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INFLUENCE OF ENRICHED INGREDIENTS ON THE FUNCTIONAL PROPERTIES AND NUTRITIONAL VALUE OF BREAD

The object of research is the organoleptic properties and nutritional value of bread enriched with various functional additives. One of the most problematic areas in the technology of bread from refined types of flour is the low biological value of bread. Unrefined and gluten-free types of flour, which have a higher biological value, negatively affect the consumer properties of bread, the structural and mechanical properties of dough, and increase production costs. During the study, standard methods for analyzing the organoleptic and physicochemical parameters of bread were used. Enriched bread recipes were developed. Sample 1 – from rye hulled flour, premium wheat flour and the food supplement "Live Grains Dark", containing quinoa, chia, flax, sunflower seeds, hop infusion and dry sourdough. Sample 2 – based on high-grade wheat flour, whole grain flour, dried cranberries and walnuts. Sample 3 was made from a mixture of gluten-free flour (quinoa, rice, flax, buckwheat, oat, psyllium). A positive assessment was received ("good" and "very good" for all organoleptic indicators). Sample 1, noted by the tasters, had well-developed uniform thin-walled porosity, regular shape and dark brown color, due to the type of main raw material. It contained the most fiber (6±0.05 g/100 g). Sample 2 had the highest nutritional value (859.2±0.05 kJ/100 g). This is due to the fact that it contains a significant amount of carbohydrates (45.87±0.05 g/100 g). Sample 3, made from gluten-free raw materials, contained more proteins (5.8±0.05 g/100 g) and fats (1.6±0.05 g/100 g), had the highest moisture content (46.7%). But its nutritional value was the lowest (828.4±0.05 kJ/100 g). Due to the use of functional plant ingredients, the nutritional value of bread changes, it has unique organoleptic properties. Compared to bread made from refined flour, the proposed types have additional functional properties and contain more biologically active components.

Keywords: *enrichment, rye hulled flour, whole grain flour, gluten-free flour, functional additives.*

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1. Introduction

The interest in developing functional foods containing natural bioactive compounds is constantly growing. The global food industry shows a clear trend towards the production and commercialization of fortified foods. Fortification is one of the most sustainable and cost-effective approaches to improving health [1]. In the search for enhancing the functional properties of products, new approaches are being tested, including fortification with additives aimed at improving their nutritional profile.

Bread is a staple food and can become an ideal functional food, being an important part of the daily diet of many people. In recent years, the food industry has focused on improving the nutritional value of bread. There are mainly three types of bread produced in the world: wheat, gluten-free and mixed. Most types of bread made from refined flour are low in vitamins, minerals, fiber, and antioxidants due to the removal of the bran and germ during the production, milling, and sieving of the grain [2]. In addition, the heat treatment of the dough during baking bread causes an additional reduction or destruction of bioactive compounds. Due to these factors, the content of bioactive substances in bread decreases, as a result – the product does not meet the needs of consumers for a healthy diet.

Since bread is an everyday food, it is important to understand the impact of its consumption on health throughout life. Therefore, there is a need to develop new methods to improve the nutritional and functional value of bread. Adding functional additives, ingredients, and flour from other cereals or legumes to the composition of bread can improve its quality. Despite the large range of enriched bread, research on the development of recipes and methods for making bread with additional functional properties is relevant.

The sources of functional ingredients used in baked goods are very diverse. A significant number of studies report on the valorization of food industry by-products as a way to obtain valuable components for inclusion in baked goods. The use of apple peel, blackcurrant pomace, apples, blueberries, carrots, banana peels, pomegranates, potatoes has been reported. Many other studies have used vegetables (pumpkin, carrots, broccoli, cabbage, cauliflower) or fruits (apple, goji berries) as sources of beneficial ingredients [3]. However, the vast majority of studies do not provide information on the change in the nutritional value of bread when these additives are added, mainly investigating their effect on the physicochemical properties of dough and finished products.

The functional and nutritional value of bread can also be improved by alternative dietary fiber and protein sources in the form of cereals, tubers, corn gluten, corn germ and rice bran. It is known that some

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cereals (rye, corn, rice and oats), cereals (buckwheat, amaranth and quinoa), sprouts improve the nutritional profile of bread [4]. They are a source of various phytochemicals, including phenolic acids, flavones, flavonoids, coumarins and terpenes. However, such additives can significantly affect the physicochemical and organoleptic properties of bread. For whole grain breads, such as rye, with the addition of oil, the shelf life and texture are improved, but the potential for lipid oxidation increases [5]. Adding biologically active compounds from plant functional ingredients to this bread can inhibit lipid and protein oxidation, as well as slow down mold growth and increase its shelf life [1, 6]. It has been proven that adding 10% of rowan powder to rye and wheat flour increases the shelf life of bread by half [7, 8], slightly enriches it with amino acids, minerals and vitamins. However, due to the negative impact on the organoleptic properties of bread, increasing the amount of the additive in the recipe is not recommended.

Similar disadvantages are observed when enriching bread with microalgae and moringa powder [9, 10]. Microalgae contain proteins, minerals, vitamins, lipids, antioxidants and dietary fiber [9], but lead to a serious deterioration in sensory properties (they give the products a dark green color, iodine taste and smell). These properties may contribute to a decrease in the acceptability of enriched bakery products and limit their inclusion in the diet.

One of the directions for improving the functional properties of bread is to change their composition by reducing the gluten content or completely eliminating it by adding a number of functional ingredients. Considering that most types of gluten-free raw materials have a low content of proteins, minerals and vitamins, it is recommended to introduce additives into the recipe that will positively affect the nutritional profile of the products. Quinoa grains are a rich source of proteins, vitamins and dietary fiber, but they have a bitter taste, which can negatively affect the sensory perception of enriched bread. A technological scheme for the production of gluten-free bread with quinoa flour has been developed, which involves reducing the bitterness of quinoa flour by pre-treatment with ultrasound [11]. However, the effect of quinoa flour on the nutritional and energy value of gluten-free bread needs additional study.

Of particular note are studies on increasing the dietary fiber content in baked goods [12]. They have a positive effect on the digestive system. In addition, fruit fibers can be a source of antioxidants in the diet. Fruit fibers are usually obtained from pomace, which contains a number of nutrients and bioactive components. The most common forms of fruit fibers are powders and extracts obtained from chokeberry, apple, cranberry and cocoa fibers [13]. However, it is not known whether dried fruits made from these types of raw materials will contribute to increasing the fiber content.

The use of flour improvers can also be included in the strategies for improving the quality of bread. Since gluten proteins are responsible for the viscoelastic characteristics of the dough, agents that act on this fraction play a significant role and regulate its properties. These agents can affect gluten proteins and starch present in flour. Four groups of improvers are known: oxidants, emulsifiers and hydrocolloids; enzymes; gluten [14, 15]. The effect of such additives on the nutritional value of bread requires additional study.

Considering the above, the studies presented in this article are focused on analyzing the effect of various functional additives on consumer properties and energy value of bread made from different types of flour.

The aim of research is to establish the effect of functional ingredients on the nutritional value and organoleptic properties of bread. The research results can become the basis for expanding the range of functional bread.

2. Materials and Methods

2.1. The object and hypothesis of research

The object of research is the organoleptic properties and nutritional value of bread enriched with various functional additives. The main working hypothesis of the study is that when food additives with certain functional properties are introduced into the recipe, the nutritional value can either increase or decrease. At the same time, the specified consumer properties of bread can be achieved using different types of flour. Using flour mixtures and plant functional additives, it was possible to obtain new types of bread with additional functional properties.

2.2. Materials

Considering which types of bread are most popular among consumers, improved recipes based on a mixture of rye and wheat flour, wheat and whole grain flour, as well as a mixture of gluten-free flour were proposed.

The custard shaped bread (sample 1) was made from a mixture of rye hulled flour of TM "Sto Pudiv" (Ukraine) flour and premium wheat flour. Salt, sugar, pressed yeast and the food additive "Live Grains Dark" were also added to the recipe, which contained quinoa, chia, flax, sunflower seeds, ground brew and dry sourdough. Baking was carried out for 30–35 min at a temperature of 220–200°C.

Sample 2 was made from a mixture of premium wheat flour and whole grain flour TM "Sto pudiv" (Ukraine). A liquid sourdough based on rice flour was used as a leavening agent [1]. The bread was enriched with dried cranberries of TM Activita Healthy Fruit (Ukraine) and walnuts of TM "Prygoschaysya" (Ukraine). Gluten-free bread (sample 3) was made from a flour mixture consisting of: rice, oat and buckwheat flour of LLC "Kaskad" (Ukraine), flax of TM "Zemledar" (Ukraine), quinoa flour of Kvartet, psyllium of Individual entrepreneur "Khramov V. M." (Ukraine), dry corn starch of LLC "Interstarch Ukraine". To reduce the bitterness of quinoa grains, they were infused in an ultrasonic bath UCleaner TV02 with a power of 120 W ($t=30\pm5$°C, 40 kHz, $\tau=20$ min). The treated seeds were dried in an infrared laboratory dryer to a mass fraction of moisture of 5–6% ($t=85\pm5$°C), crushed in a laboratory disk mill LZM-1 to a size that ensures complete passage of the material through a woven brass sieve No. 025 (0.25 mm). Honey of TM "EKO-MedOK" (Ukraine) was used as a sugar substitute in the recipe of sample 3. The duration of dough fermentation was 0.5 h (temperature 22.2 ± 2°C), and proofing was 5 hours (temperature 32 ± 2°C). Sample 3 was baked at a temperature of 220 ± 2°C for 1 h.

2.3. Study of organoleptic indicators of bread samples

The organoleptic evaluation of the samples was carried out by 10 non-professional tasters of different sexes and ages. All persons involved in the tasting had previous experience in sensory analysis of food products. The evaluation descriptors were selected taking into account the current regulatory documents characterizing the quality of bread. The evaluation was carried out on a 7-point scale: very dislike – 1 point; neutral dislike – 2 points; slightly dislike – 3 points; neutral like – 4 points; moderately good – 5 points; good – 6 points; very good – 7 points.

2.4. Study of the nutritional value of bread

A standard method was used to calculate the nutritional value. The mass fraction of proteins, fats, dry matter and fiber was determined experimentally.

The mass fraction of proteins in the bread samples was determined by the Kjeldahl method, fat by the accelerated (refractometric) method by extracting fat from a portion of bread with a solvent. To determine the mass fraction of dry matter, samples weighing 5 g were dried in a drying oven at a temperature of 130°C for 45 min. The moisture content of the bread was calculated by the formula

$$W=\frac{m_1-m_2}{m}\cdot 100, \qquad (1)$$

where m_1 – mass of the box with the bread sample before drying, m; m_2 – mass of the box with the bread sample after drying, g; m – mass of the bread sample, m.

The fiber content was determined by the Wind method. The mass fraction of carbohydrates was determined as the difference between the dry matter content and the remaining components.

First, the calorie content of the bread was calculated

$$K \cdot kp \cdot (Mp + Mc) + kf \cdot Mf, \quad (2)$$

where K – calorie content of bread, kcal; Mp – mass fraction of protein, g/100 g; Mc – mass fraction of carbohydrates, g/100 g; Mf – mass fraction of fat, g/100 g; $kp=4$ – coefficient of energy value of 1 g of protein or 1 g of carbohydrates in bread, kcal/g; $kf=9$ – coefficient of energy value of 1 g of fat in bread, kcal/g.

The following conversion was used to establish the nutritional value: 1 kcal = 4.184 kJ.

2.5. Statistical analysis

The measurement results were expressed as the mean ± standard deviation of three separate extracts, in three different studies. Comparison of group means and significance of the difference between groups was tested by Student's t-test. Statistical significance was $p \leq 0.05$.

3. Results and Discussion

3.1. Development of bread recipes with additional functional properties

Based on a number of experimental laboratory studies, three recipes of bread samples were developed (Table 1).

The choice of types of recipe components and their ratio was formed on the basis of an analysis of literature data and our own previous research.

3.2. Results of organoleptic evaluation of bread test samples

An organoleptic evaluation of test samples (Fig. 1) of bread made according to different recipes was carried out.

The consumer value of bread depends on its appearance, crumb condition, taste, aroma, and also largely determines its nutritional value. All experimental samples were sufficiently baked, had the correct shape, with a well-colored, browned crust.

The results of the organoleptic evaluation are presented in Table 2.

Table 1

Recipe and functional properties of bread samples

Raw materials, g	Sample 1	Sample 2	Sample 3	Functional properties
Rye flour, hulled	155	–	–	Contains vitamins B, E, PP, minerals (potassium, magnesium, iron, phosphorus), which play an important role in many metabolic processes. The increased content of dietary fiber helps reduce bread drying during storage and normalizes digestion. It has a low glycemic index, so it can be used in the diet of diabetics
High-grade wheat flour	45	170	–	The finely dispersed structure of the flour has a positive effect on the development of gluten and the porosity of bread
Whole grain flour	–	60	–	Due to the higher content of dietary fiber and complex carbohydrates, it helps improve digestion, reduce the risk of stroke and diabetes
Rice flour	–	–	60	Less calorie content compared to wheat, is well absorbed, has a sorbing effect. Does not contain gluten
Quinoa flour	–	–	30	Does not contain gluten. The high content of fiber helps remove toxins, toxins, cholesterol from the body
Flax flour	–	–	5	Contains dietary fiber that promotes the development of beneficial microflora in the intestine
Buckwheat flour	–	–	30	Contains B vitamins and antioxidants. Gluten-free
Oat flour	–	–	30	A source of essential amino acids and dietary fiber
Psyllium	–	–	10	Contains 85% fiber, helps slow down digestive processes and absorb nutrients
Corn starch	–	–	30	Improves structural and mechanical properties of dough based on gluten-free flours
Cranberries	–	25	–	Contributes to increasing the content of vitamins and carbohydrates, improves the taste of bread
Walnuts	–	15	–	Contributes to increasing the content of zinc and iodine. Thanks to a large number of bioactive substances and lecithin, they strengthen memory, relieve nervous tension and activate brain function
Food supplement "Live grains Dark" (quinoa, chia, flax, sunflower seeds, hop infusion, dry sourdough)	95	–	–	The food additive helps to prolong the freshness of finished products (increases resistance to mold), improves its organoleptic properties, reduces bread cooking time, enriches bread with biologically active substances of hops
Sugar	5	5	–	Gives certain taste properties
Salt	5	5	5	
Honey	–	–	10	Used as a sugar substitute, gives bread unique taste and aromatic properties
Sourdough	–	70	100	Allows to obtain a porous structure of finished products
Yeast	6	1	–	
Water	143	155	175	–
Total	454	506	485	–

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a

b

c

Fig. 1. Experimental samples of bread: *a* – sample 1; *b* – sample 2; *c* – sample 2

Table 2

Organoleptic indicators of the quality of bread with additional functional properties. Uncertainty, U (k=2, P=0.95)

Name	Appearance	Smell	Taste	Color
Sample 1	7.0±0.05	7.0±0.05	6.8±0.05	6.9±0.05
Sample 2	6.9±0.05	6.8±0.05	7.0±0.05	6.7±0.05
Sample 3	6.8±0.05	6.9±0.05	6.9±0.05	6.6±0.05

The test samples were rated good or very good for all indicators. The tasters liked sample 1 the most in terms of appearance and smell. The color of the crumb of sample 1 was dark brown. It had well-developed uniform thin-walled porosity, which positively affects the digestibility and assimilation of the bread. The shape of the bread corresponded to the form in which baking was carried out.

Sample 2 was rated "very good" for taste. It had an oblong-oval shape, not vague, without pressure points, and a white crumb color. The presence of large pores and voids was observed. Due to the introduction of dried cranberries and walnuts into the recipe, it had a pleasant sweet-sour taste and a nutty smell. However, the aroma of the product was not as pronounced as in the other samples.

The lowest organoleptic scores were obtained by the sample based on a mixture of gluten-free flour (sample 3). In terms of appearance, taste, smell and color, sample 3 received a rating of "good". The gluten-free bread had a characteristic shape, light brown color, nutty aroma (due to the addition of quinoa), was sufficiently baked, not moist to the touch. The porosity was uniform, sufficiently developed.

3.3. Results of the study of the nutritional value of bread

The results of the study of the nutritional value of bread are presented in Table 3.

The highest nutritional value (859.2±0.05 kJ/100 g) was in sample 2, made from a mixture of wheat flour (whole grain and high-grade flour) with the addition of dried cranberries and walnuts. The fiber content (2.5±0.05 g/100 g) and protein (5.0±0.05 g/100 g) in this sample was the lowest, and the carbohydrate content (45.87±0.05) was higher, compared to other experimental samples. It is worth noting that the highest moisture loss (1.6%) was observed during baking of this sample. This is probably due to the low fiber content in the flour.

Table 3

Nutritional value of bread. Uncertainty, U (k=2, P=0.95)

Name of indicators	Sample 1	Sample 2	Sample 3
Mass fraction of proteins, g/100 g	5.6±0.05	5.0±0.05	5.8±0.05
Mass fraction of fats, g/100 g	0.45±0.05	0.23±0.05	1.6±0.05
Fiber content, g/100 g	6±0.05	2.5±0.05	5.8±0.05
Dough moisture, %	45.7±0.05	48.0±0.05	47.5±0.05
Mass fraction of dry matter, g/100 g	55.0±0.05	53.6±0.05	53.3±0.05
Mass fraction of carbohydrates, g/100 g	42.95±0.05	45.87±0.05	40.1±0.05
Energy value, kcal	198.3±0.05	205.55±0.05	198.0±0.05
Nutritional value, kJ/100 g	828.7±0.05	859.2±0.05	828.4±0.05

Sample 1, made from a mixture of rye hulled and wheat flour of the highest grade, as well as the food supplement "Live Grains Dark", had the highest fiber content (6±0.05 g/100 g). The mass fraction of moisture in the carbohydrate content was higher compared to sample 3 by 2.9 g/100 g, which contributed to its higher energy value (198.3±0.05 kcal).

The highest protein content (5.8±0.05 g/100 g) was found in sample 3, made from a mixture of gluten-free flour. This sample also contained more fat (1.6±0.05 g/100 g), probably due to the use of quinoa and flax seeds. Gluten-free bread had a higher fiber content by 3.3% than bread made from wheat flour. In addition, this sample had a higher humidity (46.7%), probably due to the use of liquid sourdough. Wet dough better absorbed and retained air, which contributed to the formation of sufficient porosity of the bread. Such porosity helps to preserve its freshness and better digestibility.

Rye hulled flour is a complex multicomponent system of starch and non-starch polysaccharides, proteins and lipids. The presence of a large amount of dietary fiber negatively affects the structure-forming process when baking bread based on it. In addition, arabinoxylans contained in rye demonstrate a high water-binding capacity and the ability to form viscous solutions [16]. Taking these aspects into account, to some extent the production of bread from coarse flour is a difficult task. Therefore, the food additive "Live Grains Dark" was introduced into the recipe of experimental sample 1 (Fig. 1, *a*), which contains quinoa, chia, flax, sunflower seeds, hop infusion and dry sourdough. This allowed to improve the structural and mechanical properties of the dough and obtain a product with very good sensory properties (Table 2).

On the other hand, the polysaccharides of rye hulled flour have technological functionality, as they contribute to the overall rheology and demonstrate gel-forming properties with texturing potential [16]. By introducing a food additive with a high content of dietary fiber into the recipe of sample 1, the fiber content in the bread increases to 6 g/100 g, the nutritional value of the product is 828.7±0.05 kJ/100 g. According to other studies, the nutritional value of rye flour bread ranges from 726–786 kJ/100 g [17]. Thus, the proposed recipe for sample 1 (Table 1) allows to increase its nutritional value and fiber content in bread. The food additive "Live Grains Dark" also had a positive effect on the organoleptic properties of bread (Table 2). In terms of appearance and smell, this sample was rated with the highest scores by all tasters.

When obtaining high-grade wheat flour, up to 65% of vitamins are lost, however, such bread is better digested. The introduction of vegetable additives into the recipe leads to a decrease in the nutritional value of bread (859.2±0.05 kJ/100 g), compared to wheat bread made according to the classic recipe. This decrease occurs due to a decrease in the mass fraction of carbohydrates and an increase in the fiber content, compared to bread made on the basis of wheat flour and vegetable powders [18]. At the same time, the nutritional value of sample 2 was higher than the nutritional value of bread made from rye hulled flour and a mixture of gluten-free flour. Due to the use of dried cranberries and walnuts, the bread (sample 2) had a pleasant sweet-sour taste and nutty smell. The crumb contained large pores and single voids (Fig. 1, *b*).

The crumb of gluten-free flour bread had uniform thin-walled porosity, without cavities and signs of unripeness and hardening (Fig. 1, *c*). The color of the crumb of sample 3 was light brown. Sample 3 had a pleasant taste with a nutty aftertaste, the smell typical of bread without foreign shades. These results are consistent with the results of other researchers [19], who used quinoa flour to produce gluten-free bread. The nutritional value of gluten-free bread practically did not differ from bread made from rye flour (sample 1). It contained the largest amount of proteins (5.8±0.05 g/100 g) and fats (1.6±0.05 g/100 g), probably due to the presence of quinoa in the recipe [20]. In addition, gluten-free bread contains 5.8±0.05 g/100 g of dietary fiber (Table 3), which makes it useful for improving digestion.

The practical significance of this research lies in the possibility of expanding the range of bread with functional properties and a unique taste and aroma profile. This will contribute to improving the health of consumers. The results obtained may be of interest to manufacturers of craft bread.

The advantages of the developed recipes are that the product has not only unique consumer properties, but also a functional effect on the human body.

3.4. Research limitations and directions for its further development

The limitations of this research include the fact that the presented recipes include a significant number of components, which may be an obstacle to their implementation in mass industrial production. However, these recipes can be used by craft manufacturers of bakery products.

The disadvantage of the proposed method is that removing bitterness from quinoa grains requires additional energy costs for drying and special equipment. Also, an additional process is the creation of a liquid starter, which was used to produce samples 2 and 3.

Further research can be aimed at substantiating the economic feasibility of introducing the presented recipes into production.

4. Conclusions

Three bread recipes are proposed. Sample 1 is based on rye hulled flour, high-grade wheat flour and the food supplement "Live Grains Dark", containing quinoa, chia, flax, sunflower seeds, hop infusion and dry sourdough. Sample 2 made from high-grade wheat flour, whole grain flour, dried cranberries and walnuts. Sample 3 was made from a mixture of gluten-free flour (quinoa, rice, flax, buckwheat, oat, psyllium).

Each of the proposed food additives and ingredients had a positive effect on the organoleptic properties of the bread. According to all indicators, the samples were rated "good" and "very good". In terms of appearance and smell, the tasters liked the bread based on rye flour and the food supplement "Live Grains Dark" the most (sample 1). The taste of bread with cranberries and walnuts was recognized as the best (sample 2).

It was established that the food additive "Live Grains Dark" has a positive effect on the organoleptic and physicochemical properties of bread, allows to enrich it with dietary fiber (6 g/100 g). The use of dried cranberries and walnuts is accompanied by a decrease in the nutritional value of bread (859.2±0.05 kJ/100 g), compared to wheat bread made according to the classic recipe. This decrease occurs due to a decrease in the mass fraction of carbohydrates and an increase in the fiber content. The correct selection of gluten-free raw materials allows to obtain bread that is not inferior in physicochemical properties to bread made from traditional types of flour. Due to the high content of quinoa and flax, gluten-free bread contains 5.8 g/100 g of proteins and 1.6 g/100 g of fats.

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship or other, which could affect the study and its results presented in this article.

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Data availability

The manuscript has no related data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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