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SANITARY AND TECHNOLOGICAL PROCEDURES AND DETERMINATION OF MICROBIOLOGICAL PARAMETERS IN THE PROCESS OF MAKING YEAST-FREE BREAD

Summary. This work aims to apply sanitary and technological methods to prepare grain for grinding. It focuses on producing whole-ground wheat flour by the disintegration-wave method and making bread from it. The bread is made by mechanically loosening the dough without using baker's yeast.

The research results show that sanitary and technological methods improve grain cleaning and preparation for grinding. Whole wheat flour and bread can be made by mechanical loosening of the dough without baker's yeast, using new technology. Microbiological purity of the flour increased when using traditional grain preparation methods, the disintegration-wave grinding method, and adding concentrated apple juice to yeast-free bread. This approach produces bread with higher nutritional value.

Keywords: yeast-free bread, whole grains, wheat flour, bakery products, dough.

Problem statement. Flour products, especially wheat flour products, currently form the basis of human nutrition and are products of daily consumption among all contingents of the population. The most common type of flour products is bakery products, of which there are several hundred items [1]. In this regard, the quality and nutritional value of bread and bakery products hold paramount importance.

To create bread products with different functional properties, it is necessary to develop fundamentally new technologies and equipment that provide complex processing of grain raw materials based on modern electrophysical methods, which would not only preserve the technological properties of grain and its processed products, but also improve the quality of bakery products, ensuring their microbiological purity.

Recent research analysis. It should be emphasized that, for a healthy diet, bread made from whole-grain or low-extraction flour of diverse cereals is preferred [2].

A method for obtaining bread without the use of baker's yeast based on flour from whole-ground wheat grain has been developed using a fundamentally new technology by mechanically loosening the dough under excess air pressure entering the dough mixing chamber of the whipping unit during kneading. The quality of such bread largely depends on the quality of the grain used, on the surface of which there is a residual amount of heavy metals during the cultivation process, mycotoxins, pesticides, and other pollutants [3]. To obtain yeast-free bread by mechanical method of loosening the dough, it is necessary to carefully carry out theincoming control of the grain and its preliminary preparation for grinding into flour, since in this technology, when obtaining the dough, there is no fermentation processand the resulting yeast metabolic products (organic acids, ethyl alcohol, anhydrides, etc.), which prevent the development of foreign microflora in the product [4].

Formulation of article objectives (statement of the task). The article is aimed at applying sanitary and technological measures in preparing grain for grinding, obtaining flour from whole-ground wheat grain by the disintegration-wave method, and bread based on it by the mechanical method of loosening dough without the use of baker's yeast.

To achieve this goal, the work is planned to be carried out in three stages: at the first stage, to study the quality of grain at separate stages of its preparation forgrinding; at the second stage – to analyze the quality of whole grain flour obtained by the disintegration-wave method with a weak ultra-high-frequency informationinfluence; on the third – to assess the quality of bread based on flour from whole-ground wheat grain, obtained by mechanical method of loosening dough withoutbaker's yeast.

Main part. In order to ensure the quality and safety of flour from whole-ground wheat grain, the quality of the soft wheat grain used in the 3rd class was assessed. In terms of all organoleptic and physicochemical indicators, the grain met the standardized requirements of DSTU 3768:2019.

The dynamics of changes in the content of mycotoxins in the studied wheat grain at certain stages of its preparation for grinding are presented in the Table 1.

Table 1

Change in mycotoxin content in wheat grain

№	Mycotoxin content, μg/kg	Grain sample number				
		1	2	3	4	5
1	Aflatoxin B1	4.3	3.3	2.8	1.3	Absent
2	T-2 toxin	91.4	74.3	Absent	Absent	Absent
3	Fumonisin B1	768	631	151	22	Absent

In the initial sample of wheat grain No. 1, the content of mycotoxins did not exceed the values of the maximum permissible concentrations specified in therequirements of the technical regulation of grain composition No. 835/9434 as amended by the Order of the Ministry of Agrarian Policy No. 442 of 16.11.2004. T-2 toxin – by 18.7 %, fumonisin B1 – by 17.8 %. After passing the grains through the first wholemeal grain mill, where their surface is dry cleaned from dust, dirt, sand, tornfruit shells, foreign impurities (light, mineral, fero-impurities), as well as after partial peeling, separation of shells and damaged grain, in sample No. 3 the content ofaflatoxin decreased by another 15.2 %, fumonisin B1 – by 76.1 %, the content of T-2 toxin was not detected at all. After two more processing of grain on the second and third wholemeal grain mills with simultaneous cleaning of its surface with the help of brush devices, the content of aflatoxin B1 in sample No. 4 decreased by another 53.6 %, fumonisin B1 by 85.4 %, and in sample No. 5, the content of mycotoxins was not detected. Deoxynivalenol, ochratoxin, and zearalenone were not detected in the test samples.

The initial content of the pesticide hexachlorane in the grain was 0.22 mg/kg. This is permissible according to the technical regulations. During preparatory operations, the concentration of the pesticide in the grain significantly decreased to 0.18 mg/kg, approximately a 20 % reduction. After grinding the grain into flour using the disintegration-wave transformation method, only trace amounts of the studied pesticide were detected. A significant reduction in pesticide residues in grain can be explained, among other things, by the effect of a physical method on the product, particularly heating [5].

It has been proved that thorough cleaning of grain, repeated passage of it through wholemeal grain mills and grinding it by the method of disintegration-wavetransformation with the energy of an ultra-high frequency electromagnetic field provide effective disinfection of grain from various pollutants, which allows, among other things, to reduce the microbiological content of whole-ground flour and ensure the safety of bread obtained by mechanical method of loosening dough.

The results of the analysis of quality indicators of two batches of flour from whole-ground wheat grain, obtained by different methods and an excellent degree of grinding [6], are presented in the Table 2.

Table 2

Main quality indicators of whole-ground wheat flour

№	Quality Score	Characteristics of flour from whole ground wheat grain (norm for GSTU 46004-99)	Whole-ground wheat flour	
			Batch I (obtained on the D-150 disintegrator)	Batch II (obtained on a roller mill)
		Organoleptic indicators		
1	Color	White with a grayish tint		
2	Taste	Typical for this type of flour, without foreign flavors, not sour, not bitter		
3	Aroma	Typical for this type of flour, without foreign odors, not musty, not moldy		
4	Presence of mineral impurities	When chewing the flour, there should be no crunchiness	No crunching is felt	
5	Pest infestation	Not allowed	Not detected	
		Physico-chemical indicators		
6	Mass fraction of moisture, %	No more than 15	12.2	13.5
7	Mass fraction of ash in terms of dry matter, %	Not less than 0.07% below the ash content of the grain before cleaning, but not more than 2%	1.6	1.5
8	Mass fraction of raw gluten, %	Not less than 20	24	22
9	Compressive deformation of raw gluten, conventional units of the GDI (Gluten Deformation Index) device	–	58.3	62.1
10	Raw gluten quality, conventional units of the GDI (Gluten Deformation Index) device	Not lower than group II	I	I
11	Grinding fineness, %:	Not more than 2	Dispersion of flour particles, μm/%	
	residue on a wire mesh sieve according to RD (regulatory documentation)	Sieve № 045	0–25/7.5	0–60/15
	passage through a sieve according to RD (regulatory documentation)	At least 50 of silk fabric № 38	25–30/85	60–90/80
		or polyamide fabric № 41/43 PA	30–100/7.5	90–100/5
12	Falling number (FN), s	Not less than 160	294	285
13	Titrated acidity, deg.	–	3.7	3.4
14	Metal-magnetic impuritires, mg per 1 kg of flour; the size of the surrounding particles in the largest linear dimension 0.3 mm and (or) mass no more than 0.4 mg	Not more than 3	1.7	1.8

Whole-grain flour obtained by grinding grain on a disintegrator has a lower moisture content – 12.2 %, since with finer grinding there is stronger heating of the product and partial removal of capillary-bound moisture, and a higher content of raw gluten – 24 % (on dry matter). The total proportion of free amino acids in the protein increases on average by 1,5–2 % (on dry matter). During fine grinding, two continuous processes occur: mechanical deformation and endogenous heating of the product, while the crystal lattice of starch grains is destroyed and the so-called free starch is released from them, which contains a small part of trapped and adsorption-bound proteins, and the more intense the impact of grinding mechanisms on the grain, the more deformed starch with a destroyed crystal lattice is formed. In this case, when grinding soft wheat, up to 45 % of free starch is formed in the flour, with a protein content of about 2.7 % [7]. Due to the increase in the dispersion and specific surface area of the flour particles obtained in the disintegrator, the proportion of free water-soluble proteins-albumins increases by 7.5 mg, globulins by 15.3 mg (per 100 g of product), which is on average 1.4 and 4.9 % higher, respectively, than in flour ground by a roller method. Water-soluble proteins, as surfactants, are primarily responsible for the formation of a foam structure in whipped dough. During intensive mixing of flour and water, the flour particles are first wetted with water; the water molecules are then hydrated by the hydrophilic surface, the flour particles swell, and the water-soluble substances, including water-soluble proteins, are dissolved in the solution. Flour from whole-grain wheat contains about 2 g/100 g of water-soluble proteins. An increase in the amount of even a small proportion of water-soluble proteins contributes to the acceleration of the formation of foam films of air bubbles and better saturation of the dough with air. During highly intensive mixing of the dough, amino acids with polar and non-polar, positively and negatively charged side chains in both gluten and water-soluble protein fractions, as well as an increased amount of gelatinized starch during baking, participate in the formation of the bread crumb structure with increased humidity [8]. The results of assessing moisture binding in bread by the thermogravimetric method showed an increase in the proportion of monomolecularly bound moisture by 7–9 %, which reduces the activity of water in bread and slows the staling process and the development of microorganisms during storage.

The organoleptic and physicochemical indicators of bread obtained by mechanical dough loosening without baking yeast, based on flour from whole-grain wheat, meet the requirements of DSTU 7517:2014 and are presented in Table 3.

Table 3

Organoleptic and physicochemical indicators of yeast-free bread

№	Indicator	Indicator value
		Organoleptic:
1	Surface	Rough, without large cracks or tears
2	Color	Golden yellow
3	Taste and aroma	Corresponds to bread made from whole grain flour, without extraneous taste and smell
4	Condition of the crumb	Baked, not moist to the touch, without lumps or traces of unkneaded dough
		Physico-chemical:
5	Crumb moisture, %	51.7
6	Porosity, %	76.0
7	Acidity, deg.	3.1

The results of determining and calculating the nutritional and energy value of bread without the use of baker's yeast based on flour from whole-grain wheat are presented in Table 4.

Table 4

Nutritional and energy value of yeast-free bread and the degree of satisfaction of the body's daily need for essential nutrients

№	Nutrient	Average daily needs of the human body [9]	Contents per 1 serving (100g of bread)	Satisfaction of daily body needs, %
1	2	3	4	5
1	Protein, g	75	8.7	11.6
2	Fat, g	83	1.1	1.3
3	Digestible carbohydrates, g	365	36.3	9.9
4	Fiber, g	30	6.26	20.9
5	Organic acids, g	2	3,3	165.0

Continuation of Table 4

1	2	3	4	5
Minerals, mg:				
6	Potassium	3500	198.7	5.7
7	Calcium	1000	31.7	3.2
8	Magnesium	400	60.3	15.1
9	Phosphorus	1000	310.5	31.1
10	Iron	14	3.31	23.6
Vitamins, mg:				
11	B1	1.5	0.31	20.7
12	B2	1.8	0.11	4.3
13	PP	20	4,9	24,5
Energy value, kcal (kJ)		2500 (10 467)	169 (708)	6.8

Compared to traditional wheat-flour bread, the developed bread has higher nutritional value and lower calorie content. It contains more proteins – 1.5 times, carbohydrates – 1.2 times, as well as calcium, potassium, magnesium, and phosphorus – 3.2, 2, 1.3, 1.2 times, respectively. The resulting product contains a significant amount of fiber and vitamins B1 and PP, with degrees of satisfaction of 20.9, 20.7, and 24.5 %, respectively.

The biological value of a protein according to the amino acid scale method is determined by the composition of essential (not synthesized in the body) amino acids. The chemical score of the tested protein is the smallest ratio obtained for the content of any of the essential amino acids in the tested protein to its content in the reference protein. To assess the biological value of the protein of yeast-free bread, its amino acid score was calculated relative to the amino acid score of the reference protein [9]. The biological value of the protein of yeast-free bread is limited by the lysine content and is 52.9 %. The content of essential amino acids and some indicators of the biological value of the protein of yeast-free bread are presented in Table 5.

Table 5

Amino acid profile of yeast-free bread protein based on whole-wheat flour

№	Essential amino acid	FAO/WHO standard, g/100g of protein	Acid content, g/100g of product protein	Amino acid content, %
1	Lysine	4.5	2.38	52.9*
2	Leucine	5.9	5.87	99.5
3	Isoleucine	3.0	3.08	102.7
4	Valine	3.9	3.62	92.8
5	Methionine + cystine	2.2	1.26	57.3
6	Threonine	2.3	2.52	109.6
7	Tryptophan	0.6	1.05	175.0
8	Phenylalanine + tyrosine	3.8	4.54	119.5

Note * – limiting amino acid.

The excess amino acids in the protein can be used to meet the body's energy needs. The average excess of the amino acid score for essential amino acids relative to the limiting amino acid is characterized by KVAS (%), which shows the excess of essential amino acids used for plastic needs; in this case, the value is 48.2 %. The potential (theoretical) biological value of the protein of yeast-free bread is 51.8 %. To improve the taste characteristics, increase the nutritional value, and enhance the microbiological purity of yeast-free bread, concentrated apple juice was added to the recipe at 3 % of the dough mass [10]. The obtained indicators of microbiological contamination of the resulting bread with concentrated apple juice, packaged in a transparent polypropylene film "BIAXPLEN", after 7 days of storage, are presented in the Table. 6.

Table 6

Microbiological indicators of yeast-free bread

№	Indicator	Wholemeal wheat bread (control)	Bread made from whole-grain wheat flour obtained using the disintegration-wave method
1	Overall bacterial population, CFU/g	4.6 × 102	3.1 × 102
2	Mold, CFU/g	19	13
3	Yeast, CFU/g	Less than 10	Less than 10
4	Coliform bacteria (coliforms)	Absent	Absent

The results show that bread made with whole-grain wheat flour has a seeding rate 32.6 % lower than bread made with wheat flour (control). This proves that careful processing of grain in the electromagnetic field of a disintegrator, as well as the use of concentrated apple juice in the bread recipe, which contains a significant amount of malic, citric and tartaric organic acids, which contribute to the suppression of the growth of microflora and have an inhibitory effect on it, allows you to increase the microbiological purity of the product and extend its shelf life [8]. Studies in yeast-free bread samples with mold showed that mold appeared on the fifth day in the control, and on the seventh day in the developed bread. Coliforms were absent in both samples, and potato disease during storage was not detected in any sample.

Conclusions. The results of experimental studies illustrate the effectiveness of implementing all sanitary and technological methods for cleaning and preparing grain for grinding, obtaining flour from whole wheat grain, and producing bread based on it by mechanical dough loosening without the use of baker's yeast, using a new technology. Increasing the microbiological purity of flour from whole wheat grain became possible using traditional methods of preparing grain for grinding, the disintegration-wave method of grinding grain into flour, and adding concentrated apple juice to the recipe for yeast-free bread, enabling the production of a product of increased nutritional value.

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САНІТАРНО-ТЕХНОЛОГІЧНІ ПРОЦЕДУРИ ТА ВИЗНАЧЕННЯ МІКРОБІОЛОГІЧНИХ ПОКАЗНИКІВ У ПРОЦЕСІ ВИГОТОВЛЕННЯ БЕЗДРІЖДЖОВОГО ХЛІБУ

Анотація

Метою даної роботи є впровадження санітарно-технологічних процедур на етапах підготовки зерна до подрібнення, виготовлення борошна з неушкодженого зерна пшениці за допомогою дезінтеграційно-хвильового методу, а також виробництва на його основі хлібобулочних виробів шляхом механічного розпушування тіста без додавання пекарських дріжджів.

Для проведення дослідження було використано м'яке зерно пшениці 3-го класу (згідно ДСТУ 3768:2019) та борошно з цільнозмеленого зерна пшениці (згідно ГСТУ 46004-99). Рівень мікотоксинів, таких як афлатоксин В1, Т-2 токсин, фумонізин В1, охратоксин та зеараленон, визначався імуноферментним аналізом. Вміст гексахлору в зерні виявлявся за допомогою газової хроматографії. Очищене зерно подрібнювали методом дезінтеграційно-хвильового впливу з мінімальною потужністю надвисокочастотного поля (десяті частки мікровата) на довжинах хвиль близько 8 мм, використовуючи стандартну конфігурацію генератора на діоді Ганна. Тісто для хліба, розпушеного механічним способом, готували шляхом змішування та збивання компонентів рецептури на напівпромисловій установці змішувально-збивально-формуючого типу. Процес здійснювався при частоті обертання мішалок 16 с$^{-1}$, температурі 29±1 °С та тиску повітря 0,4 МПа протягом 1,5 хвилин. Випікання сформованих загатовок відбувалося в ротаційній печі RFS-9E при температурі 195±2 °С протягом 36–38 хвилин. Оцінка якості готового хліба проводилася відповідно до стандартів ДСТУ 7517:2014. Мікробіологічну чистоту хліба відстежували протягом 7 днів зберігання, аналізуючи кількість мезофільних аеробних та факультативно-анаеробних мікроорганізмів (МАФАМ), наявність плісняви, дріжджів та бактерій групи кишкової палички (БГКП). Поява плісняви фіксувалася візуально, а розвиток картопляної хвороби хліба контролювався щодня згідно з рекомендованими методиками.

Представлені експериментальні дані демонструють результативність застосування комплексу санітарно-гігієнічних та технологічних заходів на етапах очищення та підготовки зерна до помелу, виробництва борошна з цільнозмеленого зерна та виготовлення на його основі хліба із застосуванням механічного розпушування тіста без дріжджів, згідно з розробленою інноваційною технологією. Покращення мікробіологічних показників борошна з цільнозмеленого зерна досягнуто завдяки стандартним методам підготовки зерна, дезінтеграційно-хвильовому помелу, а також додаванню концентрованого яблучного соку до рецептури, що сприяло підвищенню харчової цінності кінцевого продукту.

Ключові слова: бездріжджовий хліб, цільнозмелене зерно, пшеничне борошно, хлібобулочні вироби, тісто.