

UDC 664.665

DOI <https://doi.org/10.32782/tnv-tech.2026.1.2.8>

JUSTIFICATION OF THE PRODUCTION OF HEALTHY BREADS

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Of the article provides a scientific justification for the production of health-promoting bread rolls using barley malt and whole-grain wheat flour. Modern nutrition requires the creation of products with increased nutritional and biological value, enriched with complete proteins, essential amino acids, vitamins and minerals. In this regard, a promising direction is the creation of functional grain products, in particular bread rolls, which are characterized by high nutritional value, good organoleptic properties and the possibility of enrichment with natural plant components. The aim of the work is to develop a technology for the production of health-promoting bread rolls using malt and whole-grain wheat flour, as well as to assess their quality indicators. Based on the analysis of literary sources and experimental studies, the choice of raw materials characterized by increased nutritional and biological value is justified. It has been established that barley malt is a source of complete protein, essential amino acids, B vitamins, minerals, and antioxidants, and the use of whole grain wheat flour ensures the preservation of fiber, biologically active substances, and contributes to the formation of functional properties of the finished product.

The optimal ratio of recipe components (70% barley malt and 20% whole grain flour) has been experimentally determined, which provides the best organoleptic indicators and a balanced chemical composition. According to the results of sensory evaluation, the highest scores were received by model composition № 4 (4,9–5,0 points), which was characterized by uniform color, pleasant taste, pronounced aroma and crispy structure. It was established that the physicochemical indicators (humidity 8,0–8,3%, acidity 5,0–5,5°) meet the requirements of current regulatory documentation, and microbiological indicators do not exceed permissible norms, which confirms the safety of the product and the stability of the technological process.

Key words: health breads, barley malt, whole grain flour, functional products.

Горач О. О. Обґрунтування виробництва хлібців оздоровчого призначення

В статті наведено наукове обґрунтування виробництва хлібців оздоровчого призначення з використанням ячмінного солоду та цільнозернового пшеничного борошна. Сучасне харчування населення потребує створення продуктів із підвищеною харчовою та біологічною цінністю, збагачених повноцінними білками, незамінними амінокислотами, вітамінами та мінеральними речовинами. У зв'язку з цим перспективним напрямом є створення зернових продуктів функціонального призначення, зокрема хлібців, які характеризуються високою харчовою цінністю, добрими органолептичними властивостями та можливістю збагачення природними рослинними компонентами. Метою роботи є розроблення технології виробництва хлібців оздоровчого призначення з використанням солодового та цільнозернового пшеничного борошна, а також оцінка їх якісних показників. На основі аналізу літературних джерел і експериментальних досліджень обґрунтовано вибір сировини, що характеризується підвищеною харчовою та біологічною цінністю. Встановлено, що ячмінний солод є джерелом повноцінного білка, незамінних амінокислот, вітамінів групи В, мінеральних речовин та антиоксидантів, а використання цільнозернового пшеничного борошна забезпечує збереження клітковини, біологічно активних речовин і сприяє формуванню функціональних властивостей готового продукту.

Експериментально визначено оптимальне співвідношення рецептурних компонентів (70% ячмінного солоду та 20% цільнозернового борошна), яке забезпечує найкращі

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органолептичні показники та збалансований хімічний склад. За результатами сенсорної оцінки найвищі бали отримала модельна композиція №4 (4,9–5,0 бала), що характеризувалася рівномірним кольором, приємним смаком, вираженим ароматом і хрусткою структурою. Встановлено, що фізико-хімічні показники (вологість 8,0–8,3%, кислотність 5,0–5,5°) відповідають вимогам чинної нормативної документації, а мікробіологічні показники не перевищують допустимих норм, що підтверджує безпечність продукції та стабільність технологічного процесу.

Ключові слова: *хлібці оздоровчого призначення, ячмінний солод, цільнозернове борошно, функціональні продукти.*

Problem statement. Modern nutrition of the population requires products of increased nutritional and biological value, enriched with proteins, essential amino acids, vitamins and minerals. The increase in the incidence of cardiovascular, metabolic and chronic pathologies makes it necessary to develop health-promoting products that contribute to the prevention of chronic diseases and improve the general condition of the body [1].

Bread and bakery products are the basis of the diet of the majority of the population, but traditional wheat breads contain a limited amount of proteins of high biological value, vitamins and mineral elements. The use of barley malt and whole grain flour allows to increase the nutritional and biological value of the product, improve its organoleptic properties and functional characteristics. The development of a technology for the production of health-promoting breads is relevant for food industry enterprises and allows to create competitive products with high indicators of biological value. The introduction of a technology for the production of health-promoting breads will allow to provide the population with products that meet the principles of healthy nutrition [2, 3].

Formulation of the objectives of the article. The purpose of the article is to substantiate the technology of production of health-promoting breads using whole-grain wheat flour.

The object of the study is health-promoting breads using whole-grain wheat flour.

The subject of the study is the technological parameters of the production of breads with whole-grain wheat flour, their recipe composition, sensory, physico-chemical and microbiological indicators.

Presentation of the main material. To justify the choice of raw materials in the production of health-promoting breads, it is important to assess the chemical composition of the main components of the recipe. Table 1 shows the average chemical composition of barley malt and whole grain wheat flour per 100 g of product, determined according to scientific sources and guides to the nutritional value of grain products [4].

As can be seen from the data in Table 1, barley malt is characterized by an increased content of biologically active components, in particular β -glucans (up to 7%), which have a pronounced physiological effect:

- reduce the level of low-density cholesterol;
- normalize carbohydrate metabolism, contributing to the slow absorption of glucose;
- increase the body's immunological reactivity;
- have a positive effect on the intestinal microbiota.

In addition, the enzymatic activity of malt (amylase, protease, β -glucanase) provides a natural breakdown of complex carbohydrates and proteins, which improves the taste, aroma and digestibility of finished breads.

Whole grain wheat flour is a source of fiber, B vitamins, tocopherols, minerals (Mg, Fe, Zn, Se) and biologically active compounds localized in the germ and shells of the grain [4]. Due to this, it provides:

- regulation of digestion;
- improvement of lipid metabolism;
- reduction of the glycemic index of the finished product;
- formation of a pleasant nutty flavor.

The joint use of barley malt and whole grain flour in the composition of the recipe allows to achieve high nutritional and biological value of the product. Due to this, the breads have the following advantages:

- increased content of β -glucans and fiber;
- balanced amino acid composition of proteins;
- natural complex of antioxidants;
- pleasant taste and aroma without the need to use synthetic additives.

Thus, the use of barley malt and whole grain flour as the main components of the recipe is a scientifically based and technologically feasible solution for creating health-promoting breads.

Due to the combination of a low glycemic index (about 40–45) and a high ability to swell, barley malt-based breads contribute to the slow absorption of glucose, preventing sharp fluctuations in blood sugar levels. This is especially important for the prevention of type 2 diabetes [1, 2].

In addition, the high fiber content reduces the energy value of the daily diet, contributing to body weight control and maintaining a healthy metabolism. Due to the complex effect on metabolism, such breads can be attributed to functional products for preventive purposes, recommended for wide groups of the population – from children to the elderly.

Given the growing attention of society to health and quality of nutrition, the development and implementation of technology for such products is a promising

Table 1

**Chemical composition of barley malt and whole grain wheat flour
(per 100 g of product)**

Indicator	Barley malt	Whole grain flour
Moisture, %	6,5	13,0
Protein, g	12,0–14,0	11,0–13,0
Fat, g	1,8–2,5	1,5–2,2
Carbohydrates, g	65–68	66–70
Including starch, g	52–55	58–62
Dietary fiber, g	9,0–10,5	8,0–9,5
β -glucans, g	4,0–7,0	0,4–0,6
Ash (minerals), g	2,5	1,7
Energy value, kcal	320–330	330–340
Vitamin B ₁ (thiamine), mg	0,45	0,40
Vitamin B ₂ (riboflavin), mg	0,32	0,25
Vitamin B ₃ (niacin), mg	4,6	4,0
Vitamin E (tocopherol), mg	0,9	1,2
Magnesium, mg	115	108
Potassium, mg	370	360
Iron, mg	3,0	3,5
Zinc, mg	2,7	2,9
Selenium, μ g	23	28

direction for innovative development of food industry enterprises in Ukraine, especially in regions with a developed raw material base – in particular, in the South of the country.

To develop a technology for the production of health-promoting breads, it is necessary to evaluate the organoleptic and physicochemical properties of the main components of the recipe: barley malt and whole wheat flour in accordance with DSTU 4282:2004 "Barley malt for brewing", DSTU 46.004-99 "Wheat flour. Technical conditions". This will allow to determine the quality of the raw material, its suitability for production and the impact on the functional and technological characteristics of the finished product. In table. 2 the physicochemical indicators of the studied raw material are given [5–7].

Table 2

Physicochemical indicators of the quality of the studied raw material

№	Indicators	Malt flour	Whole wheat flour
1	Humidity, %	4,5	13,2
2	Titrated acidity, deg	9,2	4,1
3	Mass fraction of sugar, %	4,0	1,5

Analysis of Table 2 shows that the moisture content of malt flour was 4,5%, which meets the requirements of DSTU 4282:2004 "Barley malt for brewing" and indicates good product preservation and low probability of microflora development during storage. The moisture content of whole grain wheat flour was 13,2%, which does not exceed the permissible values according to DSTU 46.004-99 "Wheat flour. Technical conditions" and characterizes the raw material as suitable for technological use. The titrated acidity of malt flour was 9,2 degrees, which is typical for malt products and is explained by the accumulation of organic acids during grain germination. Increased acidity of malt flour will contribute to the formation of a pleasant taste and increase the biological value of the finished product. The acidity of whole grain wheat flour was 4.1 degrees, which corresponds to the regulatory indicators and indicates its freshness and proper storage conditions.

The mass fraction of sugars in malt flour was 4,0%, which significantly exceeds the similar indicator of whole grain wheat flour (1,5%). The increased content of sugars in malt flour is due to enzymatic hydrolysis of starch during barley germination. The presence of easily digestible sugars will contribute to the intensification of enzymatic processes and the formation of a pleasant taste of buns. Thus, the obtained results of physicochemical studies indicate the compliance of the studied raw materials with regulatory requirements and confirm the feasibility of using malt and whole grain wheat flour in the technology of production of health buns. The established indicators ensure the proper technological properties of the raw materials and contribute to the formation of high nutritional and biological value of the finished product.

Thus, the results obtained allow us to conclude that both types of raw materials have high nutritional value and technological suitability for use in the production of health-promoting breads. Malt flour is a source of enzymes that contribute to the formation of natural sugars and aromatic compounds. Whole wheat flour provides an increased content of fiber, protein and trace elements, improving the structure and biological value of the product. The combination of these two components allows us to obtain a product balanced in composition and functional properties, aimed at improving digestion, reducing cholesterol levels and maintaining the body's energy balance.

5 model bread compositions with different ratios of ingredients in the recipe were selected for the study (Table 3):

- 1 model composition barley malt and whole wheat flour – 40:25%;
- 2 model composition barley malt and whole wheat flour – 50:20%;
- 3 model composition barley malt and whole grain wheat flour – 60:20%;
- 4 model composition barley malt and whole grain wheat flour – 70:20%;
- 5 model composition barley malt and whole grain wheat flour – 80:15%.

Table 3

Test samples of model compositions

Raw material name	Experimental samples					Experimental samples
	model composition 1	model composition 2	model composition 3	model composition 4	model composition 5	
Barley malt	40	50	60	70	80	
Whole wheat flour	25	20	20	20	15	
Water	17	17	4	-	-	
Butter	15	10	10	3,5	2,5	
Salt	1	1	4,4	5	1,2	
Spices	2	2	1,6	1,5	1,3	

The results of sensory analysis of the test samples are presented in Table 4

Table 4

Results of sensory analysis of the test samples

Name of the indicator	Experimental samples				
	model composition 1	model composition 2	model composition 3	model composition 4	model composition 5
Appearance	5	5	4,5	5	5
Taste	4,5	4,2	4,1	5	4,5
Odor	4,5	4,5	4,5	5	4,8
Color	4,8	4,7	4,5	5	5
Structure	4,5	4,8	4,7	5	5

The profile of the sensory analysis of the test samples is presented in Fig. 1.

According to the results of sensory analysis (Table 4, Fig. 1), it was found that all experimental samples have high organoleptic indicators, which confirms the correct selection of raw materials and the balance of the recipes. The appearance of most compositions received the highest score – 5,0 points, which indicates a uniform shape, smooth surface and attractive crust of the products. A slight decrease in the score in composition 3 (4,5 points) is associated with minor deviations in the formation of the structure during baking. Taste characteristics demonstrate a certain variation: the highest indicator is in composition 4 (5 points), where the optimal combination of malt sweetness and bread flavor was achieved. In compositions 2 and 3, the taste was rated lower (4,2–4,1 points), which is probably due to a slightly lower content of barley malt or an imperfect proportion of moisture. The smell of all samples is pleasant, bready, with a light malt aroma. The best aroma is characterized by composition 4 (5 points), where grain and caramel tones are harmoniously combined.

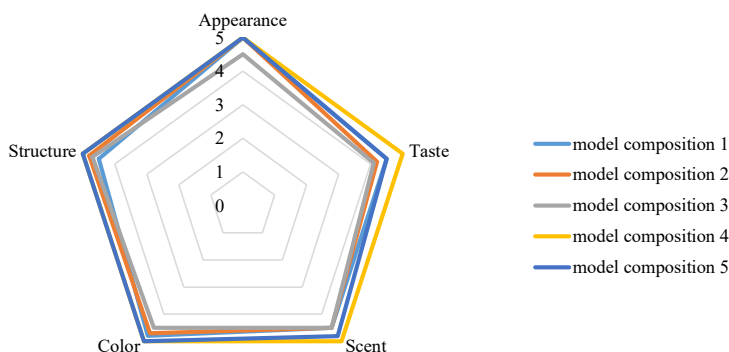


Fig. 1. Profiograph for sensory analysis of test samples

In terms of color, the highest scores were received by compositions 4 and 5 (5 points each) – the products have a uniform color from light golden to amber brown. In composition 3, the color is slightly darker, which reduced the score to 4,5 points.

The structure of the bread also varies. Thus, samples 4 and 5 received maximum scores (5.0 points) for uniform porosity and elasticity of the crumb, while in compositions 1–3 the structure is somewhat denser (4,5–4,8 points).

Summarizing the results, it can be noted that model composition 4 has the highest sensory indicators among all experimental samples. It is characterized by a pleasant taste, pronounced aroma, uniform color and elastic structure. Thus, it is appropriate to consider composition 4 as the optimal formulation option when developing health-promoting breads using barley malt and whole grain wheat flour.

The next stage of the study was the determination of physicochemical indicators. Physicochemical indicators of product quality for this work were determined by moisture and acidity. The results are presented in Table 5.

Table 5

Physicochemical indicators of the studied samples

Name of the indicator	Experimental samples				
	model composition 1	model composition 2	model composition 3	model composition 4	model composition 5
Humidity, %	8,0	8,1	8,2	8,3	8,3
Acidity, degrees	5,0	5,2	5,2	5,3	5,5

Fig. 2 shows a diagram of physicochemical indicators.

Analysis of the physicochemical indicators (Table 5, Fig. 2) of the studied samples, comparison of the obtained physicochemical data with the requirements of DSTU 2903:2005 "Food concentrates. Dry breakfasts. General technical conditions" shows that the humidity of the samples (8,0–8,3%) is within the normal range ($\leq 11\%$) according to DSTU 2903:2005, i.e. they meet the requirements. The acidity is also 5,0–5,5 degrees, which meets the requirements of the standard.

Based on a comprehensive analysis of the sensory evaluation indicators and physicochemical properties, it was determined that model composition 4 is the best and is recommended for the further production of health-promoting breads.

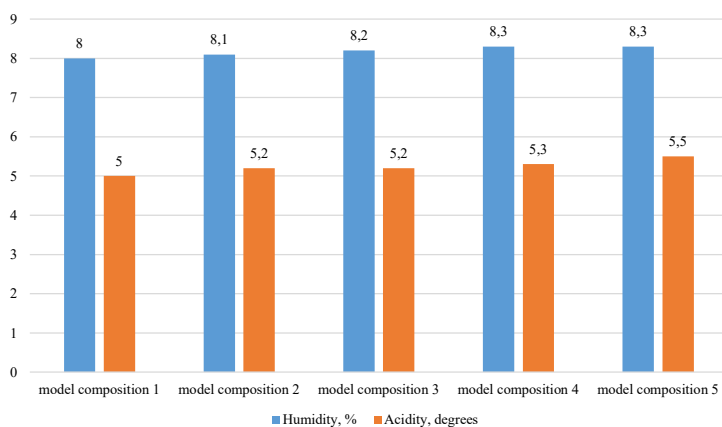


Fig. 2. Diagram of physicochemical parameters

The next stage of the study was the determination of the microbiological safety of the developed model compositions. The objectives of the study were to determine the total number of mesophilic aerobic and facultative anaerobic microorganisms (MAFAnM), assess the presence of bacteria and mold fungi, and compare the results obtained with the regulatory requirements of the State Technical Standards of Ukraine.

Microbiological analyses were performed according to the methods regulated by the current standards: DSTU ISO 4833–1:2022 – determination of the total number of microorganisms; DSTU ISO 21527–1:2015 – determination of yeast and mold fungi; DSTU ISO 4832:2019 – determination of *Escherichia coli* bacteria (EBC). Microbiological research was conducted to assess the safety and stability of the developed product of health-promoting breads based on barley malt with the addition of whole grain wheat flour. The main objectives were: to determine the total number of microorganisms (CFU/g), to detect the presence of pathogenic bacteria; to assess fungal contamination (yeast and mold fungi) [8–13].

The results of the microbiological parameters studies are presented in Table 6.

Table 6

Results of the microbiological parameters studies

Indicator	Model composition 1	Model composition 2	Model composition 3	Model composition 4	Model composition 5	DSTU standard for dry bakery products
Total number of microorganisms (CFU/g)	$1,2 \times 10^3$	$1,0 \times 10^3$	$9,0 \times 10^2$	$8,5 \times 10^2$	$8,0 \times 10^2$	$\leq 1,0 \times 10^4$
Coliforms, CFU/g	missing	missing	missing	missing	missing	missing
Salmonella spp.	missing	missing	missing	missing	missing	missing
Yeast and mold fungi, CFU/g	$1,0 \times 10^{2-3}$	$9,0 \times 10^1$	$8,0 \times 10^1$	$7,5 \times 10^1$	$7,0 \times 10^1$	$\leq 1,0 \times 10^4$

Analysis of the results of microbiological indicators in Table 6 shows that the total microbiological contamination of all samples does not exceed the norm of $\leq 1.0 \times 10^4$ CFU/g. Coliforms and Salmonella spp. were not detected in any sample, which confirms the safety of the product for consumption. Yeast and mold fungi are present in a small amount, which does not exceed the limit norm of $\leq 1.0 \times 10^3$ CFU/g. The lowest level of total microbiological contamination is observed in composition 5, which can be explained by the higher content of barley malt and lower moisture content of the product, which reduce the possibility of growth of microorganisms. Thus, the developed health-promoting breads meet the safety requirements for food products according to microbiological indicators. Compositions 4 and 5 have the best microbiological stability and are recommended for further production. The product can be stored under normal conditions without exceeding the permissible limit values of microbiological contamination.

Conclusions. Based on the presented research, the choice of raw materials for the development of a technology for the production of bread rolls using whole grain flour for health purposes was justified. It was determined that barley malt is a valuable component due to the high content of proteins, essential amino acids, B vitamins, minerals and antioxidants. The use of whole grain wheat flour allows you to preserve fiber, minerals, enzymes and biologically active substances, which provides a health-improving effect of the product. It was experimentally established that the optimal option is a variant with a content of 70% barley malt and 20% whole grain flour, which provides the best organoleptic indicators and a balanced chemical composition. Sensory quality indicators of the experimental samples were determined. According to the results of the tasting evaluation, the highest scores (average indicator 4,9–5,0) were received by model composition No. 4, which was distinguished by a uniform color, pleasant taste, pronounced aroma and crispy structure. Physico-chemical indicators (humidity 8,0–8,3%, acidity 5,0–5,5°) of the test samples fully comply with the requirements of DSTU, which confirms the quality and stability of the technological process. Microbiological studies have confirmed the safety of the developed breads – the indicators of mesophilic aerobic and facultative anaerobic microorganisms, mold fungi and yeast do not exceed the permissible norms. Production meets the requirements of the HACCP system for the control of critical points of the technological process.

The developed technology involves the use of local raw materials, energy-saving drying processes and a minimum amount of technological additives, which meets modern requirements for healthy nutrition. The study proved that malt loaves with whole grain wheat flour have increased nutritional, biological and functional value, meet quality requirements, are safe, competitive and promising for introduction into production at food industry enterprises.

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Дата першого надходження статті до видання: 20.12.2025

Дата прийняття статті до друку після рецензування: 26.01.2026

Дата публікації (оприлюднення) статті: 07.04.2026