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Methods for ensuring the quality and safety of raw materials used in food for athletes

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Abstract. The aim of the study is the scientific justification of new concepts for ensuring the safety of raw materials of plant origin for subsequent use in food for athletes. As a result of studies of dried fruits, they were found to contain fungi of the genus Penicillium, Mucor, Phomopsis. For disinfection, the energy of an electromagnetic field of ultra-high frequency (EMF-UHF) was applied. When using the minimum exposure modes, a decrease in spore content was almost halved, the organoleptic qualities corresponded to the control sample. At the maximum exposure mode, a significant reduction in infection or a complete elimination of bacteria was observed, while organoleptic qualities corresponded to the control sample. As a result of microwave exposure, there was a decrease in moisture in dried fruits by 1-3.8% and an increase in the mass fraction of total sugar by 6%. The influence of microwave exposure on vitamin C is considered: the content of vitamin C decreased by 1% compared with the control sample. Thus, the processing of dried fruits by the microwave field allows decreasing their bacterial content, preserving the raw materials for processing and to improving its taste properties. Based on dried fruits subjected to microwave exposure and flaxseed flour scientists of the Russian State Agrarian University developed a new product - "Frutolen". This product is enriched with vitamins of group B, C, β-carotene, pectin and fiber. Due to the sugars of dried fruits used in production, granulated sugar is not used in the Frutolen recipe. Flaxseed flour is a valuable source of fiber, polyunsaturated fatty acids and minerals.

Keywords: dried fruits, microwave field, seeds, elimination of bacteria, functional foods.

The modern food market is divided into individual segments depending on consumer groups. Such segmentation is aimed at orienting various population groups towards a healthy lifestyle [2].

When it comes to the balanced nutrition of athletes and its features, it is necessary to take into account the quality and safety of raw materials used in food preparation.

The daily diet of athletes is significantly different from the standard menu of ordinary people. It should fully compensate for energy costs, saturating the body with vitamins and minerals, while the calories obtained should remain reserved to ensure metabolism in the body and muscle growth.

When creating a new product rich in vitamins, minerals and essential amino acids, which are deficient in the modern rhythm of life, raw materials of plant origin (dried fruits, nuts, flax seeds and products from them) are used as a fortifier.

Before production, the raw material is subjected to additional processing aimed at the destruction of microorganisms. There are many different methods of eliminating pathogenic infections: chemical, biological, physical.

The present stage of scientific and technological development of the food industry is characterized by a change of technology, such an example is the processing of various raw materials by the energy of an electromagnetic field of ultra-high frequency (EMF-UHF) [6, 8, 9]. This method combines the effects of two fields: electromagnetic and thermal.

Under the effect of high frequency and microwave energy, a simultaneous rapid heating of the product occurs, and the microorganisms die. The microwave method is characterized by selective heating, which consists in the ability to heat wetter surfaces faster after washing, in particular, dried fruits.

Using microwave energy allows eliminating fungal and bacterial microflora from the raw materials and finished products, which is established by further studies.

As a result of product surveys, it was found that Penicillium and Mucor are the most harmful pathogens, as well as Phomopsis which is found in raisins [4].

During the study of dried fruits (prunes, dried apricots, raisins), processed by washing with sterile water ("Control") or boiling in sugar syrup (in accordance with existing technology - "Control-standard"), the following rates of microorganism infection were obtained .

Penicillium fungi infection on dried apricots: control - 2170 CFU/g, control-standard - 10 CFU/g;

Mucor infection on dried apricots: control - 1770 CFU/g, control-standard - 70 CFU/g;

The total microbial number on dried apricots: control - 4870 CFU/g, control-standard - 130 CFU/g.

For all micromycetes, the maximum permissible concentration is 100 CFU/g.

This microflora causes damage to the finished product provoking fermentation in bakery products, chocolate bloom, etc. All these processes are caused by the activity of toxic metabolic products of molds (aldehydes, ammonia, fat oxidation products).

One of the objects under consideration is the dried fruits of dried apricots, which during the experiment were exposed to microwave processing.

Based on the results of the experiments, the regression equation (1) was obtained, where Y1 is the infection of dried apricots with a pathogen of the genus Penicillium, x1 is the exposure, x2 is the heating rate.

$$Y1 = 1.5–1.6x1–4.2x2–1.9x12 + 4.0x22 + 2.2x1x2 \quad (1)$$

According to the given equation, the following regressions were obtained: response surface (Fig. 1A) and graphical dependence (Fig. 1B).

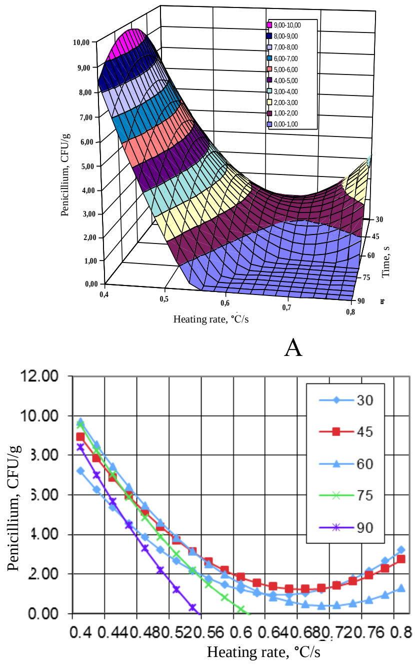


Fig. 1. Effect of microwave energy on Penicillium fungi

The obtained response surface (Fig. 1A) and graphical dependence (Fig. 1B) show that starting from the minimum values of microvawe processing (a heating rate of 0.4 ° C/ s, processing time of 30 s) partial disinfection of dried apricots from Penicillium fungi is observed. At a heating rate of 0.6 ... 0.7 ° C / s, a processing time of 30 ... 90 s and a heating temperature of 70 ... 75 °C, the biological effectiveness of the fruits is 100%. In the control sample, the infection rate is 2170 CFU/g.

With an increase in the heating rate from 0.7 ... 0.8 °C/s and exposure from 30 ... 60 s, an increase in fungal infection occurs. Complete disinfection occurs at a heating rate of 0.56 ... 0.62 °C/s, exposure time 75 ... 90 s. However, the organoleptic properties deteriorate, the fruit darkens and is caramelized (Table 1).

The most effective disinfection mode for dried apricots is characterized by the following parameters: heating rate - 0.6 °C/s, exposure - 60 s, heating temperature 75°C. In this mode, the biological effectiveness of the fruit is 67 CFU/g, and the taste is improved. The fruit becomes sweet, acquires honey aftertaste, while the color remains at the control level (Table 1).

Table 1. The influence of microwave processing on the number of molds on dried apricots

Processing	The average values of infection by microorganisms CFU/g, $1*10^{-2}$			Organoleptic properties
	Penicillium-type molds	Mucor-type molds	TBC	
Modes: V= 0.6°C/c τ = 60 c	0.67	0	1.0	Standard color, sweet taste with a honey aftertaste
Control	21.7	17.7	48.7	Yellow and brown color, sweet taste typical for dried apricots
Control-standard	0.1	0.7	0.13	Yellow and brown color, very sweet taste typical for cooked dried apricots

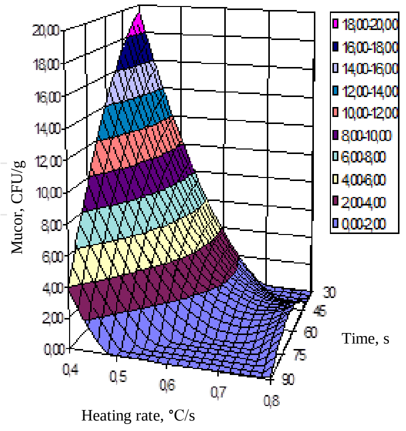
Pathogens, having a different structure of the cell membrane, respond differently to the hydration used in the experiment. According to some authors, pathogens from the genus Penicillium are toxicogenic. This genus of fungi is generally susceptible to the effects of the microwave field. Even under minimum exposure conditions, the disinfection of dried fruits occurs, and the number of pathogens reaches the maximum permissible concentration. Later, when the heating rate reaches 0.7°C/s at a temperature of 60 ... 70 …°C, the fungi of the genus Penicillium resume their growth.

When checking the control (dried apricots) sample, the infection with fungi of the genus Mucor was 1770 CFU/g, while the infection in the control-standard sample was 70 CFU/g.

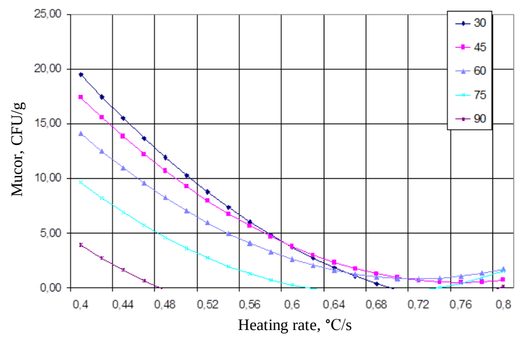
Based on the results of the study, the regression equation (2) was obtained, where Y2 is the infection of dried apricots, x1 is the exposure, x2 is the heating rate.

$$Y5 = 2.6–3.5x1–6.2x2–2.4x12 + 5.3x22 + 4.3x1x2 \quad (2)$$

As a result of processing the regression equations (2), we obtained a response surface (Fig. 2A) and graphical dependence (Fig. 2B).



A



B

Fig. 2. Effect of microwave energy on Mucor fungi

This genus of fungi manifests itself almost similarly to Penicillium-type molds. Modes with the exposure of 30 ... 75 s, heating rate 0.6 ... 0.8°C/s result in complete elimination of bacteria. However, not always the organoleptic properties of dried apricots are preserved.

Complete elimination of Mucor fungi occurs similar to Penicillium fungi (heating rate 0.6 °C/s, exposure 60 s, heating 75 ° C); at the same time, organoleptic properties improve – dried apricots become glossy, the taste is sweet, with a hint of honey (Table 1).

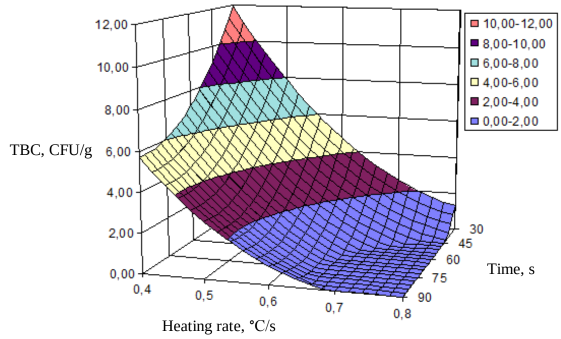
In addition to the Penicillium and Mucor-types bacteria, dried apricots are characterized by general microbial contamination. In a number of dried food products, including fruits and berries, although many living organisms are preserved, they cannot develop. Spores of not only bacteria, but also other microorganisms tolerate drying well; when moistened dried products are subjected to intensive reproduction of microorganisms.

In the control sample, the infection rate was 4870 CFU/g, in the control-standard sample - 130 CFU/g. The total microbial contamination on dried apricots exhibits extreme resistance to temperature effects. Complete elimination of bacteria occurs in the mode with exposure time 60 ... 90 s, heating rate 0.8°C/s and heating temperature 90-100°C. At the same time, the fruits darken, caramelize, acquire the aftertaste of a burnt berry.

Eliminating bacteria from dried apricots fruits was described by the regression equation (3)

$$Y3 = 11x12-4.3-10x1-7.8x2 + 0.3x22 + 5x1x2 \quad (3)$$

Based on regression (3), we obtained the response surface (Fig. 3A) and graphical dependence (Fig. 3B).



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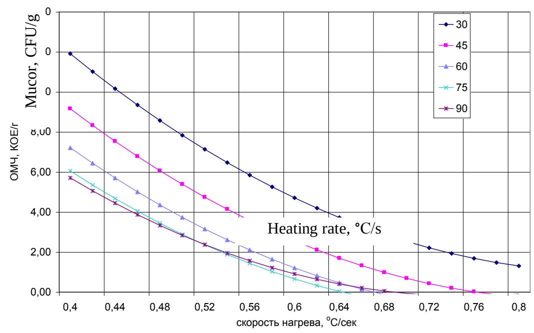

Б

Fig. 3. Effect of microwave energy on total bacteria count

Minimum exposure conditions with exposure – 30 s, heating rate 0.4 °C/s, heating temperature 40°C have practically no effect on bacterial contamination. At the same heating rate of 0.6 °C/s, but with an exposure of 60 and 90 s and at a heating temperature of 75 and 85 °C, the infection with bacteria decreases to 100 CFU/g. It should be noted that with an exposure of 60 s and heating temperature of 75°C, organoleptic properties improve (Table 1).

The action of the microwave field is not limited to the disinfecting effect. An equally important point for the study is the establishment of its influence on the physicochemical properties of all dried fruits. One of the quality indicators is humidity, which characterizes the total content of water that can evaporate at a certain temperature (Table 2).

Table 2. The influence of microwave energy on the physico-chemical properties of dried apricots

Processing	Physico-chemical indicators per 100g of product		
	Humidity %	Total sugar %	Vitamin C
Modes: V= 0.6°C/s τ = 60 s	15.7	30.11	39.9
Control	15.8	23.47	41.4
Control-standard	11.9	31.56	38.0

The results of the experiment show that after microwave processing moisture reduction of 1% occurs compared to the control sample, and 1% higher compared to the control-standard (Table 2). The decrease in moisture under the influence of the microwave field occurs due to evaporation.

Moreover, the content of total sugar expressed in sucrose was checked. According to the results of the table, the total sugar after microwave processing has become higher by 1.2% compared to the control sample and 1% lower compared to the control-standard sample (Table 2).

More than ten vitamins are found in fruits and berries - biologically active substances that are essential for human life. The most significant of them is vitamin C (ascorbic acid); its main suppliers are vegetables, fruits and berries.

From the number of vitamins in dried fruits, the content of ascorbic acid was determined before and after microwave processing. It was found that under the influence of the microwave field there is an increase of vitamin C by 1% compared to the control-standard sample, while in the control sample there is a decrease of 1%, which is due to the decomposition of vitamin C at heating.

Dry fruits and berries contain organic acids: lactic, tartaric, malic, citric, acetic, and oxalic (Fig. 4). Their content per 100 g of dried apricots increases by 1% compared with the control sample and by 2% compared to the control-standard sample. This indicates the activation of redox processes under the influence of the microwave field.

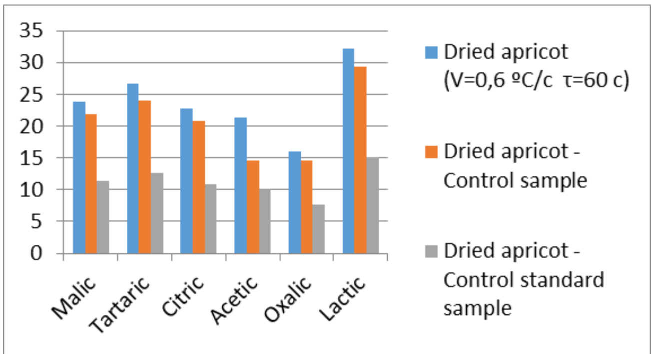

Fig. 4. Effect of microwave energy on organic acids

The high-frequency method allows preserving raw materials in accordance with regulatory documents, improving organoleptic properties and eliminating bacteria.

Scientists of the Russian State Agrarian University created a new product called “Frutolen” (Fig. 5) [5].

Fig. 5. Snacks made of flaxseed flour

The following ingredients are included in the recipe: dried fruits (dried apricots, prunes) processed with microwave energy and native flour obtained from flax seeds. All ingredients included in the recipe are considered as functional.

Dried fruits enrich the product with B vitamins, β-carotene, pectin substances, fiber. The use of dried fruits allow excluding sugar from the recipe.

Flaxseed flour includes a large number of dietary fiber, which is a shell of seed cells consisting of polysaccharides, starch and lignans [2].

Lignans belong to a group of phenolic compounds of plant origin with anticarcinogenic properties. Flaxseed flour is rich in trace elements (magnesium, potassium) and polyunsaturated fatty acids, which strengthen the walls of blood vessels, normalize cholesterol and reduce the likelihood of blood clots [2,3].

Dietary fiber helps to satisfy hunger [1-3, 7, 10, 11].

Before using flaxseed flour in the recipes, the chemical composition of wheat-flax flour was analyzed. To obtain blended flour, wheat flour was replaced with flaxseed flour in various proportions. The indicators are presented in table 3.

Table 3. The chemical composition of wheat-flax flour

Blend	Chemical composition, %						
	Proteins	Lipids	Fiber	Ash	Gluten	Ca	P
Wheat (control)	11.01	1.55	1.43	2.11	31.57	0.05	0.34
Wheat-flax (10%)	12.0	2.1	2.1	1.6	20.03	0.05	0.4
Wheat-flax (15%)	12.4	2.31	2.48	2.0	19.0	0.05	0.4
Wheat-flax (20%)	14.9	2.42	5.6	2.0	17.9	0.05	0.43

High-quality and safe raw materials, which are part of the recipe of flax snacks, helps to regulate and improve metabolic and redox processes.

The use of the proposed recipe ingredients will allow preparing a low-calorie product with high organoleptic, structural, mechanical, physico-chemical properties and balanced nutritional value, which is necessary for the diet of athletes

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