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NEW ASPECTS OF USING MILLET GRAIN IN BREAD MANUFACTURING

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Abstract. The article proves how practical it is to use whole-milled millet grain to improve the quality of bakery products. Samples of bread with the addition of different amounts of milled millet grain before and after microwave treatment have been evaluated by sensory (surface, shape, and colour of bread, porosity, structure and colour of the crumb) and physico-chemical parameters. To determine the organoleptic evaluation of bread samples with the addition of 5%, 10%, and 15% whole-milled millet grain before and after microwave treatment, a scoring scale and the profiling method were used. According to the results of the research, the advantages of introducing milled millet grain into wheat flour has been substantiated, and it has been shown that adding it to the formulation of 5–15% improves the organoleptic characteristics of the bread, namely, giving it a harmonious taste and aroma, an attractive colour, a pronounced smell, and a porous structure, comparatively with standard bread made from wheat flour. The best characteristics were observed after whole-milled millet grain that had undergone microwave treatment was added to the flour. When 15% of whole-milled millet grain is added to wheat flour after microwave treatment, there is a slight decrease in the porosity of the bread. So, the introduction of more than 15% of whole-milled millet into the formulation is considered inappropriate. It has been found that the physical-chemical parameters of bread (humidity, acidity, porosity, mass fraction of sugar and fat), when adding whole-milled millet in the amount of 5–15% before and after microwave treatment, practically do not change. The introduction of 5–15% of whole-milled millet grain into the composition of bread recipes allows you to obtain high quality bread, of high nutritional and biological value, which can be recommended for consumption by all social groups, including children, adolescents, and elderly people. These studies can be used in the future in developing a technology of obtaining bakery products of functional purpose with high consumer properties.

Key words: millet, flour, microwave treatment, organoleptic estimation, chemical composition.

НОВІТНІ АСПЕКТИ ВИКОРИСТАННЯ ЗЕРНА ПРОСА ПРИ ВИРОБНИЦТВІ ХЛІБА

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Анотація. У статті представлено доцільність використання цільнорозмеленого зерна проса для поліпшення якості хлібобулочних виробів. Зразки хліба з додаванням різної кількості розмеленого зерна проса до та після мікрохвильової обробки оцінювали за органолептичними (поверхня, форма та колір хліба і пористість, структура та колір м'якушки) та фізико-хімічними показниками. Для визначення органолептичної оцінки зразків хліба з додаванням 5%, 10% та15% цільнорозмеленого зерна проса до та після мікрохвильової обробки, використовували балову шкалу та метод профілювання. За результатами проведених досліджень обгрунтовано доцільність введення розмеленого зерна проса до пшеничного борошна та показано, що додавання його до рецептури 5–15% покращує органолептичні характеристики хліба, а саме, надають йому гармонійний смак та аромат, привабливий колір, виражений запах і пористу структуру, порівняно зі стандартним хлібом, випеченим з пшеничного борошна. Кращі показники були при додаванні у борошно цільнорозмеленого зерна проса, що пройшло мікрохвильову обробку. При додаванні 15% цільнорозмеленого зерна проса до пшеничного борошна після мікрохвильової обробки, відбувається незначне зменшення пористості хліба. Тому введення більше 15% цільнорозмеленого зерна проса до складу рецептури вважається недоцільним. Встановлено, що фізико-хімічні показники хліба (вологість, кислотність, пористість, масова частка цукру та жиру) при додаванні цільнорозмеленого зерна проса в кількості 5–15% до та після мікрохвильової обробки практично не змінюються. Введення до складу рецептури хліба 5–15 % цільнорозмеленого зерна проса дозволяє отримати якісний хліб, підвищеної харчової та біологічної цінності, який можна рекомендувати для споживання всім верствам населення, включаючи дітей, підлітків та людей похилого віку. Ці дослідження можуть бути використані в подальшому в розробці технології отримання хлібобулочних виробів функціонального призначення з високими споживчими властивостями.

Ключові слова: просо, борошно, мікрохвильова обробка, органолептична оцінка, хімічний склад.

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Introduction. Formulation of the problem

Nutrition is one of the main determinants of human health. A diet with the use of products, where the main nutrients are maximally balanced according to physiological needs, living conditions and work, is one of the most important conditions for a person's normal growth and development.

Modern trends in the formation of a healthy diet dictate the need to create new products with increased biological and physiological value. An important role in this case is played by the possibility of using plant material, which is grown in close proximity to the places of its processing. This allows you to reduce significantly the costs of transportation and storage of raw materials, to expand the range of food products.

Improving the nutrition of the population is possible due to using in the food products formulations natural vegetable raw materials, traditionally cultivated and grown in the country and having a high biological value. Recently, considerable attention of industry specialists has been devoted to the creation of products of high nutritional value, enrichment of mass products, in particular bakery products, macro and microcomponents, and the development of technologies for their production [1].

Bakery products on the basis of whole grain belong to functional products due to the preservation of amino acids, trace elements, food fibres and other biologically active substances of cereals. Despite the benefits of cereal-based grain products, they are inferior to quality products of varietal flour, which affects their demand because for consumers, the most important are the organoleptic characteristics – appearance, flavour, and aromatic properties. A promising direction for solving the problem of creating high-value food products is using for their production mixtures of grains and products of their processing of other crops [2].

The orientation of agricultural enterprises to the cultivation of profitable cereals does not contribute to a balanced supply of diverse food products to the market. As a result, lately there has taken place underproduction of some insufficiently profitable or unprofitable crops, which leads to a decrease in their supply, feverish demand, and a sharp rise in the price of goods. But every year, the climate in Ukraine becomes more arid, which negatively affects the cultivation of wheat. Therefore, it is not easy to get the planned harvest of grain, including winter wheat, whose quality in some years is reduced due to unfavourable conditions of cultivation. So, there is a need to find reserves to stabilize the production of bakery products in our country and to improve its quality.

Analysis of recent research and publications

At present, the assortment of bread is increasing and on the shelves of shops, a variety of bread types can be seen: with bran, peanuts, raisins, sunflower seeds, and the like. Demand for this type of bread is increasing, as buyers are becoming more demanding and are taking to healthy nutrition. Scientists are looking for different approaches to improve the quality and reveal the therapeutic and prophylactic properties of bread and bakery products. One of these ways is the use of mixtures of wheat flour, which is a traditional raw material for the production of bread, bakery and confectionery products, in combination with products of millet processing [3-10].

It should be noted that one of the ways to increase the gross yield of grain is to grow common or sowing millet (*Panicum miliaceum L.*), which uses soil moisture better than other crops, is less affected by drought, and responds well to the improvement of cultivation farming. In the past few years, there has been an increase in the interest in this cereal crop, as evidenced by an increase in the size of the crop area under this culture. It should also be noted that in developed countries (North America, Australia, EU countries), only this kind of millet is grown for grain [11,12].

According to FAO, today a third of humanity suffers from a lack of caloric intake, more than half of which is due to lack of protein. In Ukraine, the main cereal product containing a large amount of protein is millet groats, a product of processing the millet crop. Depending on the variety and the soil-climatic conditions for the cultivation, millet contains 12–14% of protein, 80–82% of starch, 2.0–3.5 mg/kg carotenoids, 2–3% of fat.

In addition, the protein content of a millet grain varies from 8.8 to 19.3 %, and is on average 13.7 %. In the process of producing millet groats, when removing shells, the amount of protein substances in the nucleus increases in the range of 11.2–23.5% with an average content of 16%. But when grinding millet, not only the content of protein and starch, but also of minerals, first of all of phosphorus, decreases. By the way, the protein content of grain depends on the climatic conditions, agrotechnical measures, genotype characteristics of the variety [13].

The millet is characterized by a high content of vitamins B (B_2, B_5, B_6), macro and microelements (magnesium, iodine, etc.) [14-18]. The value of millet is determined by practically non-waste use of products of its processing in the food, fodder, pharmaceutical, microbiological industries [14].

In the grains of millet in large numbers there are immutable amino acids – lysine, methionine, tryptophan, and others. In addition, millet is rich in fibre and promotes the excretion of toxins and ballast substances from the body. The chemical composition and energy value of millet grain is presented in Table. 1.

Table 1 – Chemical composition and nutritional value of millet grain [15, 18]

Name	Mass fraction, g/100 g of product
Proteins	11.2
Fat	3.9
Mono and disaccharides	1.9
Starch	54.7
Cellulose	7.9
Ash	2.9
Mineral substances: Mass fraction, mg/100 g	
sodium	28
potassium	328
calcium	51
magnesium	130
phosphorus	320
iron	3,5
Vitamins: Mass fraction, mg/100 g	
β- carotene	0.01
B_1	0.32
B_2	0.07
PP	2.85
E	2.3
Energy value, kcal	311

Millet is prescribed in the treatment of anaemia, since it contains a lot of manganese and copper. Magnesium, used regularly, expands blood vessels, which leads to normalization of blood pressure. Millet grain easily removes the remains of antibiotics from the body and protects the mucous membrane of the stomach and intestines. For this reason, patients who take antibiotics should eat this product [16]. This cereal slows down the development of tumours in the human body, and also accelerates the healing of fractures [17].

Millet is also used as a source of valuable food – millet groats. Milled millet groats are used as a supplement to flour of other crops to improve the quality of the dough, in confectionery industry, in the manufacture of dry breakfasts. In pure form, millet flour is almost unsuitable for baking.

In the course of post-harvest maturing, synthesis of protein from amino acids, starch from sugars, fats from glycerol and fatty acids ends. Part of the water released in the process of these reactions, moves to the surface of the grain and moisturizes the intergranular space. As a result, in the grain mass, vital activity of microorganisms is intensified, the process of respiration is intensified, and this is characteristic even of grain of low humidity. As a result of timely and properly carried out drying, post-harvest maturing of the grain is significantly accelerated (in the conditions of normal storage, this lasts for several weeks or even months), its stability during storage increases, its technological and seed properties improve [19,20].

The moisture content of freshly harvested grain can vary up to 20% or more depending on the weather conditions of its harvesting. When moisture rises above the established standards, the seeds should be dried. The choice of drying modes of grain depends essentially on its further purpose. Drying grain of millet with more than 16% of moisture must be carried out immediately as it comes from the field with the moisture of the seeds lowered to 13.0–13.5%. One of the promising methods of drying is the microwave field used to remove moisture from bulk materials, to obtain a given moisture content of grain and oilseeds, including the seed stock. The main difference between microwave treatment (MW-treatment) of grain and traditional heat treatment methods is the way of heating. Heat enters the product not from the surface, but is formed immediately in the entire volume, there is a uniform distribution of moisture from the centre to the surface of the grain. Microwave treatment has an advantage of there being no heat transfer from the heater. When using other heat treatment methods, first, with the help of any heater, it is required to heat the air, then to transfer heat from the heated air to the grain. At each of the stages: air heating, its transportation, heat transfer, there are inevitable losses of heat, which corresponds to the efficiency of the installation 50–60%. With MW-treatment, the source of heat is the product itself, therefore, the above losses are absent while preserving the quality of the dried product, which increases the efficiency of the plant to 90%. The use of such energy-saving technology for grain crop processing is relevant because it allows ten-fold reduction of energy costs that are part of the cost of grain. Application of treatment in the microwave field (MW field) also allows disinfecting the agricultural product and lowering the development of potentially dangerous (harmful) microflora, which can cause damage to the grain during storage. Also, the use of this energy reduces the microdamaging of leguminous and oilseed crops, which results in a high quality of grain during long-term storage, an increase in the germination ability and rate of seed germination [21,22].

At present, the intensification of technological processes under the influence of microwave radiation is used in many industrial processes. Microwave equipment becomes a necessary technological component of large, cost-effective production [23]. Drying processes are no exception, either. In recent years, new variants of drying plants using combined power supply methods, including microwave energy, have been proposed. Microwave dryers for food products, cereals, and oilseeds, including the seed stock, are being developed and started to be used. Besides, microwave dryers, while drying, disinfect the products from harmful bacteria, fungi, and mould [24]. For the implementation of microwave drying, it is of particular importance to choose the drying parameters, taking into account that the grain is a biologically active object.

Microwave drying allows providing powerful energy flows to the object of drying and to intensify significantly the evaporation of moisture. But at the same time, there is also an intense heating of the product, which can impair its quality. The possibility of supplying energy

throughout the intersection of the product allows ensuring the evaporation of moisture from the inner layers of the product, which is especially important at the end of drying, when the zone of evaporation of the moisture is significantly deepened. Therefore, the highest drying efficiency can be obtained in combined processes that take advantage of different drying methods, such as convective and microwave.

In this work, we used whole-milled millet, which, to reduce moisture during the post-harvest treatment, was dried in two ways – convective and microwave drying.

The purpose of the work was to establish the feasibility of using whole-milled millet for improving the quality of bakery products.

The objectives of the study were:

1. Trial baking of bread with the addition of whole-milled millet grain with microwave treatment and without it, in proportion of 5%, 10%, and 15% to high quality wheat flour, in order to evaluate the possibility of using millet flour in bakery.

2. Conduct an organoleptic assessment of the quality of the baked bread with the addition of different amounts of whole-milled millet grain with and without microwave treatment.

3. Estimate the quality of the baked bread with the addition of different amounts of whole-milled millet grain with and without microwave treatment by the profiling method.

Research materials and methods

In order to evaluate the possibility of using millet flour in bread baking, a test baking of bread was carried out using the formulations given in Table 2.

Table 2 – Recipes of the bread samples

Components	Sample number						
	1	2	3	4	2a	3a	4a
Water, ml	250						
Butter, g	30						
Sugar, g	5						
Milk, ml	70						
Dry yeast, g	5						
High quality wheat flour	100	95	90	85	100	95	90
Whole-milled millet	-	5	10	15	-	-	-
Whole-milled millet grain after microwave treatment	-	-	-		5	10	15

Type 1 millet grain was harvested in 2015 in the Kirovograd Oblast. It was added, after microwave treatment and without it, to high quality wheat flour (produced by the state integrated bakery plant Kulindorovsky KHP) to constitute 5%, 10%, and 15% of it. The millet grain was processed in the microwave field with the parameters determined by Prof. L.G. Kalinin et al.: processing exposure 80 s at the frequency f=2450 MHz, working wavelength λ=0,125 m. The criterion for the uniformity and efficiency of the penetration of the electromagnetic field (or penetration depth) was Δ=0.0192 [21,22]. The baking quality was assessed on the basis of the quality of the bread, and the estimates were made during the trial baking in the laboratory. As the control, they chose bread made from high quality wheat flour.

Organoleptic evaluation of the bread made with the addition of 5%, 10%, and 15% of whole-milled millet grain to high quality wheat flour, after microwave treatment and without it, was carried out on a 5-point scale.

During the tasting, all tasters were provided with experimental bread samples, a tasting sheet and a scoreboard. The tasters were experts and had sensory abilities (well-developed sense of smell and taste, sensory memory), knew the properties of the product under evaluation, and the technology of its production.

The samples of bread with the addition of different amounts of milled millet grain (5%, 10%, 15%) were evaluated using such parameters as the appearance of the bread (surface, shape, colour) and the characteristics of the crumb (porosity, structure, and colour).

During the study of the taste, smell, colour and structure of the obtained samples of bread by the profiling method, the following descriptors were taken into account:

– positive – harmonious and grainy taste, attractive and pleasant colour, pronounced smell and porous and delicate structure;

– negative – bland and rancid taste, unpleasant aftertaste, uneven colour, slightly pronounced smell and coarse structure.

Results of the research and their discussion

In the studied samples of bread made from wheat flour (control sample) and with addition of whole-milled millet in different amounts before and after microwave treatment, the organoleptic quality assessment has been performed with a scoring scale (Table 3). The samples of bread with the addition of milled millet grain before and after microwave treatment(MW treatment) are presented in Fig. 1.

Table 3 – Quality of bread baked with the addition of whole-milled millet to flour

Sample number	Composition of the flour	Volume of bread, cm^3	Mark of the bread, points						Overall mark
			Appearance of bread			Characteristics of the crumb			
			surface	shape	colour of the surface	porosity	crumb structure	colour of the crumb	
1	Wheat flour (control)	605	3	5	1	3	5	4	3.5
2	Wheat flour + 5 % of whole-milled millet	645	3	5	3	4	4	5	4.0
3	Wheat flour + 10 % of whole-milled millet	665	3	3	3	4	4	5	3.7
4	Wheat flour + 15 % of whole-milled millet	675	3	4	3	4	4	5	3.8
2a	Wheat flour + 5 % of whole-milled millet after microwave treatment	685	3	5	3	4	4	5	4.0
3a	Wheat flour + 10 % of whole-milled millet after microwave treatment	713	5	5	3	3	4	4	4.0
4a	Wheat flour + 15 % of whole-milled millet after microwave treatment	740	5	5	3	3	4	4	3.8

1) control sample; 2) 5% of whole-milled millet; 3) 10% of whole-milled millet; 4) 15% of whole-milled millet; 2a) 5% of whole-milled millet grain after MW treatment; 3a) 10% of whole-milled millet grain after MW treatment; 4a) 15% of whole-milled millet grain after MW treatment.

Fig. 1. Bread with the addition of milled millet grain before and after microwave treatment (MW treatment)

As can be seen from the photo, the addition of ground millet grain to 15 % greatly improves the general appearance of bread, while the parameters of the technological process do not change. Moreover, an increase in the amount of millet in the mixture increases the volume of bread and its porosity, although there is a decrease in the content of gluten proteins – the main structure of the dough.

The sensory characteristics of products are the most important to the consumer, because they immediately, without any physical or chemical research, give a general idea of the quality of the product. It is them that have a psychological effect on the consumer making him or her prefer a product [25].

That is why, at the Department of grain storage technology of Odessa National Academy of Food Technologies, an organoleptic evaluation of the samples of baked bread was carried out by the profiling method, from that with milled millet grain added.

which consists in presenting a complex notion of one of the organoleptic properties in the form of a set of simple components which the tasters evaluate by quality, intensity, and order of manifestation [26]. This method is the most informative, since it covers all aspects of the sensory quality of food [25-27]. According to the results of the research, a general profilogram has been constructed describing the bread samples with the addition of milled grains of millet before and after microwave treatment (Fig. 2).

As can be seen from the general profilogram, the samples of bread with the addition of milled millet grain are characterized by a harmonious taste, attractive and pleasant colour, have a pronounced smell and a delicate, porous structure.

Table 4 shows the physical and chemical parameters of bread samples made from wheat flour only and

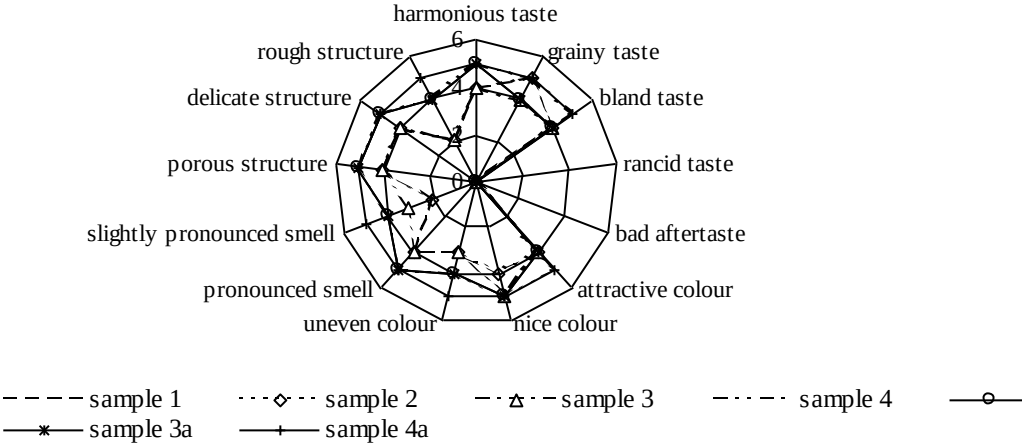

Fig. 2. General profile of the samples of bread with the addition of millet grain before and after microwave treatment

Table 4 – Physico-chemical parameters of wheat flour bread with addition of millet flour

Sample number	Variety of flour	Moisture, %, not more	Acidity, degree, no more	Porosity, %	Mass fraction on SR, % not less	
					sugar	fat
1	Wheat flour (control)	44	4	68	1.6	1.1
2	Wheat flour + 5 % of whole-milled millet	44	4	70	1.62	1.2
3	Wheat flour + 10 % of whole-milled millet	44	4	70	1.63	1.38
4	Wheat flour + 15 % of whole-milled millet	44	4	70	1.65	1.52
2a	Wheat flour + 5 % of whole-milled millet after microwave treatment	44	4	69	1.62	1.2
3a	Wheat flour + 10 % of whole-milled millet after microwave treatment	44	4	68	1.63	1.38
4a	Wheat flour + 15 % of whole-milled millet after microwave treatment	44	4	68	1.65	1.52

The data given in Table 3 show that moisture and acidity do not change with the addition of different amounts of milled millet. However, it should be noted that the addition of 10 and 15% of milled grain of millet after microwave treatment in a small amount decreases the porosity of bread.

The analysis of the data showed that the replacement of 15% of wheat flour with millet flour does not worsen the appearance of the bread, but, quite the opposite, makes the bread look attractive, and taste and smell better than standard wheat flour bread. The characteristics were better with addition of milled millet grain that had undergone microwave treatment. Moreover, millet is advisable as a component when baking bread, because it exceeds wheat by the vitamin and mineral content. Besides, this crop is more resistant to drought and economically advantageous, because it costs almost 2 times less than wheat.

Conclusion

A recipe has been developed for a new kind of bread enriched with whole-milled millet grain. Based on the data obtained, the feasibility of introducing milled millet grain into wheat flour has been proved. It has been shown that adding it to the formulation in proportion 5–15% improves the sensory characteristics of bread, namely, gives it a harmonious taste, attractive colour, pronounced smell, and porous structure.

When 15% of millet after microwave treatment is added to wheat flour, there is a slight decrease in the porosity of the bread. Therefore, the introduction of more than 15% milled millet grain into the formulation is considered inappropriate.

The physical and chemical parameters of bread with the addition of milled millet grain in proportion 5–15% before and after microwave treatment practically do not change. Enriching the bread formula with 5–15% of milled millet grain allows you to get quality bread, highly nutritional and biologically valuable, that can be recommended to all social groups, including children, adolescents, and the elderly.

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