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Development and quality control of craft breads

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ABSTRACT

Craft bakeries that use local raw materials set themselves the task of providing the population with high-quality food products. This problem requires significant efforts in finding local raw materials of high nutritional value available for mass consumption and their effective use. It is also important to identify the available reserves of food nutrients in regional raw materials to ensure a balanced diet for Ukrainians during periods of psycho-emotional stress under martial law conditions. The results of our research, described and confirmed in a previous article (1964), showed the correct choice of functional additives, such as sprouted wheat grain, pumpkin puree and milk thistle flour in bread dough recipes, which indicates a significant progress in the popularization of healthy nutrition. The tested dough samples had increased nutritional value. This article will continue research on obtaining ready-made craft bread products, such as "Family", "Slavic", and "Peasant", which are high in biological value and serve a functional purpose, meeting the modern requirements of healthy nutrition. Our further scientific research aims to substantiate the technological modes of formation and baking of the aforementioned types of bread. Our research and work on craft bread using local ingredients is important to provide the population with high-quality food. We have already researched the use of functional additives such as sprouted wheat grain, pumpkin puree and milk thistle flour to increase the nutritional value of bread dough. Thesesupplements are important for popularizing healthy nutrition among Ukrainians, especially in conditions of psycho-emotional stress and martial law. In the article, we will take concrete steps to further improve the technology of craft breads and expand the assortment of craft breads.

Keywords: craft bread, pumpkin puree, milk thistle, dietary supplements

INTRODUCTION

Today, consumers want natural products that are free from food additives, have a long shelf life, and are free from artificially synthesized dyes and flavors. Traditional factory breads are being replaced by craft breads, which are produced in small quantities and of high quality. Bread, as a flour product, is a valuable commodity for humanity. There are few values in the world that do not lose their meaning, so the famous phrase "We are what we eat" has remained relevant for many years. Humanity began to understand that health is a value for which there are no measurement units and no alternative. Recently, more and more people have begun to realize that they are responsible for their own health and lives, which is why consuming non-traditional craft products has become relevant. Antoine Auguste Permentier wrote beautiful words about them: "Bread and bakery products are a generous gift of nature, such food that cannot be replaced by anything else. When we get sick, we lose our appetite last, and as soon as it returns, it serves as a sign of recovery. Flour products can be consumed at any time of the day, at any age, in any mood; they are the main cause of both good and bad digestion. They are so necessary for people that, having just been born into the world, we can no longer do without them, and we will not get bored with them until the time of our death **[1]**. Bread is the main food product. In terms of daily consumption, the norm is 500 g per

capita. In many Ukrainian settlements on the territory of modern Ukraine, there were special huts adapted for baking bread. In these ancient bakeries, bread was made by respected master bakers. Additionally, housewives also baked bread for their own use. In addition to rye bread, our ancestors also baked many products from wheat flour, ranging from monastic prosphora to glorious cows and paskas **[2]**.

The bread market has several distinct features. The main indicators and requirements for its formation and functioning: bread is designed to meet the vital needs of the Ukrainian consumer and belongs to such perishable products, therefore they are not subject to long-term storage; the volumes of supply and demand for bakery products in all regions are traditionally large, and the range of goods presented on the market is quite wide; the volume of demand for bakery products may be lower than the needs of consumers, since, taking into account national traditions, as well as due to low incomes and the underdevelopment of the transport and sales infrastructure, the population partially supports itself at the expense of home baking; the national peculiarity of the consumption of bakery products is related to giving preference to "craft breads"; as socially significant for the country, where the share of the poor population is still significant, the market of bakery products is subject to state regulation, and given the regional features of market formation and the economic situation on it, the methods of state regulation may be different **[1]**.

The main problems of the development of the bakery products market at the current stage are the monopolization of the market by individual producers in most regions of the country; a decrease in the volume of industrial production of bakery products and an increase in the specific weight of homemade baked goods in the structure of average per capita consumption; reducing the range and quality of bakery products; complications of their delivery to villages remote from regional or district centers, in our case, the town Kozhuhiv, where the "Sonto Frans" kafta bakery is located.

Therefore, the present day sets an essential task for the further development of the bread market to meet the needs of consumers in high-quality craft bread **[2]**. The problem raised by us of the use of functional additives, such as sprouted wheat grain, pumpkin puree and thistle flour to give new properties to bread is currently relevant and requires new research and their implementation at the craft level.

Scientific Hypothesis

The use of local raw materials in the process of craft bread production and justification of technological regimes can have a positive effect on the quality of bread, ensuring its unique taste, texture and useful properties that meet modern consumer requirements. When baking new craft bread, we will get a fragrant, fresh and tasty product that can be used to create a variety of dishes. Kraft bread typically features a crispy crust and soft interior, making it ideal for sandwiches, toast, or simply enjoying it with butter. Additionally, baking bread is a creative process that involves experimenting with different ingredients and recipes to create a unique taste experience, prioritizing both the quality and safety of the bread.

MATERIAL AND METHODOLOGY

Samples

Samples description: Tests were conducted on samples of baked wheat bread with hop sourdough containing sprouted wheat grains and spotted milk thistle (sample 1), wheat bread with hop leaven with sprouted wheat grains and kvass concentrate (sample 2), and wheat bread with hop leaven with sprouted wheat grains and pumpkin puree (sample 3) were conducted.

Samples collection: Bread samples were collected and temporarily stored at 20°C.

Samples preparation: For the study, a 27 ± 0.5 cm^3 piece of bread was taken from each sample.

Number of samples analysed: 3 samples.

Chemicals

All reagents (water, malt extract) were of USP purity and labelled LC/MS.

Animals, Plants and Biological Materials.

This study used local raw materials from the Podillia region of Ukraine to produce craft bread.

Animals, Plants and Biological Materials

This study used local raw materials from the Podillia region of Ukraine to produce craft bread: wheat flour and rye flour (*Kviešu milti*), hop sourdough (*Apsēsts raugs*), wheat grain (*Kviešu graudi*), pumpkin *(Kirbis*), sunflower oil (*Saulespuķu eļļa*), milk thistle (*Silybum marianum*), fermented wort concentrate (*kvasu misas koncentrāts*).

Animal raw materials were not used in this study.

Instruments

In the process of research, electric cabinet drying laboratory SNOL 7/400, MA 50.R weight moisture analyzer was used; laboratory scales TVE 3-0.05; hygrometer psychrometric VYT-2; 2-burner induction stove

"ESPERANZA EKH008 St. Maria"; "Greentest" nitratometer; device for determining the humidity of food raw materials and products "Quartz" (Chyzhova's device); refractometer RPL-3; Zhuravlev's device; PH-262 pH-meter; digital electronic thermometer with probe TP-101; laboratory tripod Bunsen SHL; stove converted from using fuel oil for firewood (Figure 1).

Figure 1 Stove converted from using fuel oil for firewood.

Laboratory Methods

The organoleptic evaluation of bread was conducted in the laboratory of food technology, chemical and microbiological research at VTEI DTEU, certified by the quality management system (certificate No. UA.80050.063 QMS-21, recertified as of June 21, 2021). Organoleptic quality indicators are determined according to DSTU 7044:2009 "Bakery products. Acceptance rules, methods of sampling, methods of determining organoleptic indicators and weight of products." According to the physical and chemical indicators in the bread, the moisture content of the crumb, acidity, and porosity were determined, but only after 3 hours. after leaving the oven and not later than 48 hours [DSTU 7045: 2009].

The method of determining the mass fraction of moisture is described in the article **[8]**. Active acidity was determined using a pH meter (PH-262, Figure 2).

A piece 78 cm wide is cut out from the middle of the bread, and at a distance of 1 cm from the crusts, notches are made with the cylinder of the device. The sharp edge of the cylinder is pre-greased with vegetable oil and inserted into the pulp of the piece in a circular motion. To determine the porosity of wheat bread, 3 cylindrical notches are made. The cylinder filled with pulp is placed on the tray in such a way that its rim fits tightly into the slot on the tray. The pulp is pushed out of the cylinder with a wooden sleeve by 1 cm and cut with a sharp knife. The pulp that remains in the cylinder is pushed out with a wooden sleeve to the wall of the tray and is also cut off at the edge of the cylinder. The volume of each recess V (cm3) is calculated according to the formula (1):

$$V=(3.14\times d^2\times H)/4 \qquad (1)$$

Where:
d - is the inner diameter of the cylinder, cm;
H - is the length of the bread dough cylinder, cm.

The prepared recesses are weighed together with an accuracy of 0.01 g.

Porosity X (%) is calculated by the formula (2):

$$X= ((V-m/q) / V)\times 100 \qquad (2)$$

Where:
V is the total volume of bread recesses, cm3;
t – mass of notches, g;
q - is the density of the non-porous pulp mass.

The parameters of amino acid analysis (amino acid rate, %) in the developed bread were determined at the Institute of Biochemistry named after O.V. Paladin of the National Academy of Sciences of Ukraine.

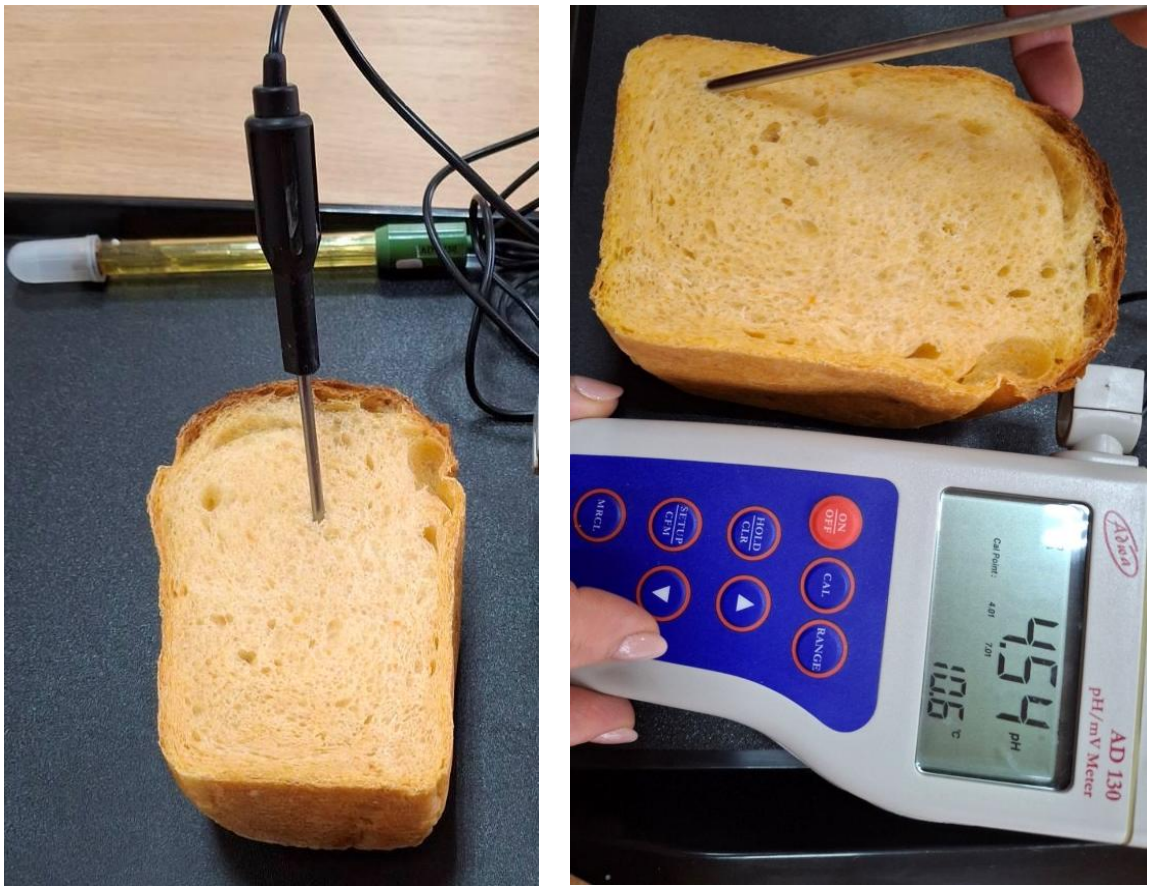


Figure 2 Determination of active acidity with pH meter PH-262.

Measurement of porosity in finished products is determined according to DSTU 7045:2009 "Bakery products. Methods of determining physicochemical parameters". Porosity was measured with Zhuravlev's device (Figure 3).

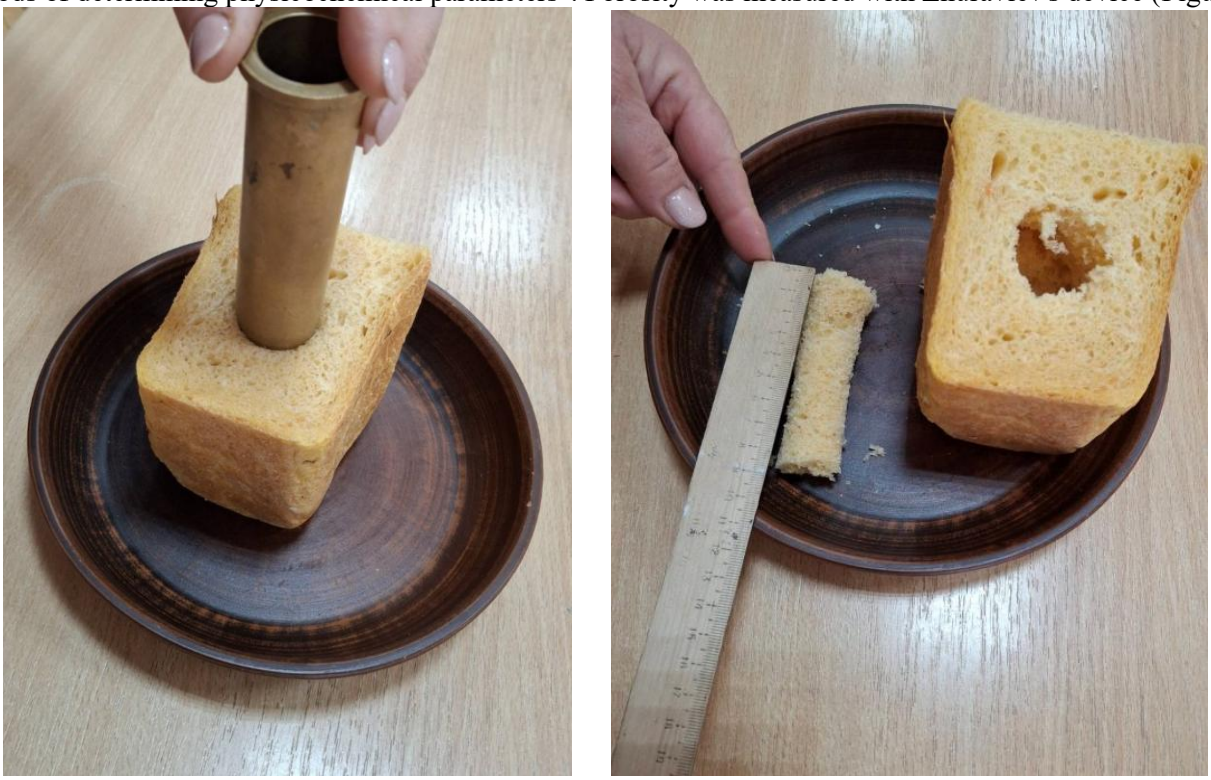


Figure 3 Measurement porosity with Zhuravlev's device.

Description of the Experiment

Study flow:

Experimental baking of developed bread samples was carried out at the craft bakery "Domashnya Vypichka Sonto France" in the Vinnytsia region, Ukraine.

The stage of work started with the development of recipes and technology of craft bread. Table 1 describes the recipe composition of the developed craft breads. Rye-wheat bread, made according to traditional technology, served as a control.

Table 1 Recipe composition of developed craft bakery products.

The name of the raw material	Rye-wheat bread on hop sourdough with sprouted wheat grain, fermented wort concentrate and milk thistle "Slovyansky"				Rye-wheat bread on hop sourdough with sprouted wheat grain "Family"		Rye-wheat bread on hop sourdough with sprouted wheat grain and pumpkin puree "Selyansky"	
	Control		Experiment 1		Experiment 2		Experiment 3	
	Gross, Mr	Netto, Mr	Gross, Mr	Netto, Mr	Gross, Mr	Netto, Mr	Gross, Mr	Netto, Mr
Rye flour	600	600	369	369	419	419	419	419
Wheat flour	350	350	246	246	246	246	246	246
Sprouted grain of wheat	-	-	285	285	285	285	285	285
Water	235	235	200	200	200	200	100	100
Salt	18	18	18	18	18	18	18	18
Yeast	75	75	-	-	-	-	-	-
Pumpkin puree	-	-	-	-	-	-	100	100
Hop starter			110	110	110	110	110	110
Sunflower oil	2	2	2	2	2	2	2	2
Fermented wort concentrate	-	-	0.25	0.25	-	-	-	-
Spotted milk thistle	-	-	50	50	-	-	-	-
All raw materials for dough	-	1280	-	1280.3	-	1280	-	1280
Sunflower oil for greasing forms	2	2	2	2	2	2	2	2
Output of the finished product	-	1000	-	1000	-	1000	-	1000

The production technology of rye-wheat bread on hop sourdough with sprouted wheat grain and "Peasant" pumpkin puree consists of the following stages:

Preparation of hop starter. To prepare hop starter, dry hop cones are poured with water at t=70-80℃ in a ratio of 1:10 and boiled for τ=3.6 · 10^3s until the liquid volume is reduced by two times. The decoction is filtered and cooled to t=400 °C. Add sugar - 100% and sifted wheat flour in a ratio of 1:5 to the finished broth, stirring constantly. Sourdough should have the consistency of thick sour cream and t=280 °C. Add sugar - 100% and sifted wheat flour in a ratio of 1:5 to the finished broth, stirring constantly. Sourdough should have the consistency of thick sour cream and t=280 °C. The resulting sourdough is left in a warm place (t=35-400 °C) atτ=8.64 · 10^3s for fermentation. During fermentation, the leaven increases in volume by 2-2.5 times, and bubbles appear on the entire surface, bursting **[3]**.

Preparation of germinated wheat grain. Wheat grain is sorted and cleaned of impurities, washed with water t=20ºC, laid out in a layer of 30 mm, soaked in water t=24ºC, τ=43.2×103s, drained and washed with water 2 times,

germinated at t=24°C τ= 43.2×103s to be received sprouts 1.5 mm long. Sprouted wheat grain is ground on an electric grinder.

Preparation of the broth. A mixture of 60% liquid and 40% flour, along with hop leaven, is used to prepare the dough. A composition of hop starter, sifted flour is added to the liquid heated to t=35-400 °C and mixed. Opara should have the consistency of thick sour cream and t=25-280°C. The surface of the dough is sprinkled with a thin layer of flour, the dish is covered with a lid and placed in a warm place (t=30-35 °C) at τ=3.6×10s for fermentation. During fermentation, the foam volume increases by 2-2.5 times, bubbles appear on the entire surface, and then burst. The readiness of the foam is determined by external signs: fermentation begins to slow down, fewer bubbles appear on the surface, and the foam settles **[4]**.

Add the rest of the liquid with dissolved salt, sprouted wheat grain, and pumpkin puree to the finished dough, mix, add the rest of the flour, and knead the dough τ=600-900s. Before the end of mixing, add vegetable oil and mix. The jar is closed with a lid and left in a warm place for 3.9 × 10^3 s to 4.9 × 10^3 s for fermentation. During fermentation, the dough is turned over 1-2 times.

Formation of semi-finished products. The finished dough is developed, shaped, laid out in ½ the volume of the mold, greased with oil, and placed in a warm place, t=30-350C °C, with relative humidity 75-85%, for τ=4.9 x 10^3 s for proofing.

Baking products. Bakery products are baked at t=200-220ºC, during τ=30000s. and ool.

The production technology of rye-wheat bread using hop leaven, with sprouted wheat grain, fermented wort concentrate, and the spotted thistle "Slovyansky", differs from the control in that it incorporates fermented wort concentrate and sprouted wheat grain into the dough.

The production technology of rye-wheat bread on hop sourdough with sprouted wheat grain "Family" differs from the control in that it includes the addition of hop sourdough and sprouted wheat grain.

The technological scheme for the preparation of "Selyansky" rye-wheat bread is presented in Figure 4.

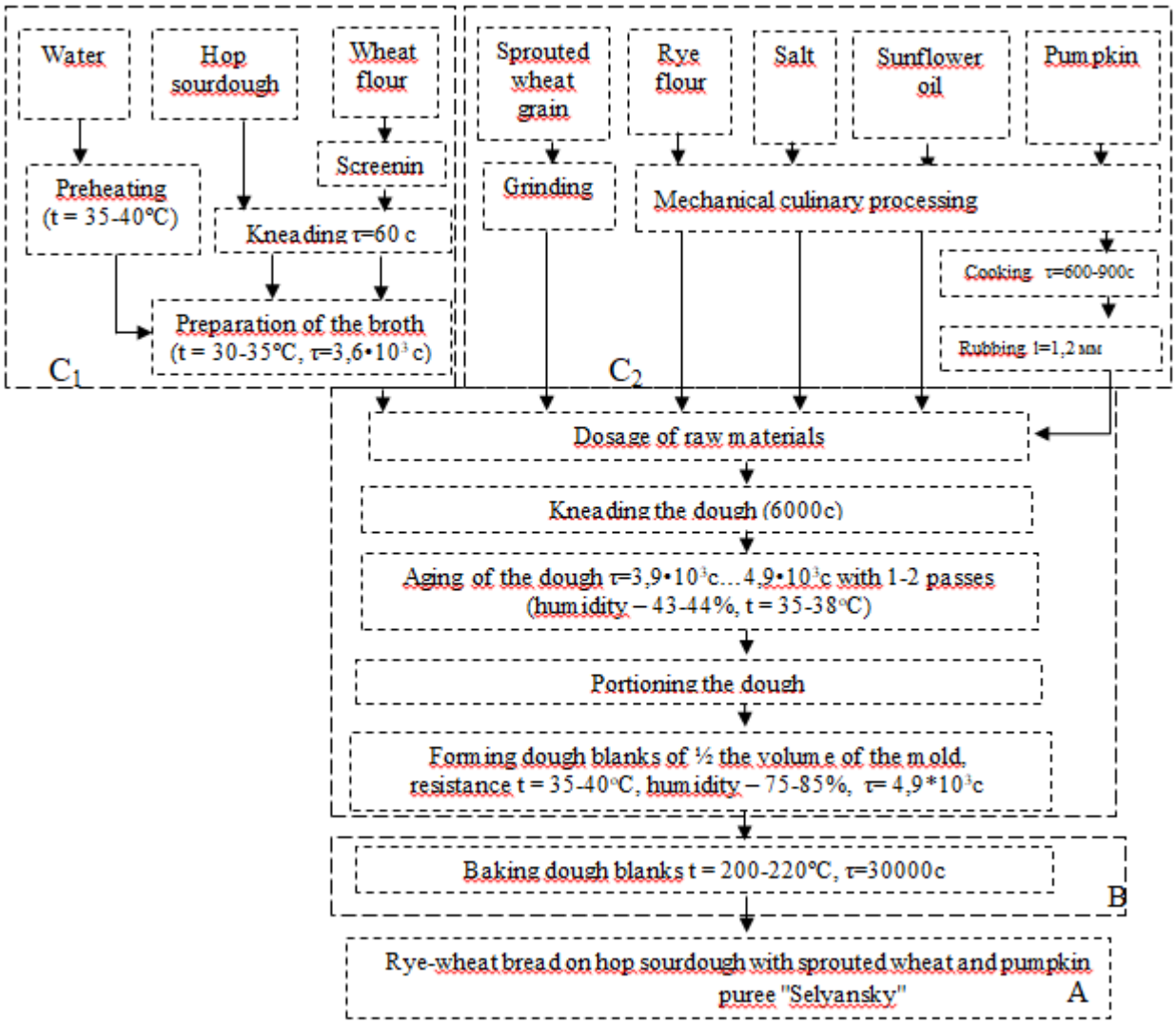


Figure 4 Technological scheme for the preparation of "Selyansky" rye-wheat bread, A, B, C1, C2 - subsystems.

The improved technology for making craft bread with vegetable raw materials and dietary supplements can be recommended both for large and medium-sized enterprises, as well as for mini-bakeries and restaurants.

Quality Assurance

Number of samples analyzed: 3 samples.

Number of repeated analyses: All biochemical procedures were conducted in 15 repetitions.

Number of experiment replication: 2 times.

Calibration: The calibration of the instruments used in the study and the presentation of the results were carried out at the Metrology Center of the State Enterprise "VINNYTSIASTANDARTMETROLOGIYA" following DSTU EN ISO/IEC 17025:2019 (EN ISO/IEC 17025:2017, IDT; ISO/IEC 17025:2017, IDT in the field of calibration for various types of measurements.

The metrological center of the state enterprise "VINNYTSIASTANDARTMETROLOGIYA" has confirmed competence in accordance with the requirements (accreditation certificate No. 40017 dated July 15, 2023).

Laboratory accreditation: Laboratory studies were conducted in the laboratory of food technologies, chemical and microbiological research of the VTEI of the DTEU, certified according to the quality management system (certificate No. UA.80050.063 QMS-21, recertified on 06/21/2021).

Data Access

The data that support the findings of this study are openly available in The Repository of VTEI at https://sel.vtei.edu.ua/repository/g.php?fname=30240.pdf

Statistical Analysis

Calculations were used on a computer. Experimental data were primarily processed using application programs for statistical analysis according to specific criteria. The research was carried out in five repetitions. An application program for experiment planning and optimization was used to optimize the package of technological process parameters.

The data were analyzed statistically using Microsoft Excel and Statistica 15. All experiments were performed in duplicate, and the results are presented as the results of these repeated determinations with standard deviations. The students' t-test was used to statistically analyze the results. Data are presented as mean ± standard error of the mean (SEM). The minimum permissible difference for probes from the same sample was 5%. Test compositions with a larger difference were not considered.

RESULTS AND DISCUSSION

In the research process, the consumer value of the developed craft breads made with vegetable raw materials and dietary supplements was evaluated based on their nutritional and biological value.

Table 2 Nutritional and energy value of bakery products per 100 g.

Name products	Indicators			
	Proteins, g	Fats, g	Food fibers, g	Energetic value, kcal
Daily need	75	83	30	2500
Bread rye-wheat (CONTROL)	8.3±0.3	1.4±0.1	7.6±0.1	243.2±1.0
Rye-wheat bread "Family"	11.0±0.1*	3.0±0.1*	7.9±0.1*	241.7±1.0*
The difference between experiments/ CONTROL, %	32.7	112.1	4.8	0.6
Rye-wheat bread "Selyansky"	34.8±0.1*	3.6±0.1*	8.1±0.1*	250.5±1.0*
The difference between experiments/ CONTROL, %	11.2	156.0	6.3	3.0
Rye-wheat bread "Slovyansky"	10.7±0.1*	3.0±0.1*	25.3±0.1*	226.1±0.9*
The difference between experiments/ CONTROL, %	29.4	113.5	234.4	7.0

Note. * – The difference with the control is significant, $p<0.05$.

The nutritional value reflects the ability of the product to provide the physiological needs of the human body in energy and nutrients, and the biological value is characterized by balance in terms of irreplaceable nutritional factors – amino acid, vitamin composition, etc. **[5]**.

The nutritional and biological value of the developed types of bread with dietary supplements was evaluated by their content of proteins, fats, vitamins, and dietary fibers. The amino acid ratio of essential amino acids determined the biological value of bread proteins with dietary supplements. The results of the studies on the chemical composition of the finished products are presented in Table 2.

The determined nutritional (Figure 5) and energy (Figure 6) value of rye-wheat bread on hop sourdough with sprouted wheat grain and dietary supplements indicates an increase in protein content by 11.15-32.77% and fat content by 112.06-156.03%.

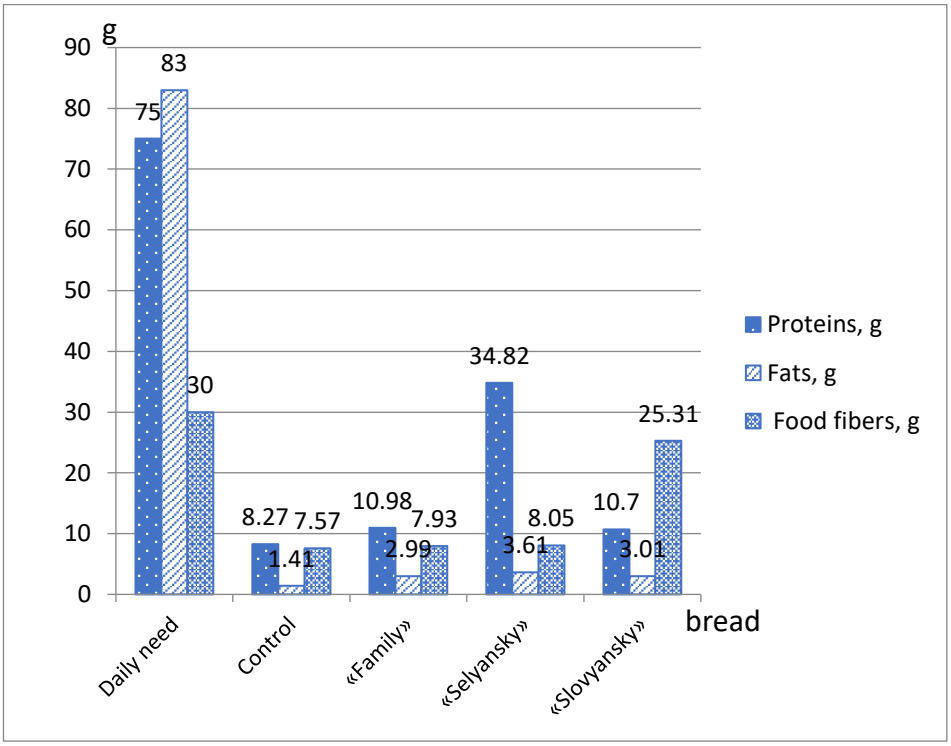


Figure 5 Nutritional value of rye-wheat bread on hop sourdough with sprouted wheat grain and dietary supplements.

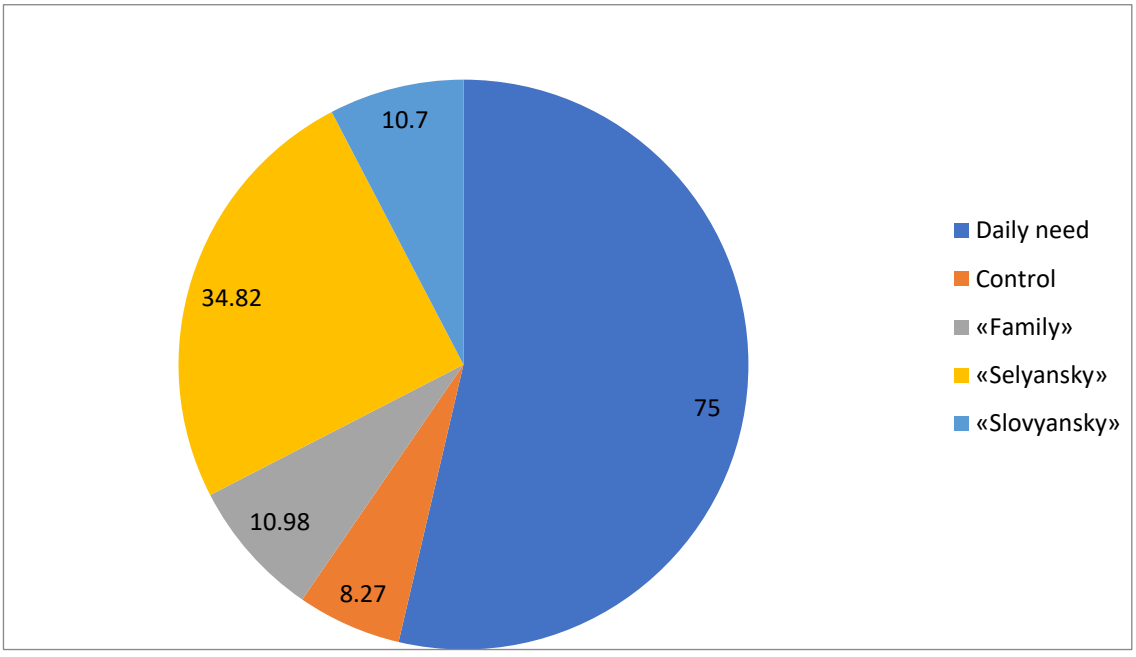


Figure 6 Energy value of rye-wheat bread on hop sourdough with sprouted wheat grain and dietary supplements.

A positive thing is the growth of dietary fibers 4.76-234.35%, which mechanically clean the walls of the intestines, ensure improved absorption of food nutrients into the blood, absorb excess cholesterol, as well as other metabolic products undesirable for the body, and reduce the energy value of vegetables **[4]**.

It was determined that the use of dietary supplements in the technology of craft yeast-free bread contributed to a decrease in the energy value: Rye-wheat bread "Slovyansky" - 7.02%. In rye-wheat "Selyansky" bread, the energy value increased by 3.02%.

The main quality criteria of the developed craft breads include their biological value, which is largely determined by the amino acid composition, the balance of amino acids, especially essential ones, and the degree of their assimilation by the body **[6]**. The characteristics of the aminoacid composition of the developed craft breads are given in the Table 3.

Table 3 Aminoacid composition of proteins of developed craft breads.

Indicators	Standard	Rye-wheat bread (control)		Rye-wheat bread "Family" (experiment 1)		Rye-wheat bread "Peasant" (experiment 2)		Rye-wheat bread "Slovyansky" (experiment 3)	
	г/100г squirrel	г/100г squirrel	hurry up %	г/100г squirrel	hurry up %	г/100г squirrel	скор, %	г/100г squirrel	hurry up %
Non-essential amino acids									
Valin	5.0	4.5	90.0	5.1	102.0	5.2	105.0	4.7	93.0
Isoleucine	4.0	3.9	98.0	4.2	105.0	4.7	117.0	4.6	116.0
Leucine	7.0	7.6	109.0	7.7	109.0	7.8	111.0	7.7	109.0
Lysine	5.5	2.3	41.0	2.9	53.0	2.5	46.0	2.5	45.0
Methionine + cystine	3.5	3.3	93.0	3.3	95.0	3.4	98.0	3.5	99.0
Threonine	4.0	2.9	73.0	3.1	78.0	3.3	81.0	3.4	85.0
Tryptophan	1.0	1.0	102.0	1.1	105.0	1.1	106.0	1.0	104.0
Phenylalanine+ Tyrosine	6.0	6.3	105.0	6.4	106.0	6.4	107.0	6.4	107.0
Total NAC, g per 100 g of protein	36.0	31.9	89.0	33.7	94.0	34.3	95.0	33.8	94.0
Coefficient of utility of amino acid composition	1.0	0.9		0.9		0.9		0.9	
Essential amino acids									
Histidine	-	0.1	2.4	0.1	2.3	0.1	2.3	0.2	2.4
Arginine	-	0.3	4.7	0.3	4.6	0.3	4.7	0.3	4.7
Aspartic acid	-	0.3	5.2	0.3	5.1	0.3	5.4	0.3	5.2
Serin	-	0.3	4.9	0.3	5.3	0.3	4.9	0.3	4.9
Glutamic acid	-	2.2	36.4	2.2	36.4	2.3	35.9	2.2	36.4
Proline	-	0.5	8.1	0.5	8.5	0.6	8.8	0.5	8.1
Glycine	-	0.2	3.9	0.3	4.1	0.2	3.9	0.2	3.9
Alanine	-	0.2	3.6	0.2	3.6	0.2	3.4	0.2	3.6
Together	-	4.2	69.1	4.2	69.9	4.3	69.2	4.2	69.2

To characterize the amino acid composition, the indicator of essential amino acid content in 100 g of protein was used, compared to the FAO/WHO scale.

Studies of the amino acid composition show that the experimental samples contain the same complex of amino acids as the control: the amount of essential amino acids in the experiments is higher than in the control (33.74, 34.34 and 33.78 g and the control - 31.87, respectively, per 100 g protein), the utilitarian coefficients of the amino acid composition of the experimental and control proteins are lower than unity and are, respectively, 0.87, 0.88, 0.89 and 0.88.

The increased content of essential amino acids in the developed craft breads is explained by the partial proteolysis of the protein in the grain at the stages of soaking and germination **[7]**. A more comprehensive picture of the biological value of protein in bakery products with protein components is provided by the amino acid score, which enables the detection of limited amino acids **[8]**. The characteristics of the amino acid score of the developed craft breads are given in Table 4.

Table 4 Amino acid score of developed craft breads.

Essential amino acids (NAA)	Amino acid rate, %			
	Rye-wheat bread (control)	Rye-wheat bread "Family" (experiment 1)	Rye-wheat bread "Peasant" (experiment 2)	Rye-wheat bread "Slovyansky" (experiment 3)
Valin	90.0	102.0	105.0	93.0
Isoleucine	98.0	105.0	117.0	116.0
Leucine	109	109.0	111.0	109.0
Lysine	41.0	53.0	46.0	45.0
Methionine + cystine	93.0	95.0	98.0	99.0
Threonine	73.0	78.0	81.0	85.0
Tryptophan	102.0	105.0	106.0	104.0
Phenylalanine+ Tyrosine	105.0	106.0	107.0	107.0

The analysis of the obtained data shows that the limiting essential amino acid in the studied products is lysine, the amino acid composition of which is: "Family" rye-wheat bread - 53%, "Selyansky" rye-wheat bread - 46%, "Slovyansky" rye-wheat bread - 45%, respectively, against the control 41%. From this, it follows that all other essential amino acids of bakery products are used by the body by 53%, 46% and 45%, respectively.

In the test samples, compared to the control, indicators increased: rye-wheat bread "Family" - valine - by 12%, lysine - by 21%, threonine - by 6%, isoleucine - by 7%, rye-wheat bread "Selyansky" - valine - by 14%, lysine - by 10%, methionine + cystine - by 5%, threonine - by 10%, tryptophan - by 4%, rye-wheat bread "Slovyansky" - valine - by 3%, lysine - by 9%, threonine - by 14%, tryptophan - by 2%, isoleucine - by 16% , methionine+cystine- by 3%, respectively. As you know, lysine and tryptophan are necessary for the growth and development of young organisms; tryptophan plays an essential role in the synthesis of blood hemoglobin **[9]**.

Analyzing the obtained data, it can be concluded that when using dietary supplements and plant raw materials (germinated wheat grain, hop starter, pumpkin puree, fermented wort concentrate, milk thistle) an increase in the number of essential amino acids is observed, which indicates an increase in the biological value of the developed functional bakery products appointment.

Experimental studies have established that the use of sprouted wheat grain, hop starter, pumpkin puree, milk thistle and fermented wort concentrate in the technology of bakery products contribute to the improvement of their mineral composition **[9]** (Table 5).

Compared to the control, in rye-wheat bread with dietary supplements and vegetable raw materials, the amount of calcium and magnesium macroelements increases significantly by 13.17-32.56% and 151.46-157.68%, respectively. Phosphorus content in bakery products exceeds the control value by 104.43-108.11%, sodium by 0.17-3.51%, potassium by 29.87-41.51%. Of particular note is the increase in iron by 39.83-53.94%, which plays a leading role in hematopoiesis and blocks the absorption of plutonium **[10]**. Iron deficiency occurs in the diet of the majority of the population of Ukraine.

The significantly increased content of minerals in the developed bakery products is explained by the use of dietary supplements in their composition, in particular, sprouted wheat grain, the technology of which involves the use of all parts of the grain, including the shell, rich in macro- and microelements **[9]**.

Thus, the increase in the total amount of minerals in experimental bakery products with a functional purpose allows them to be counted among products with a high content of magnesium, phosphorus, iron, calcium, potassium, taking into account that the degree of ensuring the daily need for these essential substances exceeds 10%.

The determination of the vitamin content in new types of bakery products was carried out in comparison with a control sample to determine the total amount of individual vitamins. Research has established the presence of water-soluble vitamins (thiamine, riboflavin, pantothenic acid, ascorbic acid, pyridoxine, etc.) and fat-soluble vitamins (tocopherol, carotenoids). Experimental studies established an increase in the content of vitamins and vitamin-like compounds in the experimental samples compared to the control (Table 6).

Table 5 Mineral composition of developed craft breads, mg/100g.

Product	Potassium	Calcium	Magnesium	Phosphorus	Sodium	Iron
Daily need		800-1000	300-500	1000-1500	2400	15
Bread rye-wheat (control)	231.1±0.9	32.0±0.1	42.0±0.2	152.5±0.6	583.0±2.3	2.4±0.1
Rye-wheat bread "Family"	309.8±1.2*	36.2±0.1*	106.8±0.4*	311.8±1.3*	584.0±2.3*	3.5±0.1*
The difference between experiments/ control, %	34.1	13.2	154.3	104.4	0.2	44.4
Rye-wheat bread "Selyansky"	327.0±1.3*	42.4±0.2*	108.1±0.4*	317.3±1.3*	603.5±2.4*	3.7±0.1*
The difference between experiments/ control, %	41.5	32.6	157.7	108.1	3.5	53.9
Rye-wheat bread "Slovyansky"	300.0±1.2*	38.9±0.2*	105.5±0.4*	314.0±1.3*	593.6±2.3*	3.4±0.1*
The difference between experiments/ control, %	29.8	21.8	151.5	105.9	1.8	39.8

Note. * – The difference with the control is significant, $p<0.05$.

Table 6 Content of vitamins and vitamin-like compounds in developed craft breads, mg/100.

Product	Thiamine (B1), mg	Riboflavin (B2), mg	Folic acid (B9) mcg	Tocopherol (E), mg	Carotenoids, mg	β-carotene, mg
Daily need	1.5-2.0	1.8	0.4	10.0	1.0	2.0-5.0
Bread rye-wheat (control)	0.3±0.1	0.1±0.1	42.0±0.1	1.8±0.1	0.2±0.1	0.1±0.1
Rye-wheat bread "Family"	0.6±0.1*	0.1±0,1*	54.0±0.3*	2.1±0,1*	0.2±0.1*	-
The difference between experiments/ control, %	111.5	-10.0	28.6	16.7	-5.26	-
Rye-wheat bread "Selyansky"	0.6±0.1*	0.1±0.1*	48.0±0.2*	4.7±0.1*	2.3±0.1*	0.2±0.1*
The difference between experiments/ control, %	115.4	15.0	14.3	161.1	1105.3	700.0
Rye-wheat bread "Slovyansky"	0.5±0.02*	0.1±0.1*	51.0±0.3*	3.2±0.1*	0.3±0.1*	-
The difference between experiments/ control, %	107.7	20.0	21.4	77.8	63.2	-

Note. * – The difference with the control is significant, $p<0.05$.

The increased content of vitamins and vitamin-like compounds (carotenoids, thiamine, and riboflavin) in the experimental samples is attributed to the presence of dietary supplements in their composition, as well as the developed technology, which involves heat treatment of germinated wheat grain and results in the maximum preservation of nutrients.

Analysis of the vitamin composition of rye-wheat bread with the addition of sprouted wheat grain, hop sourdough, pumpkin puree, milk thistle and fermented wort concentrate shows an increased content of vitamins: thiamine by 108-115%, riboflavin by 15-20%, tocopherol by 17-161% and carotenoids by 1105%. The content of β-carotene in rye-wheat "Selyansky" bread increased by 700%, which plays an important role in redox reactions, ensures the formation of glycogen in the liver and muscles, and contributes to the increase of cholesterol in the blood **[11]**.

It found that the provision of daily β-carotene needs through the consumption of 100 g of experimental bakery products exceeds the recommended values by 76.3%. As you know, carotenoids are provitamins and acquire vitamin properties after being transformed into retinol in the body. Insufficient supply of carotenoids negatively affects the human body, reducing physical and mental performance, resistance to colds and infectious diseases, and increasing the impact of harmful environmental conditions **[12]**.

The use of sprouted wheat grain in the composition of bakery products made it possible to provide 16-18% of the daily human need for folic acid, which participates in the transfer of monocarbohydrate groups, the synthesis of amino and nucleic acids, choline, purine and pyrimidine bases as a coenzyme of tetrahydrofolic acid, thus influencing on DNA synthesis and metabolism of amino acids - methionine, serine, tyrosine. Together with vitamin B12, folic acid participates in hematopoietic processes, supplying carbohydrates for protein synthesis in hemoglobin, the blood pigment. In combination with vitamin B6 and B12, it exhibits an antisclerotic effect **[13]**. Insufficient consumption of folic acid causes Down's syndrome, contributes to the development of rectal and colon cancer **[14]**.

In the developed bakery products with a functional purpose, the provision of daily human need for tocopherol is 21-47%. Vitamin E regulates the intensity of free-radical reactions in living cells, prevents the oxidation of unsaturated fatty acids in membrane lipids, affects the biosynthesis of enzymes **[15]**. A deficiency of vitamin E causes impaired reproductive function and diseases of the cardiovascular and nervous systems. As is known, vitamin E is especially active in combination with organic forms of the trace element selenium, which is also a strong antioxidant **[16]**.

Thus, the increase in the total number of vitamins, vitamin-like compounds and mineral substances in experimental bakery products with a functional purpose allows them to be counted among products with a high content of magnesium, phosphorus, iron, calcium, potassium, tocopherols, riboflavin **[17]**, taking into account that the degree of provision of daily the need for these essential substances exceeds 10%.

Summarizing the results of the research, it can be stated that the technologies of bakery products have been developed: rye-wheat bread on hop sourdough with sprouted wheat grain "Family", rye-wheat bread on hop sourdough with sprouted wheat grain with pumpkin puree "Peasant", rye-wheat bread on hop sourdough with sprouted wheat grain with fermented wort concentrate and milk thistle "Slovyansky" meet the scientific principles of creating functional food products, because they ensure maximum preservation and sufficient content of micronutrients in bakery products enriched with them **[18]** and have a higher nutritional value compared to control.

The study of the mineral composition revealed that the developed bakery products contain a higher level of macro- and microelements in a more optimal ratio, which contributes to their better assimilation by the human body. A higher content of tocopherols, carotenoids, and folic acid was experimentally demonstrated, which aligns with the work's goal.

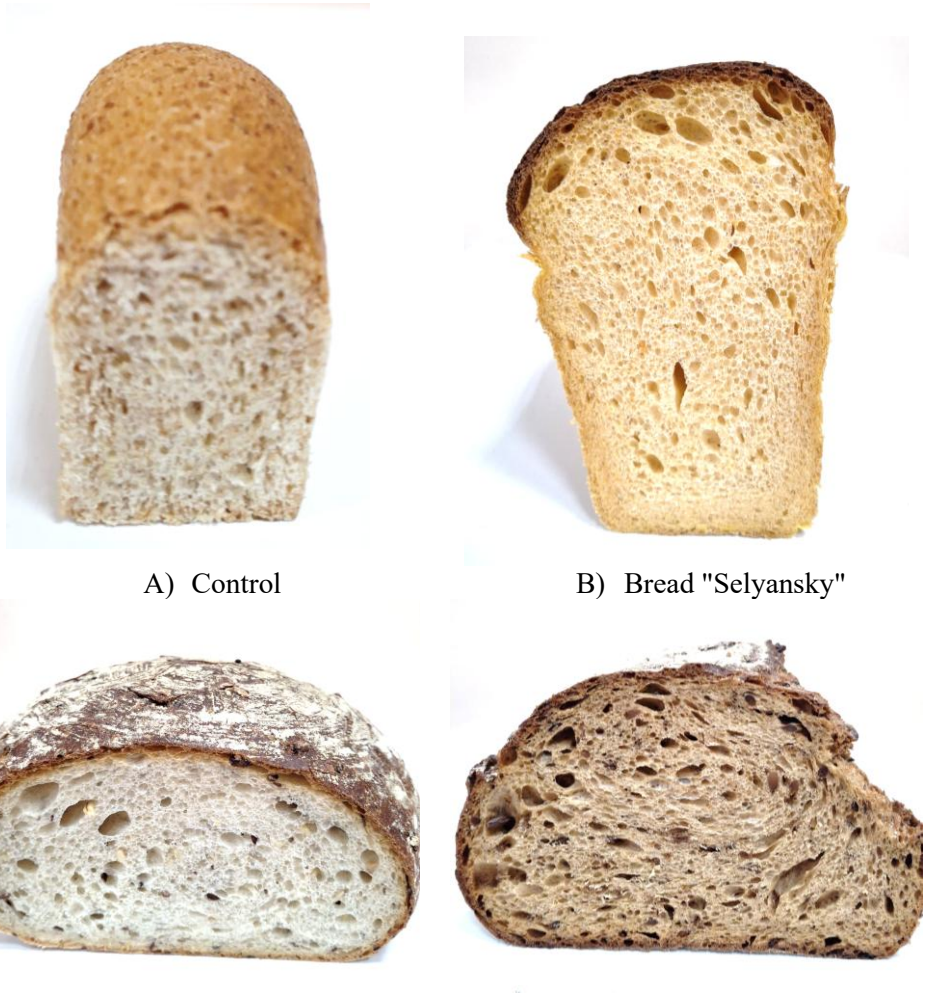
The main properties of bakery products include organoleptic indicators and microbiological safety **[19]**. Quality control of bakery products includes control of organoleptic, physicochemical and microbiological parameters **[20]**.

Organoleptic analysis precedes physico-chemical and bacteriological analysis. When valuating bakery products organoleptically, five interrelated indicators were studied: appearance, color, taste, aroma, and texture **[21]** (Figure 7).

Organoleptic indicators were evaluated using a five-point system, taking into account the weighting factors assigned to each indicator. Taste has the greatest weighting factor, as it forms the main consumer characteristics of products **[22]**.

During collective tastings, the sum of points received by each bakery product was determined and the average arithmetic value was calculated. The overall organoleptic evaluation was determined taking into account the weighting factor of each indicator. The results of organoleptic tests are given in Table. 7.

The results of the research show that the overall organoleptic evaluation of bakery products based on hop sourdough with the addition of sprouted wheat grain, pumpkin puree, milk thistle and fermented wort concentrate **[23]** is higher than the organoleptic evaluation of rye-wheat bread made according to traditional technology (Figure 8).



A) Control B) Bread "Selyansky"

C) Bread "Slovyansky" D) Bread "Family"

Figure 7 Samples of baked breads in section.

Table 7 Organoleptic indicators of the quality of developed craft breads with the use of dietary supplements and vegetable raw materials.

Samples	Quality indicators, points					
	External appearance	Color	Consistence	Scent	Taste	Overall score, points
Weighting factor	0.2	0.1	0.2	0.1	0.3	-
Rye bread wheat (control)	4.8±0.1	4.8 ±0.1	4.7±0.1	4.7±0.1	4.5±0.1	4.7±0.1
Rye-wheat bread "Family"	4.8±0.1*	5.0±0.1*	4.7±0.1*	4.8±0.1*	4.7±0.1*	4.8±0.1*
Rye-wheat bread "Selyansky"	4.9±0.1*	4.9±0,1*	4.9±0.1*	4.9±0.1*	4.8±0.1*	4.8±0.1*
Rye-wheat bread "Slovyansky"	4.8±0.1*	4.8±0.1*	4.8±0.1*	4.5±0.1*	4.5±0.1*	4.7±0.1*

Note. * – The difference with the control is significant, $p<0.05$.

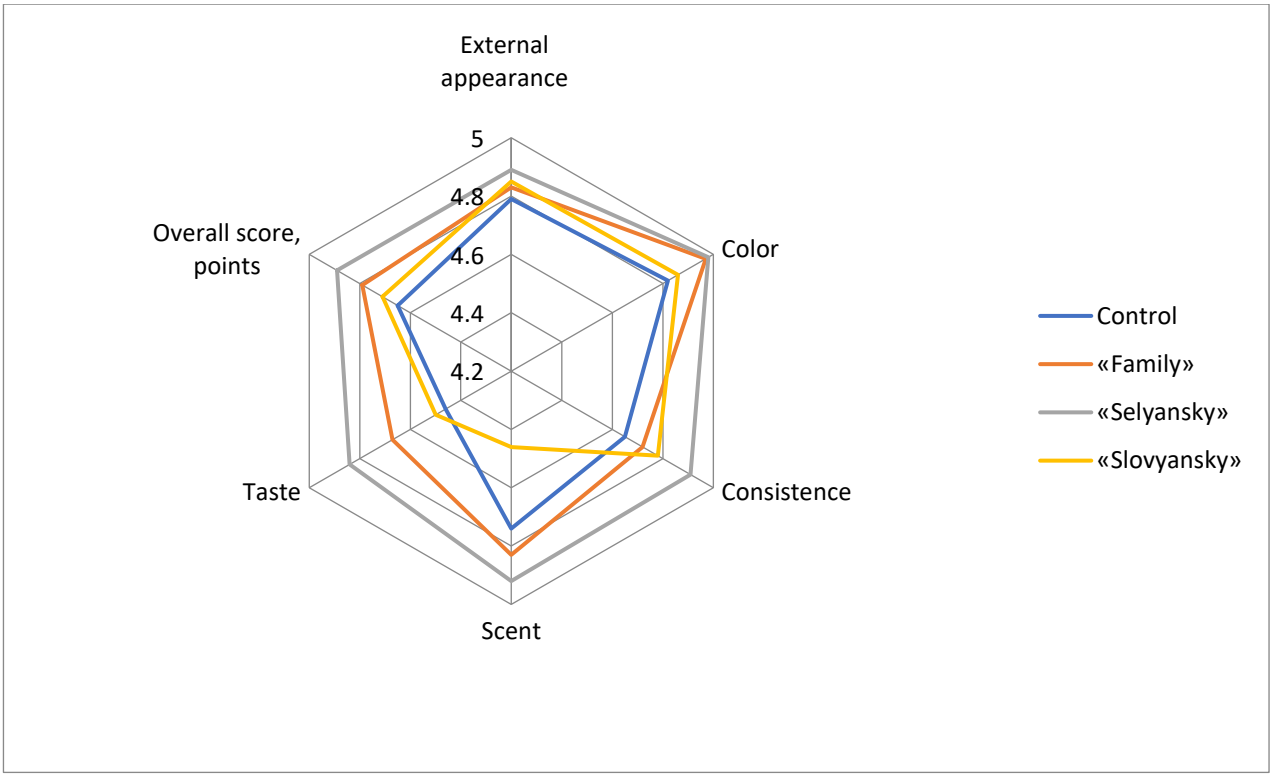


Figure 8 Organoleptic evaluation of the quality of developed craft breads on hop sourdough.

The quality of hop-leavened bread with sprouted wheat grain is characterized by physical and chemical parameters (Table 8).

Table 8 Physico-chemical indicators of bread on hop sourdough with sprouted wheat grain.

Name indicator	Rye bread wheat (control)	Rye-wheat bread "Family"	Rye-wheat bread "Selyansky"	Rye-wheat bread "Slovyansky
Acidity of pulp, degr., not more than	5.0±0.1	4.5±0.1*	4.3±0.1*	5.9±0.1*
Pulp porosity, % not less than	46.0±0.2	59.5±0.2*	53.6±0.2*	55.7±0.2*
Moisture content of pulp, % not more than	41.0±0.2	39.0±0.2*	45.0±0.2*	40.5±0.2*

Note. * – The difference with the control is significant, $p<0.05$.

The most important of these indicators is acidity, because it determines the chemical processes that took place in the bread during its baking, transportation and storage. The fermentation of the dough causes the acidity of the bread. Acids present in bread products have a positive impact on their physical and chemical properties, as well as their taste **[24]**. However, bread with increased acidity is not recommended for people with peptic ulcer disease of the stomach and duodenum, chronic gastritis **[25]**. Such bread causes heartburn, bloating of the intestines and can deepen already existing diseases of the gastrointestinal tract. Eating bread with low acidity negatively affects the health of people with gastritis **[26]**.

Another important factor on which the digestibility of bread depends is, in particular, the structure of the porosity of the crumb, which is an indirect comprehensive indicator of gas-holding and gas-forming capacity. Products with greater porosity and good elasticity are more effectively affected by enzymes. Digestive juices better permeate such bread and is better absorbed by the human body **[27]**.

Its physiological value depends on the moisture content of bread. As the humidity of bread increases, the amount of useful substances (proteins, carbohydrates, vitamins, etc.) decreases **[28]**, and **[29]**.

The analysis of the obtained data indicates a trend of increasing indicators: porosity by 14.2...22.7%, acidity (rye-wheat bread "Slovyansky" - 16.3%), moisture (rye-wheat bread "Selyansky" - 8, 9%) (Figure 9); other indicators are within normal limits. These changes can be attributed to variations in the composition and technology of experimental samples.

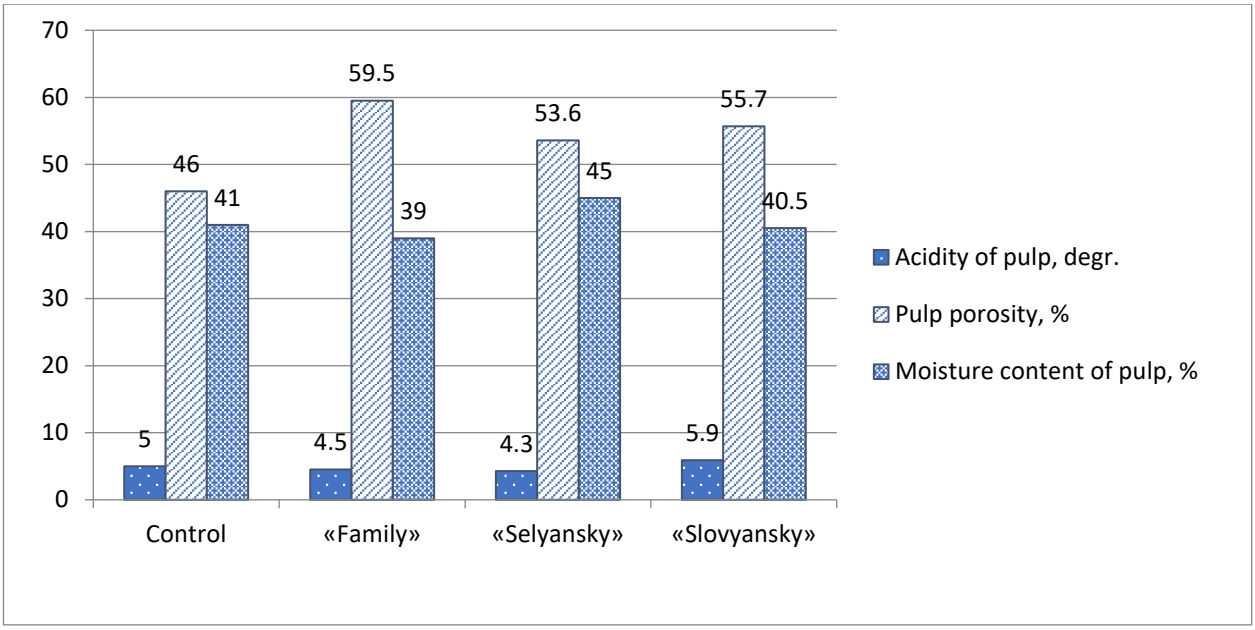


Figure 9 Analysis of physico-chemical indicators of control and experimental samples of bread on hop sourdough.

During the research, it was found that the acidity of rye-wheat "Slovyansky" bread increases by 16.3%, which contributes to a more complete swelling of polymers, which has a positive effect on the formation of the volume and crumb of bread, shortens the duration of ripening of semi-finished products in 1.5...2.0 times, and most importantly, it significantly improves the taste of bakery products.

A physical characteristic of the quality of baked semi-finished products and an important parameter at the baking stage is the porosity of the products, which largely determines the consistency of the finished products and indicates a volume increase of 10-12% **[30]**.

The specific volume of the loaf and the hardness/softness of the bread are among the main parameters of the visual and physical textural properties **[31]**. In general, the specific volume of a loaf of bread is directly proportional to the porosity and softness of the sample. Additionally, consumers generally prefer softer, spongy bread **[32]**.

The analysis of the obtained data (Figure 9) indicates a tendency to increase the indicator of the total porosity of bakery products by 14.2-22.7%.

The improved technology for producing craft bread with vegetable raw materials and dietary supplements can be utilized in both bakeries and HORECA enterprises. Figure 10 presents samples of the developed bread in the recommended form.

Figure 10 Suggested forms of craft breads for HORECA.

CONCLUSION

The results of our study demonstrate that the developed functional craft breads—"Family", "Selyansky", and "Slovyansky"—produced with sprouted wheat grain, hop sourdough, pumpkin purée, fermented wort concentrate, and milk thistle, significantly outperform traditional rye-wheat control bread in terms of nutritional, biochemical, and sensory properties. Compared to the control, the experimental breads showed: Protein content increase by up to 32.7%, and fat content by up to 156%. A marked improvement in dietary fiber content, particularly in "Slovyansky" bread, where it increased by 234.4%. Higher mineral content, including iron (up to +53.9%), magnesium (up to +157.7%), and phosphorus (up to +108.1%). Enhanced vitamin profile, with increases in thiamine (+115%), tocopherol (+161%), and carotenoids (+1105%). Improved amino acid composition, with higher levels of essential amino acids such as lysine (+21%), threonine (+14%), and isoleucine (+16%). Improved sensory properties, with all experimental samples receiving higher organoleptic scores than the control (average score: 4.8 vs. 4.7, $p < 0.05$). Technological improvements, including increased crumb porosity by 14.2–22.7%, loaf volume by 10–12%, and balanced acidity (optimal for texture and taste). All three formulations comply with the requirements of TUU 10.7-2791811531-001:2012, and the improved baking technology is suitable for adoption in small-scale bakeries, industrial settings, and the HORECA sector. These breads meet the growing demand for clean-label, nutrient-dense, and health-promoting bakery products. Given their enhanced composition and consumer appeal, these craft breads hold strong potential to support healthy nutrition under conditions of psycho-emotional stress and limited food access, such as during wartime or other crises. Future research will focus on scaling the production process, extending shelf-life stability, and validating the health benefits through clinical and population-level dietary assessments.

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