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DESIGN OF TECHNOLOGY FOR THE RYE-WHEAT BREAD "KHARKIVSKI RODNICHOK" WITH THE ADDITION OF POLYFUNCTIONAL FOOD ADDITIVE "MAGNETOFOOD"

I. Tsykhanovska

PhD, Associate Professor*

E-mail: cikhanovskaja@rambler.ru

V. Evlash

Doctor of Technical Sciences, Professor

Department of Chemistry, Microbiology and Food Hygiene

Kharkiv State University of Food Technology and Trade

Klochkivska str., 333, Kharkiv, Ukraine, 61051

E-mail: evlashvv@gmail.com

A. Alexandrov

PhD, Associate Professor, Head of Department*

E-mail: alexandrov.a.v.a.v@gmail.com

T. Lazareva

Doctor of Pedagogical Sciences, Professor*

E-mail: Lazareva_T.A@ukr.net

K. Svidlo

Doctor of Technical Sciences, Professor

Department of Technology and Restaurant Business Organization

Kharkiv Trade and Economics Institute of

Kyiv National University of Trade and Economics

O. Yarosha lane, 8, Kharkiv, Ukraine, 61045

E-mail: karinasvidlo@rambler.ru

T. Gontar

Senior Lecturer*

E-mail: taty-gontar@ukr.net

*Department of Food and Chemical Technology

Ukrainian Engineering Pedagogics Academy

Universitetska str., 16, Kharkiv, Ukraine, 61003

Розроблено технологію житньо-пшеничного хліба «Харківський родничок» з додаванням поліфункціональної харчової добавки «Магнетофуд». Досліджено якісні показники житньо-пшеничного тіста та готового виробу, збагачених харчовою добавкою «Магнетофуд». Встановлено, що введення добавки в кількості 0,15 % до маси борошна зменшує час бродіння тіста на 10,0–16,7 %; збільшує вихід тіста на 2,1–3,7 % та вихід хліба на 3,3–3,6 %

Ключові слова: поліфункціональна харчова добавка, житньо-пшеничне тісто, хліб «Харківський родничок», показники якості

Разработана технология ржано-пшеничного хлеба «Харьковский родничок» с добавлением полифункциональной пищевой добавки «Магнетофуд». Исследованы качественные показатели ржано-пшеничного теста и готового продукта, обогащенных пищевой добавкой «Магнетофуд». Установлено, что добавки в количестве 0,15 % к массе муки уменьшает время брожения теста на 10,0–16,7 %; увеличивает выход теста на 2,1–3,7 % и выход хлеба на 3,3–3,6 %

Ключевые слова: полифункциональная пищевая добавка, ржано-пшеничное тесто, хлеб «Харьковский родничок», показатели качества

1. Introduction

Bread is a staple food that is consumed on a daily basis [1], so its quality must meet all the medical and biological requirements [2]. These indicators depend on a number of factors, the main of which is the quality of basic and additional raw materials used in the production of bread [3]. The industry processes up to 50 % of the total volume of flour with decreased properties [4], large bread-making factories employ continuous technologies that have a number of shortcomings, including those affecting the quality of bread [5]. There is still a not sufficiently satisfied need of the population in products with medical-dietary and prophylactic effect, especially in the environmentally-stressed areas, as well as the need in bread with long shelf life [6].

One of the directions for improving existing, as well as designing new, technologies of food products is the development of methods for obtaining and use of food additives – enrichment agents and improvers. This will ensure:

- improvement in the quality and nutritional value of products;
- increase in the output of finished products;
- in some cases, improvement of functional-technological indicators and longer storing of food products.

In recent years, in order to create required functional-technological properties of bread, new technologies have been developed, which involve flour improvers, food additives, enrichment agents with a different principle of action, with various technological techniques applied. These innovations are necessitated, first, by the proliferation of

single-phase accelerated techniques for dough preparation; second, by the unstable quality of flour and raw materials, specifically, of those with prophylactic effect; third, by the extension of product range; fourth, by improvement in the quality of finished products, by increasing nutritional value and better resistance against microbial spoilage; fifth, by longer shelf life of bread and bakery products [6].

Improvers are the natural or synthetic substances that make it possible to adjust functional properties of food products; to intensify technological process of bread production. They also regulate the rheological properties of dough, alter organoleptic and functional-technological indicators. Specifically, they enhance the color and flavor of products, improve their shape and volume, improve the structure and properties of crumb, increase the degree of freshness of bread, etc.

It is necessary to purposefully use the improvers in order to improve the basic and additional raw materials.

At present, an important task in the production of bread and bakery products is the search for alternative raw materials. Such raw materials should alter technological properties, have rich chemical composition and various structural components. They would not only activate biotechnological processes in the production of bread but also save raw materials used in bread making. Most importantly, they would improve chemical composition and quality of the finished product.

The intensity of the course of biotechnological processes during bread production depends on the quality of rye and wheat flour, rye sourdough and the yeast used. Quality of rye sourdough depends on many factors, but to a greater extent on the composition of nutrient medium in which the cultivation of a given semi-finished product takes place. One of the techniques to improve composition of the nutrient medium for the cultivation of rye sourdough is the introduction of supplements-improvers into composition [2, 3, 5].

Therefore, in order to improve bread baking technologies, it is of practical interest to apply various additives. Food additives would enable enrichment of nutrient mixtures in order to cultivate rye sourdough with necessary substances. It contributes to the improvement of biotechnological quality indicators of rye sourdough, as well as rye-wheat dough. In addition, the use of additives and improvers in bread-making technology makes it possible to intensify technological process of production and improve quality of the finished product.

Given this, it is a relevant task to introduce the polyfunctional food supplement "Magnetofood" into a formulation composition in order to create new functional-technological properties of rye-wheat bread. "Magnetofood" is an ultra-thin powder with a particle size of 30–60 nm and with a large specific surface, high activity and specific properties: restoring, antioxidant, bacteriostatic, sorption, complexing, emulsifying, moisture-retaining, fat-retaining, moisture-binding. It is an additional source of easily digestible iron (II) [7–9].

2. Literature review and problem statement

An analysis of the scientific literature shows that nutritional supplements are used in the practice of bread making in order to extend product range and improve quality of bread and bakery products, to regulate parameters of technological processes. They can be divided into several groups:

- derived from plant and animal raw materials (products from seeds of legumes, fruit powders, dairy products, etc.);
- obtained chemically (antioxidants, synthetic vitamins, etc.);
- obtained using microbiological synthesis (enzyme preparations);
- resulting from processing natural materials (modified starch).

We shall consider these groups separately and in more detail.

Each group has certain advantages and disadvantages. The advantages of the first group, in whose composition plant supplements are most widely used, are a complex composition, balanced constituents of individual components, as well as the presence of compounds in the most physiologically digestible form. Enrichment of vegetable, fruit and herbal additives with biologically active substances promotes the increase of viscosity of dough, reduction of its adhesion, improvement of the pliability of dough to mechanical treatment; improvement in specific volume, porosity and shape stability of bread [10–15]. Disadvantages include narrow orientation and the absence of comprehensive effect.

With the aim of enriching bread with food fibers, specialists employ technologies of bread with added hardly-digestible polysaccharides (bran cereals, peas, sunflower seeds, wheat germs, oatmeal, banana and apple powders, buckthorn shroud) as well as the ethers of cellulose [12–15].

However, their effect on technological indicators of dough semi-finished products and finished products is insignificant.

Thus, in order to enrich bakery products with plant protein, specialists use soybeans and products of processing [16, 17]. Technologies of dietary products in bread and bakery industry widely utilize residual products of beer brewing: salt-laden barley grain, beer pebble and remaining beer yeast [2, 6]. The disadvantages of using such additives include low threshold of antioxidant and antimicrobial effect.

There are known bread technologies with the additives of animal origin based on milk and certain products of its processing, which positively affect the properties of dough and the quality of bread [10, 18–21]. Disadvantages include substantial friability and insufficient elasticity of crumb.

Bread baking industries apply supplements-improvers for the regulation of technological properties of dough. They are divided into several groups [22]:

- improvers with oxidative effect;
- improvers based on modified starches;
- improvers with surface-active properties;
- improvers of fermentative nature;
- mineral improvers.

The following improvers with oxidative effect have gained the most practical application in the technology of bread preparation: potassium bromate, ascorbic acid, azodicarbonamide, calcium and benzoyl peroxides [22]. The disadvantages of these additives are a low functionality in terms of texture and physical-chemical properties of baked goods.

Some technologies involve modified starches (extrusion, oxidized, swelling, phosphate, esterified), which makes it possible to improve specific volume and looseness of bread crumb. The elasticity of crumb and the color of bread are also improved. Shelf-life of finished products is prolonged [22]. These improvers, however, do not possess antioxidant properties.

Enzyme supplements (amylolytic, proteolytic, cellulolytic, pentosanes, β -galactosidase, lipoxigenase) are most efficiently applied in the technologies for processing dough with reduced fermentative activity [23]. The shortcoming of using such additives is the fact that they do not ensure sufficient output of finished products.

Mineral supplements-improvers (ammonium salts of orthophosphoric acid, sodium and potassium orthophosphates) are employed in bread making mainly to improve the activity of yeast. Their use stabilizes the rheological properties of dough, increases the volume of bread, improves porosity of crumb and eliminates its stickiness [24]. The disadvantage of these additives is the insufficient functionality in terms of specific volume, porosity and shape stability of bread.

There is known positive effect of calcium salts on the activation of flour amylases and other enzyme preparations, as well as the additives of calcium acetates and propionates to prevent molding and potato disease of bread [25]. These improvers, however, do not provide sufficient structural-mechanical and physical-chemical indicators.

In recent years, the process of bread production has commonly involved complex improvers that contain several components with different functional properties. The composition consists of enzyme preparations, antioxidants, surface-active substances, mineral salts, supplements with dietary and preventive effect. These supplements positively affect carbohydrate and protein complex of flour; the vital activity of yeast; the process of gas formation during dough fermentation, and the rheological properties of dough semi-finished products. The result is the improvement in quality indicators of bread and bakery products: an increase in the specific volume of bread, in porosity and structural-mechanical properties of crumb, shape stability of bread, and inhibition of the staling of finished products at storing [24–26]. The shortcomings include a low threshold of antioxidant and antimicrobial effects.

Modern food technologies widely employ functional ingredients obtained from industrial by-products (skin, hoof, feathers, offal, seeds, bran, whey, etc.). These supplements, however, are characterized by narrow orientation and do not demonstrate comprehensive effect [27, 28].

Bread containing wheat flour is a food with low antioxidant capacity. In recent years, bread making technologies have followed a global trend to enrich bread with phenolic antioxidants of plant origin [29, 30]. The disadvantages of these additives are a low functionality in terms of texture and physical-chemical properties of baked goods.

Bread technologies use additives based on wheat with a low content of glycemic index (GI) in order to improve health of consumers [31]. The yield and structural-mechanical indicators of finished products, however, do not improve.

The use of essential oils as natural antimicrobial agents for bakery products was reported [32]. In this case, the elasticity and porosity of crumb do not improve.

Various supplements are proposed for use in baking technologies in order to improve quality indicators of bread (especially gluten-free): soy, chickpeas, eggs, enzymes, hydrocolloids, microalgae, etc. [33–36]. These supplements have a number of disadvantages:

- chickpeas exert a negative effect on bread quality due to the loss of solubility at baking;
- adding microalgae does not significantly affect hardness and elasticity of dough semi-finished products;
- some do not improve shape stability, yield, acidity and moisture-content of crumb.

The dietary supplement “Gemovital” is used in the technology of rye-wheat bread, rye-wheat crackers and gingerbread for enriching them with valuable protein and iron in the form easily digestible for the human organism. The main task of “Gemovital” is physiological effect on the organism. The functional-technological properties of dough and finished products are not much affected by “Gemovital” [37–39].

An analysis of recent studies and publications [27–36] on the development of new advanced technologies for bread and bakery products production reveals profound changes in traditional technologies of bakery products. In recent years, technologists have increasingly paid attention to innovations in the direction of improving biological value; functional-technological, physical-chemical and organoleptic indicators; creating bread and bakery products with dietary and medicinal-preventive properties.

Leading direction in the technology of bakery products is the inclusion of compounds of varying nature to formulations that are related to food additives and improving additives. This opens up almost unlimited possibilities for the use of food additives in the production of functional food products.

In order to create new functional-technological properties in the technologies of bread and bakery products, it is possible to suggest using the polyfunctional food supplement “Magnetofood” – a nanopowder with large specific surface and high activity. The composition of this supplement includes oxides of two- and three-valent ferrum. This food additive possesses a number of properties: biological compatibility with living organisms, affinity to the protein, bacteriostatic action, high thermal stability. In food systems, “Magnetofood” exhibits regenerative, antioxidant, sorption, complexing, emulsifying, moisture-retaining, fat-retaining, moisture-binding properties, and can also act as an additional source of easily-digestible iron [7–9].

An analysis of information sources [2, 3, 5, 6, 10–15, 17–26, 29–36] reveals the lack of data on the technology of bread making using polyfunctional food additives, specifically of the nanopowder type, which improve technological parameters of semi-finished products and quality of bread. The discovered properties of the additive “Magnetofood” allow us to recommend it for improving functional-technological indicators of rye-wheat bread.

3. The aim and objectives of the study

The aim of present work is to design the technology of rye-wheat bread with the addition of polyfunctional food supplement “Magnetofood”.

To achieve the aim, the following tasks have been set:

- to investigate the effect of the food additive “Magnetofood” on physical-chemical parameters of the experimental samples of rye-wheat dough;
- to investigate the effect of the food additive “Magnetofood” on technological indicators of the experimental samples of rye-wheat dough;
- to investigate the effect of the food additive “Magnetofood” on physical-chemical and technological indicators of the experimental samples of the bread “Kharkivski rodnichok”;
- to investigate the effect of the food additive “Magnetofood” on organoleptic indicators of the experimental samples of the rye-wheat bread “Kharkivski rodnichok”.

4. Materials and methods for the study of the food additive “Magnetofood”

4.1. Examined materials and equipment used in the experiment

We investigated in the present study the effect of the polyfunctional food supplement “Magnetofood” on physical-chemical, technological and organoleptic indicators of rye-wheat dough and the finished product.

Object of research: technology of rye-wheat bread.

Subjects of research:

Bread prepared using pressed yeast and wheat flour of grade 1:

– sample 1, control, rye-wheat bread “Darnytski” [GOST 26983-2015 and DSTU-P 4583:2006] with the following quality indicators: moisture content of crumb – not exceeding 48.5 %; acidity not exceeding 8.0°; porosity not less than 59.0 %;

– sample 2, rye-wheat bread “Kharkivski rodnichok” with the polyfunctional food supplement “Magnetofood” in the amount of 0.15 % by weight of flour in the form of powder [7, 8];

– sample 3, rye-wheat bread “Kharkivski rodnichok” with the polyfunctional food supplement “Magnetofood” in the form of an oil-magnetofood suspension (OMS); in this case, OMS is introduced in the amount of 0.35 % by weight of flour [7–9].

Bread prepared using pressed yeast and wheat flour of grade 2:

– sample 4, control, rye-wheat bread “Darnytski” [GOST 26983-2015 and DSTU-P 4583:2006], prepared using flour of grade 2 (with short-tearing gluten and reduced amylolytic activity) [GOST R 52189-2003];

– sample 5, rye-wheat bread “Kharkivski rodnichok” with the polyfunctional food supplement “Magnetofood” in the amount of 0.15 % by weight of flour in the form of powder [7, 8], prepared using flour of grade 2 (with short-tearing gluten and reduced amylolytic activity) [GOST R 52189-2003];

– sample 6, rye-wheat bread “Kharkivski rodnichok” with the polyfunctional food supplement “Magnetofood” in the form of an oil-magnetofood suspension (OMS); in this case, OMS is introduced in the amount of 0.35 %

by weight of flour [7–9], prepared using flour of grade 2 (with short-tearing gluten and reduced amylolytic activity) [GOST R 52189-2003].

The examined materials and equipment used in the experiment, as well as techniques for determining organoleptic, physical-chemical and technological indicators, are described in detail in paper [40].

5. Results of study of the effect of the food additive “Magnetofood” on quality indicators of the experimental samples of wheat-rye bread

We studied effect of the polyfunctional food supplement “Magnetofood” on rye-wheat bread on model systems. The base formulation that we chose to examine is the rye-wheat dough formulation, which is used for making the bread “Darnytski” (Table 1) [41].

Two techniques were applied to introduce the polyfunctional food supplement “Magnetofood”:

1) the food additive “Magnetofood” was introduced in a dry form when kneading the dough in the amount of 150 g per 100 kg of flour;

2) the food additive “Magnetofood” was introduced in the form of OMS (oil-magnetofood suspension) in the amount of 350 grams per 100 kg of flour when kneading the dough. The optimal quantity of the food additive “Magnetofood” and OMS was chosen experimentally.

OMS was used for better distribution of the polyfunctional food supplement “Magnetofood” and for obtaining a homogeneous structure of dough and bread. OMS was obtained by mixing sunflower oil (99.0–99.25 %), heated to 60–70 °C, with a suspension (0.75–1.0 %), heated to 60–70 °C. The suspension was obtained on the base of “Magnetofood” and a surface-active substance (SAS) – monoacylglycerol Dimodan HP. The optimal ration in the suspension “Magnetofood”:SAS (stabilizer)=15.0:65.0 % [7–9].

Fig. 1 shows duration of the fermentation of rye-wheat dough in the experimental samples whose formulation is given in detail in Table 1.

Table 1

Formulation of experimental samples of the rye-wheat bread “Darnytski” and “Kharkivski rodnichok” with the food additive “Magnetofood”

Ingredients of experimental samples of rye-wheat bread	Experimental samples of rye-wheat bread					
	Bread with pressed yeast and flour of grade 1			Bread with pressed yeast and flour of grade 2		
	Bread «Darnytski»	Bread «Kharkivski rodnichok» with the food supplement «Magnetofood», % by weight of flour		Bread «Darnytski»	Bread «Kharkivski rodnichok» with the food supplement «Magnetofood», % by weight of flour	
		in the form of powder 0.15	in the form of suspension (OMS – 0.35)		in the form of powder 0.15	in the form of suspension (OMS – 0.35)
Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	
Wheat flour, kg	40 normal	40 normal	40 normal	40 short-tearing gluten and low amylolytic activity	40 short-tearing gluten and low amylolytic activity	40 short-tearing gluten and low amylolytic activity
Rye wheat peeled, kg	60	60	60	60	60	60
Pressed yeast, kg	0.5	0.5	0.5	0.5	0.5	0.5
Salt, kg	1.4	1.4	1.4	1.4	1.4	1.4
Magnetofood, kg	–	0.15	–	–	0.15	–
OMS, kg	–	–	0.35	–	–	0.35

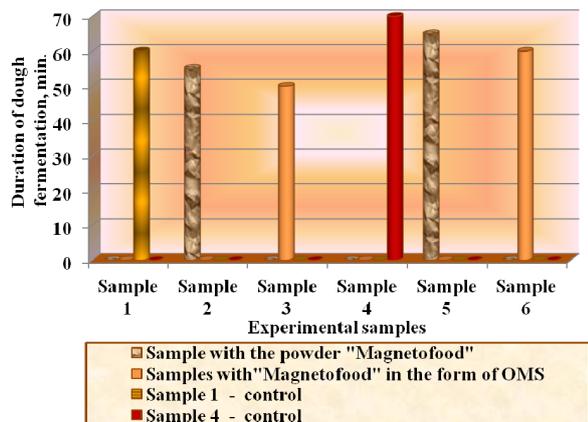


Fig. 1. Effect of the food additive “Magnetofood” on duration of fermentation in the experimental samples of rye-wheat dough

An analysis of experimental data (Fig. 1) shows that the introduction of the polyfunctional food supplement “Magnetofood” to the rye-wheat dough contributes to the reduction of time for the fermentation of dough:

- by 10.0–16.7 % (for dough using wheat flour of grade 1 and pressed yeast);
- by 7.1–14.3 % (for dough using flour of grade 2 and pressed yeast with low amyolytic activity).

Results of research into physical-chemical indicators of the experimental samples of rye-wheat dough are given in Table 2.

Table 2

Physical-chemical indicators of the experimental samples of rye-wheat dough

Wheat-rye dough	Moisture content, %	Deviation from GOST	Acidity, degrees	Deviation from GOST
Sample 1	49.0	+0.5	7.5	–
Sample 2	48.5	–	7.3	–
Sample 3	48.5	–	7.2	–
Sample 4	52.0	+3.5	8.5	+0.5
Sample 5	49.0	+0.5	7.9	–
Sample 6	49.0	+0.5	7.8	–
GOST	–	48.5	–	7–8

Data from Table 2 show that moisture content and acidity of the dough were different in experimental samples. Moreover, introduction of the food supplement “Magnetofood” to rye-wheat dough helps to reduce moisture content and acidity of the dough:

- by 1.0 % and 2.7–4.0 %, respectively (for the dough prepared using wheat flour of grade 1 and pressed yeast);
- by 5.8 % and 7.1–8.2 %, respectively (for the dough prepared using wheat flour of grade 2 and pressed yeast with low amyolytic activity).

The introduction of the food additive “Magnetofood” also affects the yield of the dough. Indicators of the yield for the experimental samples of rye-wheat dough are shown in Fig. 2.

By analyzing experimental data in Fig. 2 we can conclude that the use of the food additive “Magnetofood” leads to an increase in the yield of dough.

Organoleptic indicators of bread quality significantly affect consumer demand. Table 3 and Fig. 3–6 show the esti-

mate of organoleptic indicators of the experimental samples of rye-wheat bread “Kharkivski rodnichok” compared with control samples (by a five-point scale).

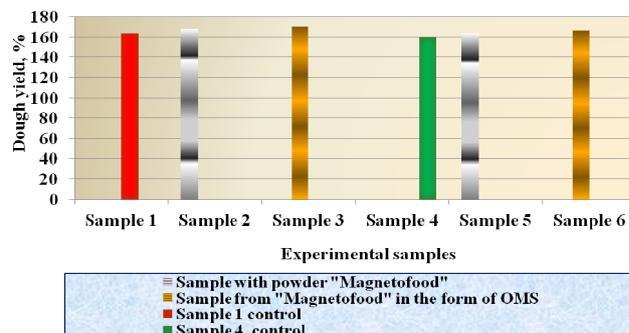


Fig. 2. Effect of the food additive “Magnetofood” on the yield for the experimental samples of rye-wheat dough

Table 3

Estimation of organoleptic indicators of the experimental samples of rye-wheat bread “Kharkivski rodnichok” compared with control samples

Samples of rye-wheat bread	Organoleptic indicators of rye-wheat bread				
	Taste	Color	Porosity	Physical appearance and bread surface	Flavor
Sample 1 – control	5	4	4	5	4
Sample 2	5	5	5	5	5
Sample 3	5	5	5	5	5
Sample 4 – control	3	3	3	3	3
Sample 5	4	5	5	5	4
Sample 6	4	5	5	5	4

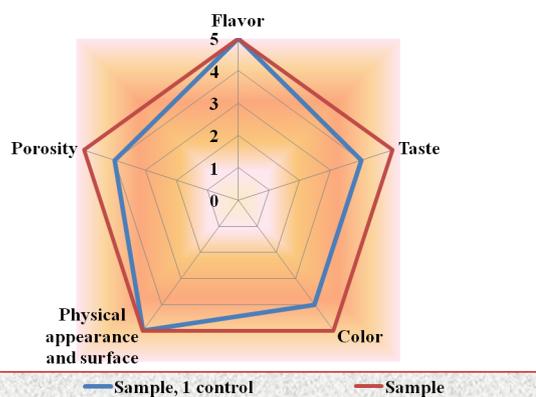


Fig. 3. Effect of the food additive “Magnetofood” on organoleptic indicators of experimental sample 2 of the rye-wheat bread “Kharkivski rodnichok” compared with control (bread “Darnytski”, prepared using wheat flour of grade 1 and pressed yeast)

Experimental data in Table 3 and Fig. 3–6 show that applying the polyfunctional food supplement “Magnetofood” in the production of rye-wheat bread “Kharkivski rodnichok” improves its organoleptic properties: taste, color, porosity and crumb state.

Table 4 gives physical-chemical indicators of the experimental samples of rye-wheat bread “Kharkivski rodnichok” compared with control samples.

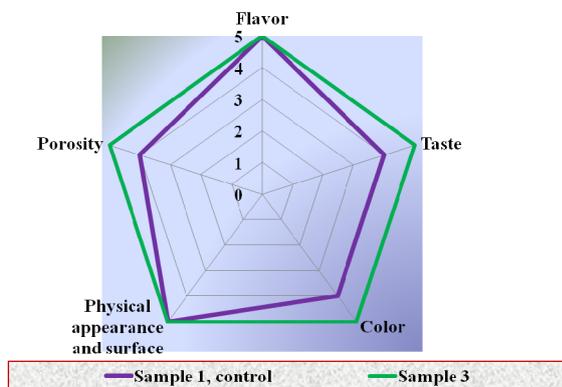


Fig. 4. Effect of the food additive “Magnetofood” on organoleptic indicators of experimental sample 3 of the rye-wheat bread “Kharkivski rodnichok” compared with control (bread “Darnytski”, prepared using wheat flour of grade 1 and pressed yeast)

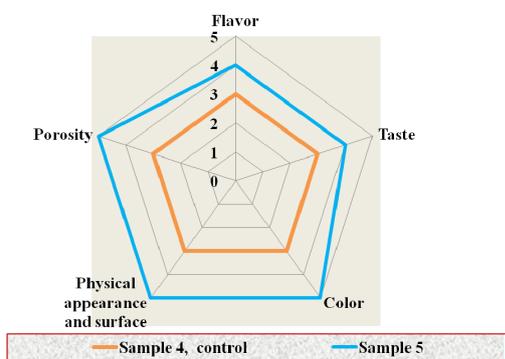


Fig. 5. Effect of the food additive “Magnetofood” on organoleptic indicators of experimental sample 5 of the rye-wheat bread “Kharkivski rodnichok” compared with control (bread “Darnytski”, prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity)

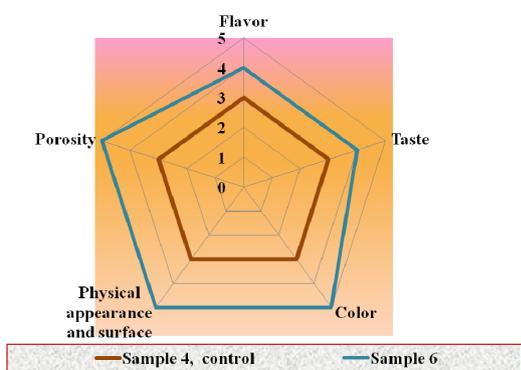


Fig. 6. Effect of the food additive “Magnetofood” on organoleptic indicators of experimental sample 6 of the rye-wheat bread “Kharkivski rodnichok” compared with control (bread “Darnytski”, prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity)

Data in Table 4 show that physical-chemical indicators for the experimental samples of rye-wheat bread “Kharkivski rodnichok” with the addition of food additive “Magnetofood” are better than for control samples without food additive “Magnetofood”.

The influence of the polyfunctional food supplement “Magnetofood” on the yield for the experimental samples

of rye-wheat bread “Kharkivski rodnichok” compared with control samples is shown in Fig. 7

Table 4

Results of research into physical-chemical indicators of the experimental samples of bread “Kharkivski rodnichok” compared with control samples

Samples of rye-wheat bread	Moisture content, %	Acidity, degrees	Porosity, %
Sample 1 – control	48.5	7.5	59.0
Sample 2	48.0	7.0	61.0
Sample 3	48.0	6.7	62.0
Sample 4 – control	51.0	8.0	56.0
Sample 5	48.0	7.2	58.0
Sample 6	48.0	7.0	59.0
GOST	Not exceeding 48.5	7.5–8.0	Not less 59.0

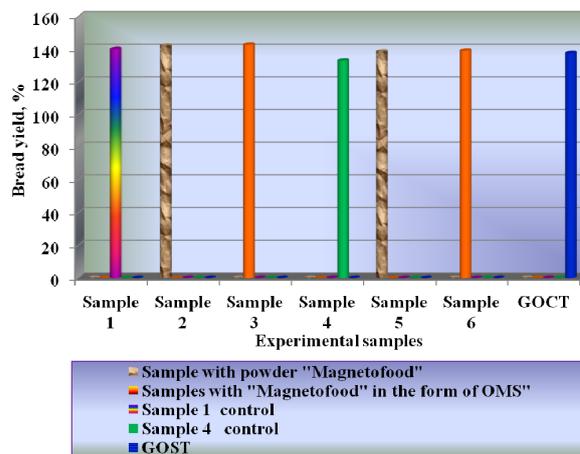


Fig. 7. Effect of the food additive “Magnetofood” on the yield of experimental samples of the rye-wheat bread “Kharkivski rodnichok” compared with control samples (bread “Darnytski”)

Data in Fig. 7 show that the yield of bread in the experimental samples of rye-wheat bread “Kharkivski rodnichok” with the addition of food additive “Magnetofood” is higher than that in the control samples without food additive “Magnetofood”.

Based on results of the study, we propose a technological scheme for the production of rye-wheat bread “Kharkivski rodnichok” with the addition of the polyfunctional food supplement “Magnetofood” (Fig. 8) [34–36].

A distinctive feature of the new technology is the preliminary mixing of the food additive “Magnetofood” with the wheat flour, which is used when kneading the dough [41].

The dough for preparing the rye-wheat bread “Kharkivski rodnichok” is prepared using thick leaven with moisture content 48–50 %. Table 5 gives the formulation and basic parameters for preparing dough using thick leaven [41].

When kneading the dough, a portion of leaven is mixed with a yeast suspension, a sugar-saline solution, a concentrate of leavened wort and water. Then wheat flour is introduced, preliminary mixed with the food additive “Magnetofood”. Kneading lasts for (12–15)×60 s. Dough matures for (50–60)×60 s at a temperature of 25–28 °C. Acidity of the matured dough is not less than 10–12 degrees by Neumann.

Table 5
Formulation and technological parameters for preparing dough using thick leaven with the ratio between rye peeled flour and wheat flour of grade 1 at 60:40

Raw materials, semi-finished products and indicators of the process	Consumption of raw materials and parameters for preparing dough using leaven	
	Leaven	Dough
Leaven, kg	19	57
Flour in leaven, kg	–	33
Rye peeled flour, kg	22	27
Wheat flour of grade 1, kg	–	40
Brewing (1:2,5), kg	–	–
Pressed yeast, kg	–	0.5
Kitchen salt, kg	–	1.4
Water, kg	16	as estimated
Moisture content, %	48–50	$W_{m.c} \pm 1$
Starting temperature, °C	25–28	28–30
Fermentation duration, min	180–240	60–90
Resulting acidity, degrees	12–14	7–8

At the next stage, dough is divided into pieces with a certain weight, make them round-shaped, put into molds, greased with oil, and taken to the chamber for aging over 60×60 s at a temperature of 30–32 °C and relative air humidity 75–80 %.

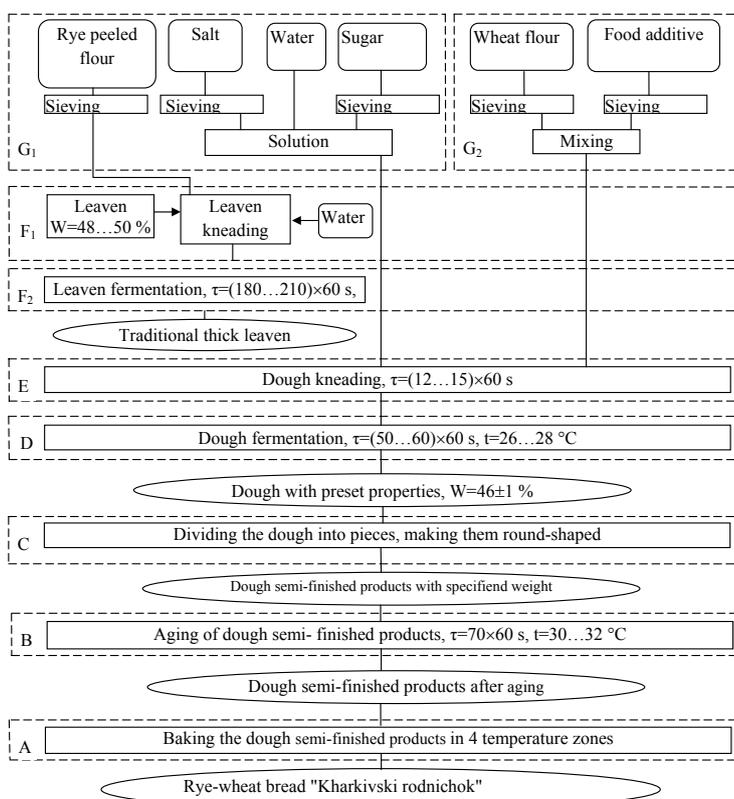


Fig. 8. Technological scheme of the rye-wheat bread “Kharkivski rodnichok” with the addition of the polyfunctional food additive “Magnetofood” A, B, C, D, E, F₁, F₂, G₁, G₂ are subsystems of the technological scheme for bread production

Baking of dough semi-finished products is carried out in the oven in 4 temperature zones for 34×60 s: 230–240 °C – 7×60 s, 220–230 °C – 7×60 s, 210–220 °C – 13×60 s, 200–210 °C – 9×60 s.

Cooling and storing bread after baking is carried out under conditions of a bread storing facility at relative air humidity 70–75 % [35, 36, 41].

In order to implement a technological process of the production of rye-wheat bread “Kharkivski rodnichok” using the food additive “Magnetofood”, it is proposed to apply the equipment, shown in Fig. 9, at the stage of dosing raw materials and mixing the additive with wheat flour.

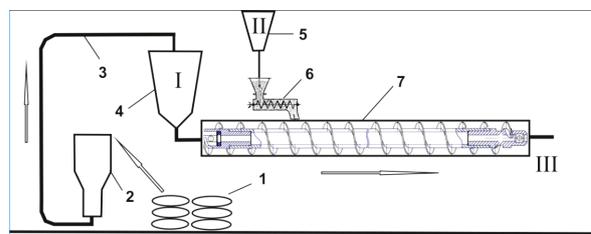


Fig. 9. Unit for the fortification of flour with magnetofood: 1 – storage of flour in containers; 2 – vibratory sifter unloader; 3 – device for the transportation of ingredients; 4 – bunker for supplying the flour; 5 – bunker for supplying the polyfunctional food supplement “Magnetofood”; 6 – screw micro dozer; 7 – screw conveyor-agitator: I – flour, II – magnetofood, III – fortified flour for kneading

Technological scheme of the bread “Kharkivski rodnichok” easily fits the work of enterprises in the baking industry and can be implemented without significant changes in the organization of their work.

6. Discussion of results of the study of properties of the additive “Magnetofood” in the technology of rye-wheat bread

One of the basic stages in bread production is the kneading of dough. The kneading of dough is performed in dough-mixing machines with the purpose of obtaining from the components of a formulation the dough uniform in its mass and structure. After the kneading dough undergoes fermentation. Fermentation is carried out in order to obtain dough with optimal organoleptic and rheological properties. These properties are acquired by dough as a result of alcohol and lactic acid fermentation caused by yeast cells and lactic acid bacteria. Control over dough kneading is performed based on organoleptic indicators (flavor, structure, an increase in volume, taste), moisture content and acidity. The quality of dough affects quality of bread [3, 5].

The quality of raw materials significantly affects the duration and temperature of dough fermentation, as well as the technology of its preparation. Dough fermentation time is determined by the resulting temperature and acidity. Initial temperature of dough for the production of rye-wheat bread “Darnytski” according to production regulations should be 27 °C, dough fermentation finishes at a temperature of 30 °C. Moisture content of the dough should be 48.5 %, acidity 7–8°. Optimum dough fermentation time for the bread “Darnytski” at good starting raw material is 60 minutes, the yield of dough in this case will reach 164 % [3, 5].

Fig. 1 shows that we observe minimum dough fermentation time in samples 2, 3 (in this case, when the food additive “Magnetofood” was introduced in the form of OMS, sample 3, the effect is 11 % better in comparison with the technique for introducing it in the dry form – sample 2). In control sample 4 (for dough prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity), dough fermentation time was maximum – 70 min. It was 10 minutes longer in comparison with control sample 1 (for dough prepared using wheat flour of grade 1 and pressed yeast). This time difference is associated with the use of low quality wheat flour and pressed yeast with reduced amylolytic activity. Consequently, the dough was poorly kneaded and did not reach the required temperature. In samples 5, 6 (the introduction of food additive “Magnetofood” to which was carried out in the form of OMS, sample 5, and in a dry form, sample 6), dough fermentation time, compared with control sample 4, was 5 and 10 min. less, respectively. However, dough fermentation time for these experimental samples 5, 6 also exceeded that of control sample 1 by 5–10 min., respectively. Here, compared with experimental sample 4, we observed reduced time of fermentation, which is probably due to the activating properties of Fe_3O_4 , which is the basic component of food additive “Magnetofood”.

Nanoparticles of the food additive “Magnetofood” have a biological compatibility with protein components of enzymes and the capability to interact with them through activation, with improves the quality of dough via influence on β -amylase.

When analyzing Fig. 1, it can be assumed that the use of the polyfunctional food supplement “Magnetofood” in the production of rye-wheat bread “Kharkivski rodnichok” leads to a reduction in the time of fermentation of dough. It also makes it possible to bring the time of fermentation of dough prepared with wheat flour of grade 2 and pressed yeast with low amylolytic activity closer to control sample 1 (dough prepared using wheat flour of grade 1 and pressed yeast).

Data in Table 2 show that the introduction of food additive “Magnetofood” significantly affect physical-chemical indicators of dough. In samples 1, 6, we obtain dough whose moisture content and acidity met the standard requirements [GOST 26983-2015]. In samples 2, 3 (the food additive “Magnetofood” to which was introduced in the form of OMS, sample 3, and in a dry form, sample 2), moisture content and acidity of the dough were about 1.0 % and 2.7–4.0 % lower, respectively. In experimental sample 4 (the dough was prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity), we observe increasing moisture content and acidity of the dough: 6.0 % and 1.0° higher, respectively, than that in control sample 1. This may be due to the use of low-quality flour, as a result of which dough accumulates large amounts of water-soluble substances. Increasing acidity is due to the fact that in the course of their life activities acid-forming bacteria decompose glucose with the formation of lactic acid. At the same time, dough accumulates as by-products a certain amount of other organic acids: acetic, succinic, malic, citric, wine, formic [3, 5]. And since the time of fermentation in this sample was longer, the content of the above acids was greater. In samples 5, 6, we used wheat flour of grade 2, pressed yeast with low amylolytic activity and the food additive “Magnetofood”. In sample 5, “Magnetofood” was introduced in a dry form; in sample 6 – in the form of OMS. We can observe in these samples improvement of the physical-chemical properties

of dough and that these indicators approach the standard requirements – control sample 1 [GOST 26983-2015]. This is probably due to the use of the polyfunctional food supplement “Magnetofood”, which reduced the time of fermentation of dough and improved its indicators. In addition, the introduction of food additive “Magnetofood” not only slows down the processes of hydrolysis of carbohydrate and protein components of dough (the accumulation of free organic acids) but also sorbs some amount of organic acids on Fe_3O_4 . This indicates that “Magnetofood” improves the quality of dough.

The maximum yield of dough was obtained in experimental samples 2, 3 (Fig. 2). They were introduced with the polyfunctional food additive “Magnetofood” in a dry form, sample 2, and in the form of OMS, sample 3. In samples 2, 3, the yield of dough exceeded that of control sample 1 by 2.1 % and 3.7 %, respectively. In control sample 4, we used wheat flour of grade 2 and pressed yeast with low amylolytic activity. In this sample, the yield of dough was minimal, 2.1 % less than that of control sample 1. In experimental samples 5, 6 (prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity), the yield of dough compared with that of control sample 4 was higher by 3.8 % and 1.2 %, respectively. In experimental samples 5, 6, the yield of dough also met the standard requirements – control sample 1 [GOST 26983-2015]. Analyzing the experimental data, we can conclude that the use of food additive “Magnetofood” in the production of rye-wheat bread “Kharkivski rodnichok” leads to an increase in the yield of dough. After all, in experimental sample 5 (the dough prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity), it is the application of the food additive “Magnetofood” that made it possible to obtain the yield of dough close to that in control sample 1, while experimental samples 2, 3, 6 had a larger yield.

Introduction of the polyfunctional food supplement “Magnetofood” to the wheat-rye bread “Kharkivski rodnichok” (Table 3 and Fig. 3–6) improves organoleptic characteristics: taste, color, porosity, and crumb state by 1–2 points on average compared with control samples.

Physical-chemical and technological indicators of bread quality characterize strict adherence to the formulation and the procedure of technological process at a bread baking enterprise. This group includes moisture content, acidity, and porosity.

In experimental samples 2, 3, 5, 6 with the food additive “Magnetofood”, the rye-wheat bread “Kharkivski rodnichok” exhibited better physical-chemical and technological indicators compared with control samples 1 and 4. First, the moisture content and acidity of bread decreased:

- by 1.0 % and by 7.1–10.7 %, respectively (for the dough prepared using wheat flour of grade 1 and pressed yeast);

- by 5.9 % and by 10.0–12.5 %, respectively (for the dough prepared using flour of grade 2 level and pressed yeast with low amylolytic activity).

Second, the porosity of crumb bread grew:

- by 3.4–5.1 % (for the dough prepared using wheat flour of grade 1 and pressed yeast);

- by 3.6–5.4 % (for the dough prepared using flour of grade 2 level and pressed yeast with low amylolytic activity).

An increase in the porosity occurred, probably, due to the biochemical processes. The action of nanoparticles in the food additive “Magnetofood” activates vital activity of microflora in dough semi-finished products. The result is the

enhanced release of CO₂; thermal expansion of air bubbles and CO₂; the increase in the migration of ethanol that is produced as a result of the process of alcohol fermentation to the gaseous state, with further thermal expansion of its vapor [3, 5]. In control sample 4 (prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity), the rye-wheat bread was inferior in terms of moisture content and porosity to all experimental samples of the bread “Kharkivski rodnichok”, the acidity was maximal and corresponded to the upper limit in GOST. In samples 5, 6 (where we used wheat flour of grade 2, pressed yeast with low amylolytic activity, and the food additive “Magnetofood”), the rye-wheat bread “Kharkivski rodnichok” met requirements of the standard. By analyzing data in Table 4 we can conclude that it was the action of the food additive “Magnetofood” that made it possible for experimental samples 5, 6 to meet the requirements of GOST 26983-2015 for physical-chemical and technological indicators of bread quality, and for samples 2, 3 to show the best results.

The yield of bread is one of the main technical-economic indicators of performance of a bakery enterprise. The yield of bread is understood as the weight of finished products, expressed as a percentage to the weight of the utilized flour (typically per 100 kg of flour) [3, 5].

Fig. 7 shows that the maximum yield of the rye-wheat bread “Kharkivski rodnichok” was obtained in experimental samples 2, 3 (with the food additive “Magnetofood”), which was 3.3–3.6 % higher than that in GOST. Experimental samples 5, 6 (with the food additive “Magnetofood”) enable the yield of bread larger than that of control sample 4, by 4.0–4.5 %, and their yield is only 0.7–1.0 % lower than that of control sample 1. It should be noted that all experimental samples of the bread “Kharkivski rodnichok” with the addition of food additive “Magnetofood” demonstrated the larger yield of bread than that in experimental samples of the bread “Darnytski” without added “Magnetofood”.

By analyzing obtained experimental data, we can conclude that the use of food additive “Magnetofood” in the production of rye-wheat bread “Kharkivski rodnichok” leads to an increase in its yield. First, due to the moisture-retaining capacity of the primary component of “Magnetofood” – Fe₃O₄. It helps maintain dough moisture content at the boundary level and ensures standard moisture content in bread. Second, nanoparticles of “Magnetofood” are capable of activating the action of enzymes. This contributes to lowering the temperature and reducing the time of dough fermentation.

Thus, using the polyfunctional food supplement “Magnetofood” leads to a significant improvement in the quality indicators of rye-wheat bread. It could be applied when using raw materials of low quality, which was implemented in the design

of technology for the rye-wheat bread “Kharkivski rodnichok”. Given this perspective, the research results are of interest not only for Ukraine but for the entire scientific world.

7. Conclusions

1. It was established that the introduction to wheat flour of the polyfunctional food supplement “Magnetofood” helps to reduce the moisture content and acidity of dough:

- by 1.0 % and by 2.7–4.0 %, respectively (for the dough prepared using wheat flour of grade 1 and pressed yeast);
- by 5.8 % and by 7.1–8.2 %, respectively (for the dough prepared using flour of grade 2 and pressed yeast with low amylolytic activity).

2. It was proven that adding the food additive “Magnetofood” helps to reduce the time of dough fermentation:

- by 10.0–16.7 % (for the dough prepared using wheat flour of grade 1 and pressed yeast);
- by 7.1–14.3 % (for the dough prepared using flour of grade 2 and pressed yeast with low amylolytic activity);
- increases dough yield by 2.1–3.7 %.

3. It was established that the introduction of food additive “Magnetofood” to flour:

1) helps to reduce the moisture content and acidity of bread:

- by 1.0 % and by 7.1–10.7 %, respectively (for the dough prepared using wheat flour of grade 1 and pressed yeast);
- by 5.9 % and by 10.0–12.5 %, respectively (for the dough prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity);

2) helps increase porosity of the bread crumb:

- by 3.4–5.1 % (for the dough prepared using wheat flour of grade 1 and pressed yeast);
- by 3.6–5.4 % (for the dough prepared using wheat flour of grade 2 and pressed yeast with low amylolytic activity).

It was proven that experimental samples of the rye-wheat bread “Kharkivski rodnichok” with the addition of food additive “Magnetofood” demonstrated the yield of bread that is larger than that in control samples without added “Magnetofood” by 3.3–3.6 %.

4. It was established that using the polyfunctional food additive “Magnetofood” in the production of rye-wheat bread “Kharkivski rodnichok” improves its organoleptic properties: taste, color, porosity and condition of crumb, by 1–2 points on average, compared with control samples.

Based on the research results, we proposed functional scheme for a technological process of the rye-wheat bread “Kharkivski rodnichok” with the addition of polyfunctional food additive “Magnetofood”.

References

1. Nechaev, A. P. Pishchevaya himiya [Text]: ucheb. / A. P. Nechaev, S. E. Traubenberg, A. A. Kochetkova. – Sankt-Peterburg: GIORD, 2003. – 640 p.
2. Shilkina, E. Ingridyenty dlya uluchsheniya kachestva hlebobulochnyh i muchnyh konditerskih izdeliy [Text] / E. Shilkina // Hleboprodukt. – 2007. – Issue 12. – P. 40–43.
3. Tsyganova, T. B. Tekhnologiya hlebopekarnogo proizvodstva [Text]: ucheb. / T. B. Tsyganova. – Moscow: Profobrizdat, 2001. – 432 p.
4. Tsyganova, T. B. Tekhnologiya hlebopekarnogo proizvodstva [Text]: ucheb. / T. B. Tsyganova. – Moscow: Profobrizdat, 2001. – 432 p.
5. Lichko, N. M. Tekhnologiya hlebopekarnogo proizvodstva [Text] / N. M. Lichko; N. M. Lichko (Ed.). – Moscow: Kolos, 2000. – 552 p.
6. Chernyh, V. Uluchshenie kachestva muchnyh natsional'nyh izdeliy [Text] / V. Chernyh, D. Tsetsgee // Hleboprodukt. – 2007. – Issue 4. – P. 45–47.

7. Tsykhanovska, I. V. Doslidzhennia protsesiv okysniuvalnykh ta termichnykh peretvorenn v systemi: oliyno-lipido-mahnetytova suspenziya [Text] / I. V. Tsykhanovska, I. M. Demydov, Z. V. Barsova, L. F. Pavlotska // Prohresyivna tekhnika ta tekhnolohiy kharchovykh vyrobnytstv restorannoho hospodarstva i torhivli. – 2015. – Issue 1 (21). – P. 353–362.
8. Ilyuha, N. G. Production technology and quality indicators of food additives based on magnetite [Text] / N. G. Ilyuha, Z. V. Barsova, I. V. Tsihanovskaya, V. A. Kovalenko // Eastern-European Journal of Enterprise Technologies. – 2010. – Vol. 6, Issue 10 (48). – P. 32–35. – Available at: <http://journals.urau.ua/eejet/article/view/5847/5271>
9. Koniushenko, I. S. Syntez, fizyko-khimichni doslidzhennia i biolohichna diya mahnetytu na ob'ektakh in vivo [Text] / I. S. Koniushenko, Z. V. Barsova, I. V. Tsykhanovska // Zbirka tez dopovidei naukovykh i praktichnykh konferentsiy Vseukrainskyi konkurs studentskykh naukovykh robit za napriamkom «Khimichna tekhnolohiya ta inzheneriya». – Donetsk: Donetskyyi natsionalnyi tekhnichnyi universytet, 2011. – P. 54–57.
10. Buldakov, A. Pishchevye dobavki [Text]: spravochnik / A. Buldakov. – 2-e izd., pererab. i dop. – Moscow: SPb., 2008. – 280 p.
11. Drobot, V. I. Ispol'zovanie netraditsionnogo syr'ya v hlebopekarnoy promyshlennosti [Text] / V. I. Drobot. – Kyiv: Urozhay, 2008. – 152 p.
12. Chugunova, O. V. Modeling of organoleptic indicators of bread with plant supplements [Text] / O. V. Chugunova, E. V. Pastushkova // Bulletin of the South Ural State University. Series Food and Biotechnology. – 2015. – Vol. 3, Issue 4. – P. 80–87. doi: 10.14529/food150411
13. Tamazova, S. U. Food supplements based on vegetable raw materials in the production of baked goods and pastries [Text] / S. U. Tamazova, V. V. Lisovoy, T. V. Pershakova, M. A. Kasimirova // Polythematic Online Scientific Journal of Kuban State Agrarian University. – 2016. – Issue 122 (08). doi: 10.21515/1990-4665-122-076
14. Roslyakov, Yu. F. Nauchnye razrabotki dlya hlebopekarnoy i konditerskoy otrasley [Text] / Yu. F. Roslyakov, O. L. Vershinina, V. V. Gonchar // Tekhnologii pishchevoy i pererabatyvayushchey promyshlennosti APK-produkty zdorovogo pitaniya. – 2016. – Issue 6. – P. 42–47.
15. Roslyakov, Yu. F. Perspektivnye issledovaniya tekhnologiy hlebobulochnykh izdeliy funktsional'nogo naznacheniya [Text] / Yu. F. Roslyakov, O. L. Vershinina, V. V. Gonchar // Izvestiya vuzov. Pishchevaya tekhnologiya. – 2010. – Issue 1. – P. 123–125.
16. Gabdukaeva, L. Z. Charakteristika sovremennogo rynka hlebobulochnykh izdeliy dlya funktsional'nogo pitaniya [Text] / L. Z. Gabdukaeva, E. S. Sorokina // Vestnik Kazanskogo tekhnologicheskogo universiteta. – 2017. – Vol. 20, Issue 1. – P. 151–154.
17. Huzin, F. K. Perfection of technology of production of bakery products on the basis of crushed sprouted wheat grain [Text] / F. K. Huzin, Z. A. Kanarskaya, A. R. Ivleva, V. M. Gematdinova // Proceedings of the Voronezh State University of Engineering Technologies. – 2017. – Vol. 79, Issue 1. – P. 178–187. doi: 10.20914/2310-1202-2017-1-178-187
18. Magomedov, G. O. Razrabotka sbivnogo hleba funktsional'nogo naznacheniya iz muki tsel'nosmolotogo zerna pshenitsy, rzhanyh i pshenichnykh otrubey [Text] / G. O. Magomedov, N. P. Zatsopilina, A. A. Zhuravlev, V. L. Cheshinskiy // Vestnik Voronezhskogo gosudarstvennogo universiteta inzhenernykh tekhnologiy. – 2015. – Issue 4. – P. 104–112.
19. Matveeva, T. V. Fiziologicheski funktsional'nye pishchevye ingredienty dlya hlebobulochnykh izdeliy [Text] / T. V. Matveeva, S. Ya. Koryachkina. – Orel: FGBOU VPO «Gosuniversitet-UNPK», 2012. – 947 p.
20. Bakin, I. A. Izuchenie tekhnologicheskikh aspektov netraditsionnogo syr'ya v proizvodstve bulochnykh izdeliy [Text] / I. A. Bakin, A. S. Mustafina, A. Yu. Kolbina // Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta. – 2016. – Issue 12. – P. 128–134.
21. Tipsina, N. N. Kartofel'noe pyure kak uluchshitel' kachestva bulochnykh izdeliy [Text] / N. N. Tipsina, G. K. Seleznyova // Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta. – 2015. – Issue 12. – P. 81–86.
22. Belokurova, E. V. Ryabina chernoplodnaya – retsepturnyy komponent dlya bulochnykh izdeliy [Text] / E. V. Belokurova, M. A. Kurova, M. A. Kuznetsova // Vestnik Voronezhskogo gosudarstvennogo universiteta inzhenernykh tekhnologiy. – 2015. – Issue 2. – P. 135–138.
23. Potoroko, I. Application of stevioside in providing functional properties buns of bakery products [Text] / I. Potoroko, A. Paymulina // Bulletin of the South Ural State University. Series Food and Biotechnology. – 2015. – Vol. 3, Issue 3. – P. 63–68. doi: 10.14529/food150309
24. Bakin, I. A. Ispol'zovanie vtorykh resursov yagodnogo syr'ya v tekhnologii konditers'kikh i hlebobulochnykh izdeliy [Text] / I. A. Bakin, A. S. Mustafina, E. A. Vechtomova, A. Yu. Kolbina // Tekhnika i tekhnologiya pishchevykh proizvodstv. – 2017. – Vol. 45, Issue 2. – P. 5–12.
25. Sokol, N. V. Ispol'zovanie bogatogo pektinom rastitel'nogo syr'ya v hlebopekarnom proizvodstve [Text] / N. V. Sokol, N. S. Hramova // Politematicheskyy setevoy elektronnyy nauchnyy zhurnal KubGAU. – 2005. – Issue 07 (015). – P. 94–103.
26. Djahangirova, G. The use of herbal supplements to increase the nutritive value and physiologic significance of bakery products [Text] / G. Djahangirova // Universum: Tekhnicheskie nauki. – 2017. – Issue 1 (34). – Available at: [https://docs.google.com/viewer?url=http://7universum.com/pdf/tech/1\(34\)/Djahangirova.pdf](https://docs.google.com/viewer?url=http://7universum.com/pdf/tech/1(34)/Djahangirova.pdf)
27. Martins, Z. E. Food industry by-products used as functional ingredients of bakery products [Text] / Z. E. Martins, O. Pinho, I. M. P. L. V. O. Ferreira // Trends in Food Science & Technology. – 2017. – Vol. 67. – P. 106–128. doi: 10.1016/j.tifs.2017.07.003
28. Lai, W. T. A review: Modified agricultural by-products for the development and fortification of food products and nutraceuticals [Text] / W. T. Lai, N. M. H. Khong, S. S. Lim, Y. Y. Hee, B. I. Sim, K. Y. Lau, O. M. Lai // Trends in Food Science & Technology. – 2017. – Vol. 59. – P. 148–160. doi: 10.1016/j.tifs.2016.11.014

29. Dziki, D. Current trends in the enhancement of antioxidant activity of wheat bread by the addition of plant materials rich in phenolic compounds [Text] / D. Dziki, R. Różyło, U. Gawlik-Dziki, M. Świeca // Trends in Food Science & Technology. – 2014. – Vol. 40, Issue 1. – P. 48–61. doi: 10.1016/j.tifs.2014.07.010
30. Torres-León, C. Mango seed: Functional and nutritional properties [Text] / C. Torres-León, R. Rojas, J. C. Contreras-Esquivel, L. Serna-Cock, R. E. Belmares-Cerda, C. N. Aguilar // Trends in Food Science & Technology. – 2016. – Vol. 55. – P. 109–117. doi: 10.1016/j.tifs.2016.06.009
31. Bharath Kumar, S. Low glycemic index ingredients and modified starches in wheat based food processing: A review [Text] / S. Bharath Kumar, P. Prabhasankar // Trends in Food Science & Technology. – 2014. – Vol. 35, Issue 1. – P. 32–41. doi: 10.1016/j.tifs.2013.10.007
32. Patrignani, F. Innovative strategies based on the use of essential oils and their components to improve safety, shelf-life and quality of minimally processed fruits and vegetables [Text] / F. Patrignani, L. Siroli, D. I. Serrazanetti, F. Gardini, R. Lanciotti // Trends in Food Science & Technology. – 2015. – Vol. 46, Issue 2. – P. 311–319. doi: 10.1016/j.tifs.2015.03.009
33. Nitcheu Ngemakwe, P. H. Advances in gluten-free bread technology [Text] / P. H. Nitcheu Ngemakwe, M. Le Roes-Hill, V. Jideani // Food Science and Technology International. – 2014. – Vol. 21, Issue 4. – P. 256–276. doi: 10.1177/1082013214531425
34. Bird, L. G. Products of chickpea processing as texture improvers in gluten-free bread [Text] / L. G. Bird, C. L. Pilkington, A. Saputra, L. Serventi // Food Science and Technology International. – 2017. – Vol. 23, Issue 8. – P. 690–698. doi: 10.1177/1082013217717802
35. García-Segovia, P. Effect of microalgae incorporation on physicochemical and textural properties in wheat bread formulation [Text] / P. García-Segovia, M. J. Pagán-Moreno, I. F. Lara, J. Martínez-Monzó // Food Science and Technology International. – 2017. – Vol. 23, Issue 5. – P. 437–447. doi: 10.1177/1082013217700259
36. Boubaker, M. Fibre concentrate from artichoke (*Cynara scolymus* L.) stem by-products: Characterization and application as a bakery product ingredient [Text] / M. Boubaker, A. E. Omri, C. Blecker, N. Bouzouita // Food Science and Technology International. – 2016. – Vol. 22, Issue 8. – P. 759–768. doi: 10.1177/1082013216654598
37. Pat. No. 26696U UA. Sposib vyrobnytstva prianykiv "Badorist". MPK7 A21D13/08 [Text] / Yevlash V. V., Pohozhykh M. I., Niemirich O. V., Vinnikova V. O. – No. u200700379; declared: 15.01.2007; published: 10.10.2007, Bul. No. 16. – 5 p.
38. Yevlash, V. V. Tekhnolohiya khliba zhytno-pshenychnoho, shcho zbahachenyi na hemove zalizo, ta otsinka yakosti (pochatok) [Text] / V. V. Yevlash, O. V. Niemirich, V. O. Vinnikova // Hlebopekarskoe i konditerskoe delo. – 2008. – Issue 1 (16). – P. 48–51.
39. Yevlash, V. V. Tekhnolohiya khliba zhytno-pshenychnoho, shcho zbahachenyi na hemove zalizo, ta otsinka yakosti (zakinchennia) [Text] / V. V. Yevlash, O. V. Niemirich, V. O. Vinnikova // Hlebopekarskoe i konditerskoe delo. – 2008. – Issue 2 (16). – P. 48–50.
40. Tsykhanovska, I. Research into technological indicators of a rye-wheat dough semi-finished product with the addition of the polyfunctional food supplement «Magnetofood» [Text] / I. Tsykhanovska, V. Evlash, A. Alexandrov, T. Lazareva, K. Svidlo, T. Gontar // EUREKA: Life Sciences. – 2017. – Issue 6. – P. 43–50. doi: 10.21303/2504-5695.2017.00511
41. Ershov, P. S. Sbornik retseptur na hleb i hlebobulochnye izdeliya [Text] / P. S. Ershov. – Sankt-Peterburg: Profi-inform, 2004. – 190 p.