use of oats sourdough of spontaneous fermentation will make it possible not only to shorten the technological process, but also to increase the nutritional value of the product due to the simultaneous application of the CGFS and oatmeal of sourdough.

7. Conclusions

1. According to the results of the experimental laboratory studies, it was found that the technologically possible dosage of the CGFS to enrich wheat bread with its physiologically functional ingredients is the dosage up to 20 % to the weight of flour.

2. It was established that adding CGFS in dough causes the extension of the duration of its kneading, worsening elasticity and an increase in its dilution. A significant reduction in the amount of gluten and its quality was noticed in the samples with CGFS. It was also found that the deterioration of fermentation of sugars, their accumulation and starch susceptibility to amylolysis was observed in the dough system with CGFS. Such influence of CGFS was mainly caused by the influence of water-soluble dietary fibers, which during dough kneading interact with water, forming mucilage.

3. The effectiveness of the application of pre-soaking of CGFS while making wheat bread was found. It makes it possible to increase dough viscosity as a result of significant formation of mucilage. This contributes to the shape stability of hearth products.

4. It is proven that the use of oats sourdough of spontaneous fermentation in the production of wheat bread, enriched with the CGFS, contributes to reduction of fermentation up to 60 min and improvement of its quality.

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