UDC 66.075.8
DOI: 10.15587/1729-4061.2017.111522

INFLUENCE OF THE POLYFUNCTIONAL FOOD SUPPLEMENT "MAGNETOFOOD" ON THE QUALITY OF THE WHEAT-RYE BREAD "KHARKIV RODNICHOK" IN THE STORAGE PROCESS

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Досліджено вплив поліфункціональної харчової добавки «Магнетофуд» на показники якості пшенично-житнього хліба «Харківський родничок» в процесі зберігання. Встановлено, що введення харчової добавки «Магнетофуд» в кількості 0,15 мас. % у вигляді ультратонкого порошку або у вигляді масляної суспензії (при цьому ОМС вводиться 0,35 мас. %) зменшує втрати вологи на 6,25 %, крошковатість м'якушки в 2,0 рази, КМАФАнМ в 4 рази, число спор бактерій Bac. subtilis в 1,5 рази; збільшує набухаємість м'якушки в 1,5 рази, еластичність на 6,5 %, пористість на 2,75 %

Ключові слова: магнетофуд, пшенично-житній хліб «Харківський родничок», антимікробна дія, набухаємість, крошковатість, еластичність, пористість, вологість м'якушки

Исследовано влияние полифункционального пищевой добавки «Магнетофуд» на показатели качества пшенично-ржаного хлеба «Харковский родничок» в процессе хранения. Установлено, что введение пищевой добавки «Магнетофуд» в количестве 0,15 мас. % в виде ультратонкого порошка или в виде масляной суспензии (при этом ОМС вводится 0,35 мас. %) уменьшает потерю влаги на 6,25 %, крошковатость мякиша в 2,0 раза, КМАФАнМ в 4 раза, число спор бактерий Bac. subtilis в 1,5 раза; увеличивает набухаемость мякиша в 1,5 раза, эластичность на 6,5 %, пористость на 2,75 %

Ключевые слова: магнетофуд, пшенично-ржаной хлеб «Харковский родничок», антимикробное действие, набухаемость, крошковатость, эластичность, пористость, влажность мякиша

1. Introduction

Creating an assortment of bakery products of functional purpose with an extended shelf life is one of the priority and topical tasks of the food industry [1, 2].

The quality of bread, which is a labile product, undergoes significant changes in the process of storage (staling, drying, color change, the appearance of unpleasant taste and smell, "potato" disease, molding) [3].

Various additives are used to improve the quality of bread [4–20]. Therefore, it is relevant to create new enrichment and polyfunctional food supplements of complex action.

As a food supplement, "Magnetofood" may be offered. This is a highly dispersed powder with a well-developed, active surface. "Magnetofood" has specific properties: bacteriostatic, antioxidant, complexing, moisture-retaining, sorption. It exhibits antimicrobial activity, emulsifying ability, good compatibility with proteins, carbohydrates [4, 5]. This entire complex of characteristics allows us to recommend "Magnetofood" as a polyfunctional food supplement in bakery products.

Therefore, the study of the influence of the polyfunctional food supplement "Magnetofood" on the quality of wheat-rye bread "Kharkiv Rodnichok" in the process of storage is relevant.

2. Literature review and problem statement

Improving the quality, nutritional value, resistance to microbial damage, extending the shelf life, improving the range of bakery products contribute to the implementation of the modern concept of healthy eating [1, 2].

The following is a list of the most common enhancement supplements in breadmaking.

In breadmaking, pectin and its derivatives are used, which help to fill the shortage of biologically active substances [6]. Their disadvantage is a significant crumbliness and insufficient elasticity of the crumb. Modified starches are used in the recipes of bakery products [7]. However, these enhancers do not possess antimicrobial activity.

Oils prolong the shelf life of bakery products [8], but do not provide sufficient structural and mechanical and physico-chemical indicators.

The use of wheat gluten has significantly expanded, which allows increasing the shelf life, reducing the crumbliness [9]. The disadvantages include the low antioxidant and antimicrobial threshold.

The surface-active component – lecithin, improves the quality of the dough, increases the porosity of the crumb [10]. However, lecithin does not have antimicrobial activity and does not provide sufficient output of finished products.

In modern food technologies, functional ingredients derived from industrial by-products (skin, hooves, feathers, offal, seeds, bran, whey, etc.) are widely used. However, these additives are characterized by a narrow effect and do not have complex action [11, 12].

Bread containing wheat flour is a food with a low antioxidant capacity. In recent years, there has been a global trend towards the enrichment of bread with phenolic antioxidants of vegetable origin [13, 14]. The disadvantages of these additives are low functionality regarding the texture and physico-chemical properties of bakery products.

To improve the health of consumers, wheat-based supplements with low GI content are used [15]. However, output and structural-mechanical characteristics of finished products are not improved.

The use of essential oils as natural antimicrobial agents of bakery products was noted [16]. In this case, the elasticity and porosity of the crumb are not improved.

In order to improve the quality of bread (especially gluten-free), various additives are proposed: some dairy products, soybean, eggs, enzymes, hydrocolloids, chickpea, microalgae, etc. [17–20]. Additives have a number of disadvantages, for example: chickpea negatively affects the quality of bread due to loss of solubility in baking, hardness; and elasticity are not modified by the addition of microalgae, while others do not improve the dimensional stability, yield, acidity and moisture content of the crumb.

The powder-based dietary supplement "Gemovital", used to form an assortment of antianemic flour products is known [21], however, it does not provide sufficient rheological parameters.

The analysis of information sources did not reveal data on the influence of polyfunctional food supplements, in particular, nanopowders, on the quality and shelf life of bakery products.

Therefore, it is necessary to carry out the following scientific research:

– to study the influence of nanopowder polyfunctional food supplement on the quality indices of bakery products during storage;

– to study the effect of nanopowder polyfunctional food supplement on the shelf life and microbiological parameters of bakery products during their storage.

3. The aim and objectives of the study

The aim of the work is to study the influence of the polyfunctional food supplement "Magnetofood" on the quality indicators of wheat-rye bread "Kharkiv Rodnichok" in the process of storage and to determine a guaranteed shelf life of the bread.

To achieve the aim, the following objectives were set:

– to study the influence of the food supplement "Magnetofood" on the organoleptic parameters of the experimental samples of wheat-rye bread "Kharkiv Rodnichok" in the process of their storage;

– to study the influence of the food supplement "Magnetofood" on the physico-chemical parameters of the experimental samples of bread "Kharkiv Rodnichok" in the process of their storage;

– to study the influence of the food supplement "Magnetofood" on the structural and mechanical parameters of the experimental samples of bread "Kharkiv Rodnichok" in the process of their storage;

– to study the effect of the polyfunctional food supplement "Magnetofood" on the microbiological parameters of the experimental samples of wheat-rye bread "Kharkiv Rodnichok" in the process of their storage.

4. Materials and methods of studying the food supplement "Magnetofood"

4. 1. Explored materials and equipment used in the experiment

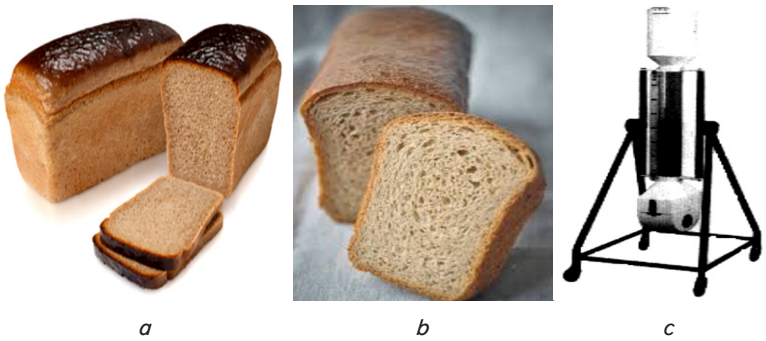
The following was used in the study:

– control – wheat-rye bread "Darnytskyi" [GOST 26983-2015 and DSTU-P 4583: 2006];

– sample 1 – wheat-rye bread "Kharkiv Rodnichok" with 0.15 % "Magnetofood" in the form of powder [4];

– sample 2 – wheat-rye bread "Kharkiv Rodnichok" with 0.15 % "Magnetofood" in the form of oil-magnetofood suspension (OMS), 0.35 wt. % OMS is introduced [5].

Fig. 1, 2 show the experimental samples of wheat-rye bread "Kharkiv Rodnichok" and devices used for the research on quality indicators of bread.



a *b* *c*

Fig. 1. Experimental bread samples and a unit for determining the specific size: *a* – bread "Kharkiv Rodnichok"; *b* – Darnytskyi bread; *c* – size-meter RZ-BIO

a *b* *c* *d*

Fig. 2. Devices used for research of qualitative indicators of bread:
a – device Zhuravlev; *b* – penetrometer AP-4/2; *c* – amilograph-E; *d* – VFH-250

The specific size of the bread was measured with the help of the size-meter RZ-BIO (Russia); determination of the crumb porosity was carried out on the device Zhuravlev; swelling – on amylograph (Amylograph "Amilographer-E", "Brabender" company, Germany).

Structural-mechanical properties (elasticity, shrinkage) – on automated penetrometer AP-4/2 ("Feynmass" company, Germany). Sizes of the bread were determined on the device VFH-250 (analog Y1-ENX) (Russia).

4. 2. Methods of determination of organoleptic, physico-chemical, structural and microbiological parameters

In the process of performing the experimental work, standard research methods were used [22–30].

Organoleptic evaluation of the wheat-rye bread quality was carried out in accordance with GOST 52961-2008 and DSTU-P 4583:2006. The assessment of freshness was carried out on a 5-point scale of the following gradation: very fresh 5, fresh 4, moderately stale 3, stale 2, very stale 1 [22].

Determination of humidity was driven by the standard accelerated method according to GOST 21094-75. Porosity was determined by the standard method [23, 24]. The mass fraction of bound damp was detected by indicator medote [22, 25]. The structural and mechanical properties of bread crumb (elasticity, shrinkage) were determined on a penetrometer AP-4/2 [22, 24]. Crushing was determined by the ratio of the mass of the formed crumb to the mass of the cake [22, 23]. Dimensional stability and specific volume were determined by standard methods [22–24].

The list of microbiological indicators, which were used to control the quality of finished bakery products, was established in accordance with the requirements of DSP 4.4.5.078 and MBT No. 5061-89 [26–28]. To determine the bactericidal threshold of the action of the food supplement "Magnetofood" in relation to spore bacteria, bacteria were added to the flour in the amount of 1·103 spores/g of flour. After baking, the products were incubated in provocative conditions (humidity 80–85 %, temperature 15–25 °C) for three days and the number of CFU (colony-forming units) Bac. subtilis in the crumb sample was determined by sowing on MPA (meat-peptone agar) and incubation at +40 °C within one day.

The study of the influence of the polyfunctional food supplement "Magnetofood" on the quality of wheat-rye bread "Darnytskyi" and "Kharkiv Rodnichok" during storage was carried out on prototype samples (control, sample 1, 2 – see section 4.1.). As a basic formulation in the research, the formula for wheat-rye bread "Darnytskyi" [GOST 26983-2015 and DSTU-P 4583: 2006] was chosen (Table 1). Baking was carried out at a temperature of 180–200 °C for a further 3 to 5 minutes [JU 15.8-37-00032744-004: 2005].

Table 1

Recipe for experimental samples of wheat-rye bread "Darnytskyi" and "Kharkiv Rodnichok" with the food supplement "Magnetofood"

Ingredients of experimental samples of wheat-rye bread	Bread "Darnytskyi"	Bread "Kharkiv Rodnichok" with the food supplement "Magnetofood" (0.15 %)	
		In the form of a powder	In the form of a suspension (OMS – 0.35 %)
	Control	Sample 1	Sample 2
Net weight of one loaf, kg	0.7	0.7	0.7
The composition of the product (per 100 kg)	–	–	–
Wheat Flour Extra Class, kg	80	80	80
Flour rye peeled, kg	20	20	20
Yeast, compressed, kg	1.0	1.0	1.0
Salt, kg	1.5	1.5	1.5
Magnetofood, kg	–	0.15	–
OMS, kg	–	–	0.35

Experimental samples of the bread were stored at a temperature of (20±2) °C and relative humidity (75±2) %, and in regimes corresponding to the necessary storage conditions [JUU 15.8-37-00032744-004:2005]. The evaluation of bread quality indicators was carried out in several stages: 6, 12, 24, 36, 48, 60, 72, 84 hours after baking.

Table 2 shows the chemical composition, nutritional value and shelf-life of experimental samples of wheat-rye bread "Darnytskyi" and "Kharkiv Rodnichok".

The data in Table 2 show an increase in the content of the trace element Fe, the energy value and the shelf life of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control.

Table 2

Chemical composition, nutritional value and shelf-life of experimental samples of wheat-rye bread "Darnytskyi" and "Kharkiv Rodnichok"

Experimental samples of bread	Chemical composition, g/100 g of the product				Energy value, kcal/100 g (kJ/100 g)	Shelf life, hours
	Proteins	Fat	Carbohydrates	Micro element, mg: Fe		
Control	7.4	0.9	47.0	–	216.0 (904.0)	72
Sample 1	7.4	0.9	47.0	3.0	216.0 (904.0)	84
Sample 2	7.4	1.24	47.0	3.0	219.0 (916.6)	84

5. Results of research on the influence of the food supplement "Magnetofood" on the quality indices of test samples of wheat-rye bread

The results of the assessment of the degree of freshness of the experimental samples of wheat-rye bread "Kharkiv Rodnichok" in comparison with "Darnytskyi" bread by the organoleptic method during storage are shown in Fig. 3. The first changes in the bread can be set in about 9–10 hours after baking (Fig. 3).

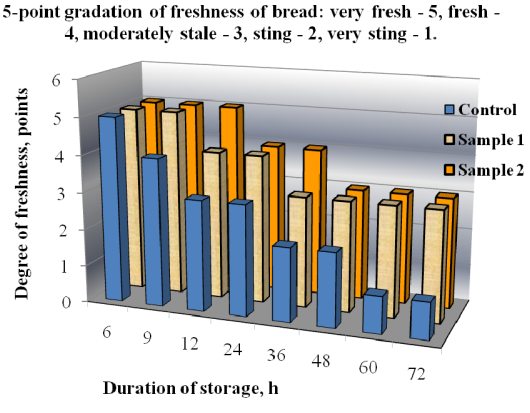


Fig. 3. Influence of the food supplement "Magnetofood" on the freshness of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control during storage

Fig. 4 shows the influence of the food supplement "Magnetofood" on the shrinkage of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage.

Analysis of experimental data in Fig. 4 shows that the introduction of the food supplement "Magnetofood" improves the quality of wheat-rye bread, because its shrinkage is lower than that of the control sample and is practically maintained for the first 36 hours.

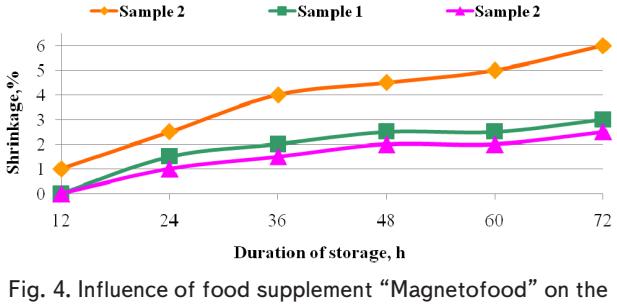


Fig. 4. Influence of food supplement "Magnetofood" on the shrinkage of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control during storage

Fig. 5 shows the influence of the food supplement "Magnetofood" on the elasticity of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage.

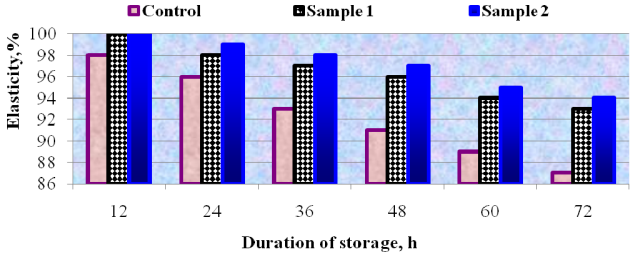


Fig. 5. Influence of the food supplement "Magnetofood" on the elasticity of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control during storage

From Fig. 5, it is evident that the introduction of the food supplement "Magnetofood" contributes to a significant increase in the elasticity of the experimental samples of wheat-rye bread "Kharkiv Rodnichok" in comparison with the control. Fig. 6 shows the dynamics of changes in the moisture content of the experimental samples of wheat-rye bread "Kharkiv Rodnichok" in comparison with the control in the process of storage.

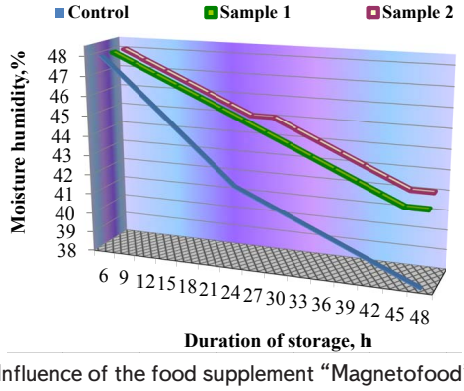


Fig. 6. Influence of the food supplement "Magnetofood" on the moisture content of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control during storage

From Fig. 6, it follows that after 48 hours of storage, the moisture losses of wheat-rye bread were: for the control: 21 %, for the bread "Kharkiv Rodnichok" (sample 1 and sample 2): 12.5 % and 10.4 %, respectively. Fig. 7 shows the influence of the food supplement "Magnetofood" on the compressibility of the crumb of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control during storage for 60 hours.

From Fig. 7, it is evident that when storing bread for 60 hours, the compression of the crumb is reduced for the

control – 9 times, for samples 1, 2 (bread "Kharkiv Rodnichok", enriched with the food supplement "Magnetofood") – 7 and 6 times, respectively.

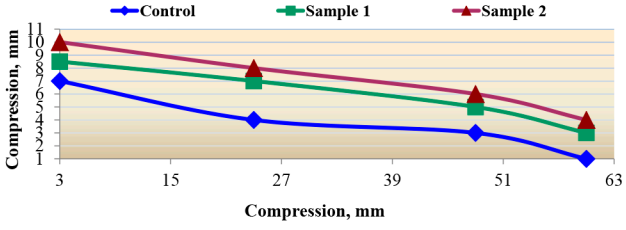


Fig. 7. Influence of the food supplement "Magnetofood" on the compressibility of the crumb of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage

Preserving the freshness of bread to a certain extent depends on the structure, specific capacity and dimensional stability Table 3 shows the influence of the food supplement "Magnetofood" on the dimensional stability and specific volume of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage.

Table 3

Influence of the food supplement "Magnetofood" on the dimensional stability and specific volume of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage

Quality indicators of wheat-rye bread	Experimental samples of wheat-rye bread								
	Control			Sample 1			Sample 2		
	Shelf life, hours								
	0	36	72	0	36	72	0	36	72
Dimensional stability: $F=N/P$	0.45	0.43	0.41	0.57	0.57	0.56	0.60	0.60	0.60
Specific volume, cm^3/g	4.09	4.05	4.00	5.11	5.11	5.10	5.21	5.21	5.21

Fig. 8 shows the influence of the food supplement "Magnetofood" on the porosity of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage.

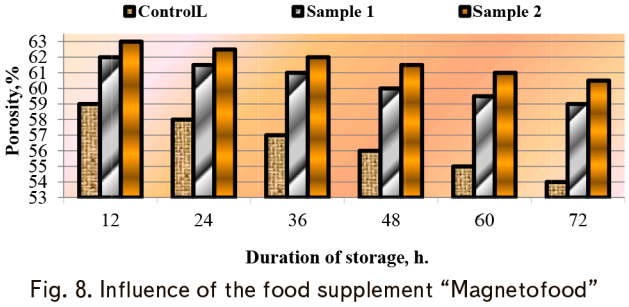


Fig. 8. Influence of the food supplement "Magnetofood" on the porosity of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage

Experimental data in Fig. 8 show that changes in the porosity of wheat-rye bread "Kharkiv Rodnichok" correspond to trends in the change of specific volume (Table 3): in samples 1 and 2, the value of specific volume and elasticity is greater than that of the control. The experimental samples of bread "Kharkiv Rodnichok", enriched with the food supplement "Magnetofood", had good elasticity and well-developed uniform porosity; pores of the same size with thin walls; the crumb did not crumble and did not rumple.

For a more in-depth study of the process of staling of wheat-rye bread, the parameters of swelling and crumbliness of the crumb were determined.

The results of the determination of the crumbliness index for the experimental samples of wheat-rye bread are presented in Fig. 9. From the experimental data of Fig. 9 it follows that gradually, in the process of storage, the value of crumbliness increased in all the samples under study.

In parallel with the growth of crumbliness, there are changes in the values of swelling (Fig. 10). But this process is reversible.

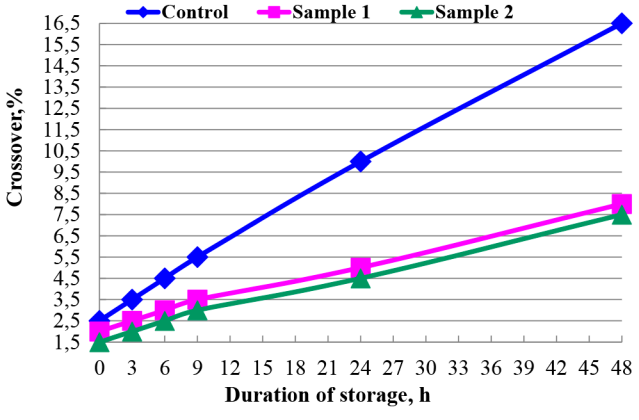


Fig. 9. Influence of the food supplement "Magnetofood" on the crumbliness of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control during storage

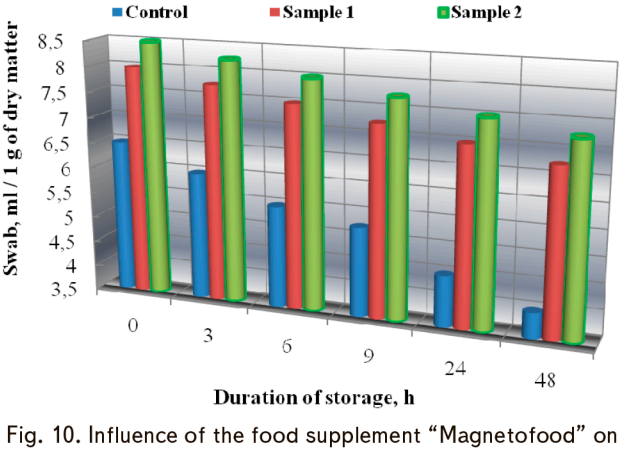


Fig. 10. Influence of the food supplement "Magnetofood" on the swelling of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control during storage

Table 4 shows the microbiological parameters of the experimental samples of wheat-rye bread immediately after baking and after storage for 72 hours and 10 days (in determining the number of Bac. subtilis spores).

The obtained data confirm the antimicrobial action of the food supplement "Magnetofood" and the microbiological safety of wheat-rye bread "Kharkiv Rodnichok" and the compliance with the standards established for this type of products [26–28].

Table 4

Influence of the food supplement "Magnetofood" on the microbiological parameters of the experimental samples of bread "Kharkiv Rodnichok" in comparison with the control in the process of storage

Indicator	Standard	Experimental samples of wheat-rye bread		
		Control	Sample 1	Sample 2
QMAFAnM, CFU/g, immediately/after 72 hours	1.0×10^3	$1.0\times10^3/1.2\times10^3$	$0.25\times10^3/0.30\times10^3$	$0.22\times10^3/0.26\times10^3$
S.aureus, immediately/after 72 hours	not allowed in 1.0 g	absent in 1.0 g	absent in 1.0 g	absent in 1.0 g
Coliforms, immediately/after 72 hours	not allowed in 0.001 g	absent in 0.001 g	absent in 0.001 g	absent in 0.001 g
Proteus, immediately/after 72 hours	not allowed in 0.1 g	absent in 0.1 g	absent in 0.1 g	absent in 0.1 g
Salmonella, L.monocytogenes, immediately/after 72 hours	not allowed in 25.0 g	absent in 25.0 g	absent in 25.0 g	absent in 25.0 g
The number of Bac. Subtilis spores, CFU/g, immediately/after 72 hours	0.4×10^3	$0.20\times10^3/0.26\times10^3$	$0.15\times10^3/0.16\times10^3$	$0.13\times10^3/0.15\times10^3$
The number of Bac. Subtilis spores, CFU/g, immediately/after 10 days	0.4×10^3	$0.20\times10^3/0.40\times10^3$	$0.15\times10^3/0.20\times10^3$	$0.13\times10^3/0.17\times10^3$

6. Discussion of the results of the study of the influence of the polyfunctional food supplement "Magnetofood"

The polyfunctional food supplement "Magnetofood" is an ultrathin powder with a particle size of 30–60 nm. It has beneficial properties: bacteriostatic, antioxidant, emulsifying, sorption, complexing, fat- and moisture-retaining [4, 5]. Therefore, "Magnetofood" can be offered as a polyfunctional food supplement.

In order to introduce the polyfunctional food supplement "Magnetofood" in wheat-rye bread, two methods were used:

1) the food supplement "Magnetofood" was introduced in a dry form when mixing the dough in the amount of 150 g per 100 kg of flour;

2) the food supplement "Magnetofood" was introduced in the form of OMS (oil-magnetite suspension) in the amount of 350 g per 100 kg of flour when mixing the dough. The optimum amounts of the food supplement "Magnetofood" and OMS were selected experimentally. The optimum ratio in the suspension of "Magnetofood": surfactant (monoacylglycerol)=15.0 wt. %: 65.0 wt. % [5].

According to the data of Table 2, it follows that in the experimental samples of wheat-rye bread "Kharkiv Rodnichok" with the food supplement "Magnetofood" in comparison with the control, the shelf life of the finished product increases by 12 hours, its biological and energy value increase.

An organoleptic analysis of the degree of freshness of the experimental bread samples was carried out using the 5-point scale, for which a close correlation with the value of the elasticity modulus of the crumb was established, and the correlation coefficient was 0.96.

The results of the evaluation of freshness of the experimental samples of wheat-rye bread (Fig. 3) showed that the food supplement "Magnetofood" slows down the processes of bread staling. The greatest difference in the degree of freshness of the experimental samples – 2 points was noted after 12, 36, 60 and 72 hours.

Analysis of shrinkage of the experimental bread samples (Fig. 4) shows that on the first day after baking, the bread almost does not stale, after 24 hours: the shrinkage is: for the control – 2.5 %, for samples 1.2–1.5 % and 1.0 %, respectively. In addition, in samples 1, 2, such shrinkage is practically maintained for the first 36 hours, unlike the control, where it grows 1.6 times. After 72 hours, shrinkage increases: for the control – up to 6.0 %, for samples 1, 2 much less – up to 3.0 % and 2.5 %, respectively.

With increasing the storage period, the elasticity of all experimental samples of bread is reduced (Fig. 5): after 24 hours for the control – by 4.0 %, for samples 1, 2 significantly less – by 2.0 % and 1.0 %, respectively. After 72 hours, elasticity decreases: for the control – by 13.0 %, for samples 1, 2 – much less: by 7.0 % and 6.0 %, respectively.

In Fig. 6, the curves characterizing the loss of moisture in the experimental samples of wheat-rye bread show that this process takes place most intensively in the first 24 hours of storage: for the control – 12.5 %, for samples 1, 2 less – 6.25 %. In the next 24 hours, the loss of moisture in the bread is reduced: for the control – 9.5 %, for samples 1, 2 – 7.8 % and 6.7 %, respectively. That is, the food supplement "Magnetofood" slows down the process of moisture loss and, as a consequence, shrinkage of bread in the process of storage.

The compressibility of the crumb is one of the main indicators by which the consumer assesses the degree of freshness or staleness of bread. Fig. 7 shows that when storing bread for 60 hours, the crumb compressibility is reduced for the control – 9 times, for samples 1, 2 – 7 and 6 times, respectively. At the same time, the mechanical strength of pore walls increases. Bread is considered stale when its compressibility decreases by more than 40 % [4, 30]. In our case, the compressibility of the experimental samples of wheat-rye bread decreases: by 40 % for the control – after 22 hours, for samples 1, 2 – 47 and 48 hours, respectively.

From Table 3, it follows that the polyfunctional food supplement "Magnetofood" improves the dimensional stability and specific volume of wheat-rye bread: in comparison with the control, the specific volume in samples 1 and 2 increases by 26.4 % and 27.4 %, respectively; dimensional stability – by 26.7 % and 33.3 %, respectively. Large specific volume is characteristic for bread with well-developed porosity and thin walls, which can increase its period of storage in fresh form. Besides, digestibility of bread is better, the higher the porosity and specific volume.

The increase in the specific volume and dimensional stability of the bread is probably due to the complex formation and clusterization abilities of the polyfunctional food supplement "Magnetofood".

From Fig. 8, it follows that the introduction of the food supplement "Magnetofood" contributes to the improvement of porosity of bread – after 24 hours, the porosity decreases:

for the control – by 1.0 %, for samples 1, 2 less – by 0.5 %. After 72 hours, the porosity decreases: for the control – by 5.0 %, for samples 1, 2, much less – by 3.0 % and 2.5 %, respectively.

The data presented in Fig. 9 suggest that wheat-rye bread without supplements (control) was different from the bread "Kharkiv Rodnichok", enriched with the food supplement "Magnetofood" (samples 1, 2) by higher values of crumbliness, and this tendency was maintained for 48 hours. That is, the samples 2, 3 had a more elastic crumb. This is probably due to the presence of the food supplement "Magnetofood", which is characterized by moisture-retaining ability.

When analyzing Fig. 10, we can say that changes in the swelling index of the experimental samples most intensively occur in the first 12–20 hours after baking. The swelling of the crumb of the samples of 1, 2 at all stages of storage is higher than that of the control. This is probably due to the formation of hydrophilic complexes of the food supplement "Magnetofood" with the components of wheat-rye bread "Kharkiv Rodnichok".

After 48 hours, the value of swelling reached: for the control – 4.0 ml per 1 g of dry substances versus 6.75 and 7.25 ml per 1 g of dry substances in samples 1, 2, more than 1.7 and 1.8 times, respectively.

The analysis of microbiological indicators of bread (Table 4) shows that the number of microorganisms (QMAFAnM) in 1 g of samples 1, 2 decreases 4.0–4.2 times both immediately and after 72 hours; the number of Bac. subtilis spores after 10 days increases: in the control 2 times, and in samples 1, 2 –1.3 times. In this case, coliforms in 0.001 g of the bread, bacteria of the genus Salmonella and L. monocytogenes – in 25.0 g were not found.

The decrease in the number of microorganisms is probably due to the bacteriostatic and bactericidal action of the food supplement "Magnetofood", which confirms the possibility of using "Magnetofood" as a food supplement that exhibits antimicrobial activity. And this, together with the above-listed indicators leads to an improvement in the quality of wheat-rye bread and to extending the term of its storage in fresh form.

In this work, two technological methods of introduction of the food supplement "Magnetofood" in a dough (in the form of a powder or as an oil suspension) were also evaluated. Analysis of experimental data (Table 2–4), Fig. 1–10 showed that of all the considered indicators, the quality of wheat-rye bread is by 0.5–0.8 % better when introducing the supplement "Magnetofood" into a dough in the form of an oil suspension (OMS).

This work is the development of the application of nanotechnology in the food industry. Will nanotechnology in the food industry be welcomed by consumers, will they be desirable and in demand?

According to the AVC Research, the global volume of nanotechnology market is about $ 12 billion [32] and with the minimum growth in five years will increase more than twice. The volume of sales of Russian nanoproducts in 2015 exceeded 300 billion rubles [32–34]. At present, the total capacity of the food nanotechnology market reaches 2.7 billion euros [33]. Worldwide sales of food nanoproducts are increasing, and, apparently, this trend will continue. This process was initiated in 2000, when the American company Kraft Foods founded the first nanotechnology laboratory and the consortium "Nanotek", which covers 15 universities from different countries. Since 2005, the conferences on integrating nanotechnologies into the food industry "Nanofood" have been held every year, among the main goals of which are improving the quality, health benefits, safety of products, prevention of certain diseases, creation of therapeutic and prophylactic and functional products [34].

To date, the world market already has several hundreds of foods produced using nanotechnology. Basically, such products are distributed in the markets of the USA, the Asian region and Europe. Among the food "nanoproducts" that have already been or will soon be available for sale, we can mention the dairy product of Friesland Campina with nanoparticles for faster calcium absorption. In Australia, bread is baked with the addition of nanocapsules containing tuna fat. In Russia, silver nanobiocomposite (Patent No. 2245151) is added to the bakery products as an antiseptic. The use of nanoactivated media in the production of minced meat products allows excluding chemical additives (carrageenan, phosphates) from chemical formulations and improving the technological parameters of meat products (yield, organoleptic characteristics) [34].

However, all known food nanoadditives have a narrow effect and do not exhibit a complex effect on the quality of food products. In addition, synthetic nanoadditives often have a toxic effect on the human body.

The scientific community does not clearly assess the possibility of using nanotechnologies in the creation of food products. According to experts of the Great Britain Food Standards Agency, the effects of nanotechnology products on the human body require additional analysis [35]. In this regard, in 2000, 57 countries signed the Cartagena Protocol, which established the so-called precautionary principle. Official documents show that nanoparticles have an active, well-developed surface; the complex of physical, chemical properties and biological action (sometimes toxic), which is often radically different from the properties of this substance in the form of continuous phases or macroscopic dispersions [34]. All this determines both the positive effect of nanoadditives on technological characteristics and quality indicators of food and can cause quite specific risks when using them as a part of food products.

For the first time at the state level, official certification of food nanoproducts was introduced in Taiwan, where in 2005 the "Nano-Mark" certificate was developed. Products with such a mark must meet at least two requirements: the size of nanoparticles must be in the range from 1 to 100 nm; a nanoproduct should have fundamentally new consumer properties or improved characteristics precisely due to its nanosized dimensions. In total, Taiwan has certified 42 nanoproducts [34].

The British non-governmental organization Soil Association (SA), dealing with the certification of organic products, has refused to certify nanotechnology products, referring to the danger to human health. It is believed that the SA standards are tighter than the UK and EU regulatory documents. Many British analysts in the field of nanotechnology have responded to this statement critically. Given the importance and priority of new technologies, the Russian Corporation of Nanotechnologies was established in the Russian Federation, the Federal Law No. 139-FZ of July 19, 2007 "On the Russian Corporation of Technologies" was adopted, the government allocated more than $ 1 billion for the development of nanotechnology [34].

The aim of this work was to study the influence of the polyfunctional food supplement "Magnetofood" on the

quality indicators of wheat-rye bread "Kharkiv Rodnichok". It has been experimentally found that "Magnetofood" can be used as a polyfunctional food supplement with complex action: it has a beneficial biological effect on the human body; due to the nanosize, well-developed active surface, compatibility with proteins and carbohydrates, the presence of iron cations, possesses sorption, complexing, emulsifying, moisture and fat-retaining properties; due to bacteriostatic and bactericidal action, shows antimicrobial activity, which leads to improvement of quality, preservation of freshness and extension of the terms of storage of bakery products. In addition, the food supplement "Magnetofood" due to Fe^{2+} can be recommended as an antioxidant and a source of easily digestible iron and antianaemic agent. Thus, the introduction of the polyfunctional food supplement "Magnetofood" in wheat-rye bread increases its quality and storage time [4, 5]. From this perspective, the research results are of interest not only for Ukraine, but also for the scientific world of other countries.

7. Conclusions

1. Investigation of the degree of freshness of the experimental samples of wheat-rye bread "Darnytskyi" and "Kharkiv Rodnichok", enriched with the polyfunctional food supplement "Magnetofood", was carried out by the organoleptic method. The results of the assessment of freshness showed that the bread staling process proceeds more intensively without the food supplement "Magnetofood". Immediately after baking, all the experimental samples were marked with five points. In 12 hours, the difference in the degree of freshness of the samples was 2 points.

2. The influence of the food supplement "Magnetofood" on the physico-chemical parameters of the experimental samples of wheat-rye bread in the course of their storage was studied.

The most intense loss of moisture occurs in the first 24 hours of storage: in the control – 12.5 %, in samples 1, 2 – 6.25 %; and after 48 hours of storage – 21.0 % and 11.5 %, respectively.

In the process of storage, the value of crumbliness grew gradually, and the rate of swelling decreased in all the experimental samples: this process occurred most intensively in the first 12–20 hours after baking. In addition, the control differed from the samples 1, 2 by higher values of crumbliness, and this trend was maintained throughout the storage period.

The swelling of the crumb of bread samples for 48 hours: was: for the control – 4.0 ml per gram of dry matter versus 6.75 and 7.25 ml per 1 g of dry matter in samples 1, 2, correspondingly, which is more by 1.7 and 1.8 times.

3. The influence of the food supplement "Magnetofood" on the structural and mechanical parameters of the experimental samples of wheat-rye bread in the course of their storage was studied.

The shrinkage of the samples with the supplement "Magnetofood" over time is lower than that of the bread without the food supplement and is practically maintained for the first 36 hours. With an increase in the storage period, the elasticity of all the experimental samples decreases: after 24 hours – by 4.0 % and 2.0 % and 1.0 %, and after 72 hours – by 13.0 % and by 7.0 % and 6.0 % for the control and samples 1, 2, respectively. This is due to the gradual drying of the bread crumb. But with the introduction of the food supplement "Magnetofood", there is a significant increase in the elasticity of the bread samples, probably due to the moisture-retaining capacity of "Magnetofood".

The polyfunctional food supplement "Magnetofood" improves the specific volume and dimensional stability of bread: compared to the control, the specific volume in samples 1, 2 increases by 26.4 % and 27.4 %, respectively; dimensional stability – by 26.7 % and 33.3 %, respectively. This effect is probably due to the complex formation and clustering abilities of "Magnetofood".

In all the experimental samples, porosity decreases with time: after 24 hours after baking – by 1.0 % and 0.5 %; after 72 hours – by 5.0 % and by 3.0 % and 2.5 % for the control and samples 1, 2, respectively.

4. The influence of the polyfunctional food supplement "Magnetofood" on the microbiological parameters of the experimental samples of wheat-rye bread in the process of their storage was studied.

The level of total microbial contamination of both freshly baked wheat-rye bread and bread stored for 72 hours (and 10 days) at a temperature of 20 °C did not exceed the permissible levels and was: after baking and cooling – the number of microorganisms (QMAFAnM) in 1 g of samples 1, 2 compared with the control decreases 4.0–4.2 times both immediately and after 72 hours; the number of Bac. subtilis spores after 10 days increases: in the control 2 times, and in samples 1, 2 – 1.3 times. All the experimental samples stored at a temperature of 20 °C for 72 hours (and 10 days) were in compliance with the microbiological standards established for this product in Ukraine [26, 27].

That is, the food supplement "Magnetofood" has the antimicrobial effect and increases the quality and shelf life of wheat-rye bread.

Thus, the results of the studies allow justifying the expediency of using the polyfunctional food supplement "Magnetofood" in the technology of wheat-rye bread.

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UDC 664 : [663.26 : [641.1 : 613.31]
DOI: 10.15587/1729-4061.2017.108992

RESEARCH OF EXTRACTION OF BIOLOGICALLY ACTIVE SUBSTANCES FROM GRAPE POMACE BY SUBCRITICAL WATER

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Досліджено процес вилучення біологічно активних речовин з виноградних вичавок субкритичною водою. Ідентифіковано наявність галової кислоти і фурфуролу. Встановлено вплив технологічних параметрів процесу екстрагування (розмір фракції сухих виноградних вичавок, температура, тиск, гідромодуль) на антиоксидантну активність екстрактів, вихід сухих речовин, загальний вихід поліфенолів, винно-кислих сполук, редукуючих речовин. Визначено раціональні параметри даного процесу

Ключові слова: виноградні вичавки, біологічно активні речовини, екстрагування, субкритична вода, антиоксидантна активність

Исследован процесс извлечения биологически активных веществ из виноградных выжимок субкритической водой. Идентифицировано наличие галловой кислоты и фурфурола. Установлено влияние технологических параметров процесса экстрагирования (размер фракции сухих виноградных выжимок, температура, давление, гидромодуль) на антиоксидантную активность экстрактов, выход сухих веществ, общий выход полифенолов, винно-кислых соединений, редуцирующих веществ. Определены рациональные параметры данного процесса.

Ключевые слова: виноградные выжимки, биологически активные вещества, экстрагирование, субкритичная вода, антиоксидантная активность

1. Introduction

According to the UN FAO (Food and Agriculture Organization of the United Nations), the world production of grapes is more than 76 million tons per year. The production of grapes in Ukraine in recent years has been growing, and in 2016 exceeded 390 thousand tons [1].

As a result of grape processing, up to 20 % of waste grape pomace (GP) is produced, which has a rich polysaccharide complex and contains a considerable amount of phenolic