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The effect of functional bars on the biochemical parameters of blood during physical exertion

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ABSTRACT

Currently, the fast pace of life, changes in consumers' habits, and the trend toward a healthy lifestyle around the world create the need for new healthy foods for immediate consumption. In this regard, the production of snacks with high nutritional value, as well as giving them functional properties through the use of various types of raw materials, seems promising. The choice of components following the physiological needs of various population groups in snack production allows getting new specialized food products, which improves people's quality of life and health. The most promising is the production of functional snack bars by combining vegetable and dairy raw materials. It is promising to use mare's milk as a dairy raw material. The clinical efficacy of the new fruit-protein bars based on mare's milk (FBBs) was tested on 25 volunteers aged 25-35 years for 60 days. The control group consisted of 15 people who received two KDV fruit and nut bars for 60 days, the nutritional and energy value of which was comparable to the snacks studied. Before and after taking snacks, blood biochemical and immunological parameters were evaluated. The results indicate a positive effect of new snacks based on mare's milk on performance indicators, the state of cellular immunity, blood parameters, biochemical parameters, and antioxidant status. There is a decrease in fat mass, intracellular and extracellular fluid levels, and a reducing the number of final and intermediate lipid peroxidation products. The blood level of haemoglobin, erythrocytes, platelets, hematocrit, and all classes of immunoglobulins increased. Specialized functional protein bars, enriched with dry mare's milk, can be recommended to various categories of the population experiencing intensive physical activity and psychoemotional stress to increase their adaptive capabilities and performance.

Keywords: specialized nutrition, functional protein bars, mare's milk, physical activity, adaptive capabilities

INTRODUCTION

To date, there is an increase in the use of snacks (ready-to-eat light meals intended for a "snack") around the world, which is caused by the acceleration of the pace of life and changes in the culture of consumption of various goods **[1]**. The choice of snack products is becoming more and more diverse every year: these are crispy crackers made of wheat and rye bread, sweet and salty straws, all kinds of nuts and seafood that have undergone appropriate processing, instant porridge from various kinds of cereal, potato chips and other mouth-watering delicacies. The largest segment of the Kazakhstan snack market is the category "crackers", which accounts for 51% of the market in physical terms, as well as chips – 25% and nuts – 24% **[2]**, **[3]**.

In the rational and balanced nutrition system, a person needs two or three snacks during the day between main meals. Each meal should have an individual combination of proteins, fats, carbohydrates, and dietary fiber with the specified parameters of caloric content and antioxidant activity **[4]**, **[5]**, **[6]**. In turn, most snack products are characterized by high-calorie content and minimal content of vitamins and trace elements. They often have increased levels of oil and sugar, which causes obesity, hypertension, etc. Despite this, the market of snack products is actively developing and has a high investment attractiveness **[1]**.

The COVID-19 pandemic has seriously changed the population's eating behavior. Consumers are paying more attention to the general state of health, and people are looking for products with clean labels, which means that they are more and more selective in choosing products. Demand is rapidly shifting away from fatty-spicy foods towards healthier, sugar-free, and low-calorie snacks packed in small portions. This is an important trend that stimulates the growth of the industry. In this regard, many scientific research works aim to increase snack products' nutritional value and give them functional properties with various raw materials (grain, fruit and vegetable, dairy, nuts, probiotics, etc.) **[1]**.

A review of the global and domestic market of functional snack products indicates the prospects for developing this direction in Kazakhstan. The global functional snacks market volume in 2021 was estimated at 85.6 billion US dollars. The cumulative annual growth rate (CAGR) is expected to be 6.6% from 2022 to 2030 **[1]**. In Kazakhstan, more and more people adhere to a healthy lifestyle, encouraging them to gradually switch from traditional chocolate bars to healthier alternatives containing cereals, fruits, and muesli. The domestic market for functional snacks is not yet large compared to the traditional one, but it is growing steadily. The annual consumption of snacks and fruit and vegetable-based bars has approached a 10% increase, and we expect this trend to continue **[7]**.

Snacks with different functional properties are prospects for improving the quality of life and health of the population of Kazakhstan. The selection of various components by the physiological needs of various groups of the population in the production of snacks allows you to get new specialized food products.

It is known that by the Technical Regulations of the Customs Union TR CU 027/2012 "On the safety of certain types of specialized food products, including dietary preventive and dietary therapeutic nutrition", all specialized food products are divided into the following groups:

- food products for baby food;
- food products for athletes' nutrition;
- food products for dietary preventive nutrition;
- food products for dietary therapeutic nutrition;
- food products for pregnant and lactating women.

The design of specialized snack products requires a scientifically based approach to selecting ingredients, considering the target consumers' needs. The choice of the composition of specialized snacks should be determined by several factors: age needs at the group level for food and biologically active substances (micronutrients), physical activity, or energy consumption (associated in the case of sports nutrition - with a sport, under difficult working conditions – with the peculiarities of harmful production, for dietary preventive or dietary therapeutic nutrition – with the nature of the disease). However, the key factor in selecting a scientifically based composition of specialized snacks is the features of the diet, allowing for the achievement of maximum efficiency of new products. When scientifically substantiating the composition of certain types of specialized snack products, it is necessary to consider the anthropometric characteristics of target consumers (Figure 1).

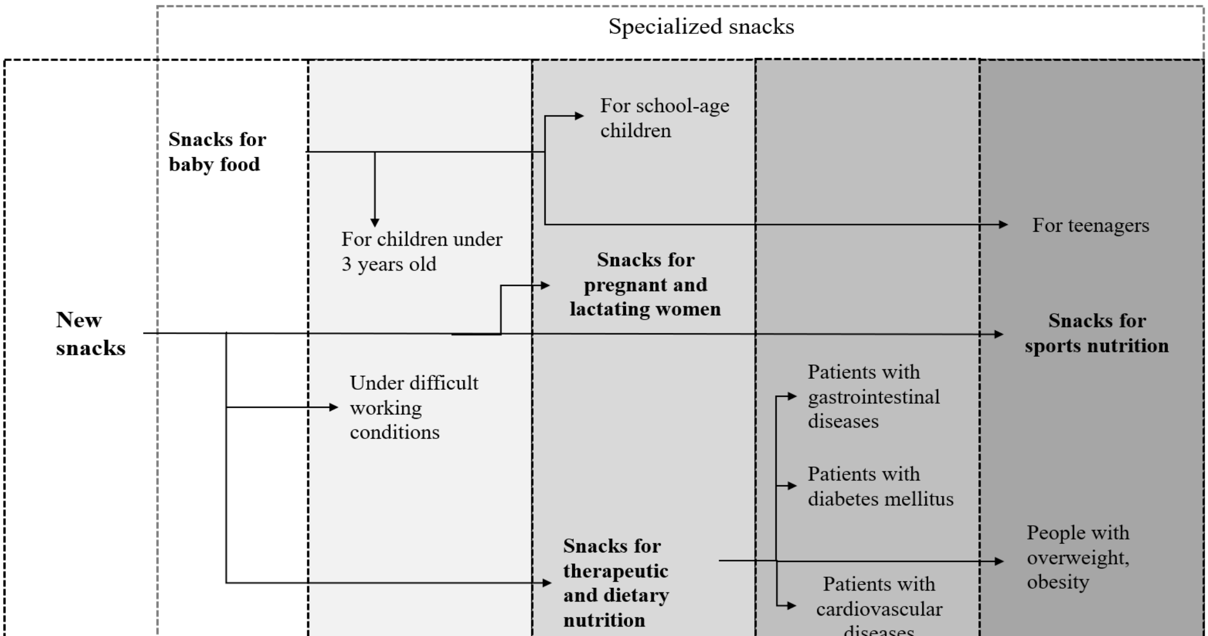

Figure 1 Specialized snacks for feeding target groups of consumers.

Snacks for sports nutrition are often presented in the form of bars. At the same time, research aimed at developing new products for sports nutrition indicates the prospects of using plant raw materials.

One of the promising directions for the development of the range of snack bars is the development of bars based on grain, dairy, and fruit and vegetable raw materials, which corresponds to the principles of healthy nutrition **[8]**, **[5]**, **[9]**, **[10]**. Developing technologies and recipes for new bars will make it possible to obtain high-quality products enriched with useful biologically active substances and low energy value. If necessary, such bars can be stored for 12 months or more. Expanding the range of snack bars also makes it possible to increase the possibilities of using local dairy, grain and fruit, and vegetable raw materials.

Bars from dairy, grain and fruit, and vegetable raw materials are rich in dietary fibers (pectin, hemicellulose, cellulose), minerals, macronutrients (potassium, sodium, magnesium, calcium, phosphorus), trace elements (iron, zinc, copper, manganese), the functional properties of which meet the requirements of preventive nutrition. New types of snacks can be used as biologically active food additives, as they have increased nutritional and biological value and good consumer and technological properties **[8]**, **[5]**, **[9]**, **[10]**.

Recently, dry mare's milk obtained by freeze-drying has become much more widely used for technological purposes since it has a higher content of the main biologically active ingredients than native milk **[11]**, **[12]**. Mare's milk is characterized by high lactose, low fat, and protein content, especially casein. The uniqueness of the mare's milk is also due to the high level of low molecular weight peptides and lysozyme, which is one of the main antibacterial proteins of milk and plays an important role in the formation of nonspecific immunity **[13]**, **[14]**.

According to literature data, low-molecular-weight peptides of mare's milk with a molecular weight of up to 15 kDa can maintain body homeostasis, showing antibacterial, antiviral, antioxidant, and regenerative activity **[15]**, **[16]**.

The production of specialized bars with new functional properties through the introduction of mare's milk will allow the market to release products that positively affect biochemical and immunological indicators, performance indicators, and the state of the antioxidant status of the body.

Scientific hypothesis

Snacks in the form of fruit-protein bars (FBBs) based on mare's milk positively affect biochemical and immunological indicators, performance indicators, and the state of the body's antioxidant status. We expect increased haemoglobin, erythrocytes, and immunoglobulins level and a decrease in malondialdehyde's and diene conjugates' levels.

MATERIAL AND METHODOLOGY

Samples

In clinical trials, fruit and protein bars based on mare's milk were used.

Instruments

The volunteers' body composition was studied on the InBody 770 analyzer (South Korea).

Biochemical blood tests of volunteers were performed on the ARCHITECT c8000 analyzer, manufactured by Abbott.

A full blood count (FBC) was completed on a UNICEL DXH-800 haematological analyzer, manufactured by Beckman Coulter.

Laboratory Methods

The InBody 770 analyzer was used to determine: the total amount of water, proteins, minerals, the ratio of muscle and fat mass, fat content, body mass index (BMI), weight, and skeletal muscle mass.

The immuno-chemiluminescent method was used in the study of blood biochemical parameters. Biochemical and immunological parameters were evaluated in the blood of the subjects before and after taking snacks: total protein, albumin, globulins, albumin-globulin ratio, the activity of alanine aminotransferase (ALT), aspartate aminotransferase (AST), glucose, iron in serum, immunoglobulin G (IgG), immunoglobulin A (IgA), immunoglobulin M (IgM) **[17]**.

The colorimetric method was used to determine the lipogram (Cholesterol, HDL, LDL, triglycerides, atherogenicity coefficient) **[18]**.

The level of glucose, pyruvic, and lactic acid was determined to assess the direction of bioenergetic processes. The state of lipid peroxidation (LP) was determined by the serum levels of diene conjugates (DC), malondialdehyde (MDA), as well as catalase activity **[19]**, **[20]**.

According to Mancini, the level of immunoglobulins in blood serum was determined by radial immunodiffusion **[21]**.

A detailed general blood test (erythrocytes, haemoglobin, leukocytes, platelets, ESR, reticulocytes, hematocrit, ferritin) was analyzed using accepted clinical research methods **[17]**, **[22]**.

Description of the Experiment

The clinical efficacy of FBB was assessed on 25 volunteers aged 25-35 years, who received two FBBs daily for 60 days. The recipe for the FBB snacks is given in Table 1. The energy value of bars per 100 g of product is proteins – 7.4 g, fats – 5.8 g, carbohydrates – 68.0 g, caloric content – 365.0 kcal.

Table 1 FBB recipe for 100 g of product.

Ingredients	Quantity, g
Dates	31.66
Sunflower seeds	14.01
Dried apples	13.15
Cranberry	12.38
Dry protein mixture:	10.0
Mare's milk	6.5
Fruit additives (dry currant berries)	1.0
Low molecular weight peptides from mare's milk	1.0
Soy Protein Isolate	0.5
Pectin	0.1
Maltodextrin	0.23
Inulin	0.1
Bacterial starter culture	0.5
Vitamin and mineral premix	0.05
Fucoidan	0.02
Raisin	9.78
Pumpkin Seeds	8.25
Almond	0.77

FBB photos are provided in Figure 2.

Figure 2 Fruit-protein bars (FBBs) based on mare's milk.

The control group consisted of 15 people who received two KDV fruit and nut bars for 60 days, the nutritional and energy value of which was comparable to the snacks studied. Fruit and nut bars of the "KDV" company (Konditerskij Dom Vostok - Confectionery house Vostok) contain 20.0 g of protein, 17.0 g of fat, and 47.0 g of carbohydrates, with a calorie content of 370 kcal.

The composition of the fruit and nut bars of the "KDV" company: chocolate glaze (granulated sugar, cocoa butter equivalent (refined deodorized vegetable oils (palm, shea), emulsifier – sunflower lecithin), cocoa mass, cocoa powder, cocoa butter, emulsifiers (soy lecithin, E476), vanilla flavor), dried apricots (apricots, preservative

E220), whey protein concentrate, dried grapes (raisins), roasted crushed peanut kernels, granulated sugar, dried bananas, passion fruit granules (passion fruit juice concentrate, corn starch), starch molasses, acidity regulator - citric acid, vegetable extract "Guarana extract" (natural guarana extract, maltodextrin, stabilizer -gum arabic, natural caffeine), flavor "Apricot", roasted crushed hazelnut kernels, vegetable extract "Apricot extract".

The basic volunteers' diet was balanced by the main nutrients and amounted to 2760 kcal (Table 2). In terms of calories, the additional nutrition of the experimental and control groups was identical. The caloric content of additional nutrition due to the bars was about 730-740 kcal in the experimental and control groups.

Table 2 The content of nutrients in the volunteers' diet.

Nutritional substances	The content of nutrients in the diet of volunteers
Energy, kcal	2760
Protein calories, %	15
Total Protein, g	104
Animal proteins, g	58
% animal proteins in total	55.8
Fat calories, %	32.7
Total fat, g	100
Vegetable fat, g	46.2
% vegetable fat in total	46
Saturated Fatty Acids (SFA), g	25.1
MUFAs, g	22.1
PUFAs, g	24.8
Cholesterol, mg	439
Carbohydrate calories, %	52.2
Total carbohydrates, g	360
Starch, g	221
Mono- and disaccharides, g	51
Dietary fiber, g	38.6
% of sugars from total carbohydrates	42
Vitamin A (RE), mcg	1319
Vitamin E, mg	26
Vitamin B1, mg	1.5
Vitamin B2, mg	1.72
Vitamin B3 (niacin), mg	18.6
Vitamin C, mg	123
Folate (folic acid), mcg	187
Calcium, mg	957
Magnesium, mg	457
Phosphorus, mg	1756
Iron, mg	25
Zinc, mg	10
Selenium, mcg	29.7
Iodine, mcg	127

Both the persons of the experimental and control groups were monitored for 60 days, receiving the recommended products daily as part of the diet. The composition of the FBB can have a positive effect on human endurance, so it was decided to introduce physical activity into the program of the experimental group: running, swimming, and cycling. The control group was not subjected to physical exertion. Before and after taking FBB, the body composition and biochemical and immunological parameters of the volunteers' blood were evaluated. Also, throughout the 60-day follow-up, volunteers were interviewed about their perception of products, the effect of products on the state of the gastrointestinal tract, and general well-being. All persons in the control and experimental group agreed to participate in the studies. Blood sampling was performed on an empty stomach in the morning (9:00 am).

Statistical Analysis

The results were statistically processed using the XLSTAT program, calculating the arithmetic mean of the parameter, the mean square deviation, and the error of the arithmetic mean. The differences were considered significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

The clinical efficacy of FBB was tested on a group of 25 volunteers aged 25-35 years. The analysis of body composition in the experimental group of individuals who received two FBB daily (Table 3) showed a significant decrease in the total water content in the body, as well as intracellular fluid from 25.0 ±0.4 l to 23.2 ±0.5, ($p \leq 0.05$). The protein content after taking the bars increased significantly from 10.2 ±0.5 to 11.5 ±0.4 kg. Although the difference was only 1.3 kg, this is considered a good result, which indicates the normalization of protein metabolism. The content of minerals in the body of volunteers significantly increased from 3.3 ±0.1 kg to 4.1 ±0.2 kg.

Table 3 Analysis of the body composition of the experimental group (n = 25) before and after FBB (M ±m) consumption.

Indicators	Before reception	After reception
Body weight	73.1 ±1.3	74.4 ±1.4
Total water content	39.0 ±0.6	36.2 ±0.7*
Intracellular fluid	25.0 ±0.4	23.2 ±0.5*
Extracellular fluid	14.0 ±0.2	13.0 ±0.3
Protein content	10.2 ±0.5	11.5 ±0.4*
Mineral content	3.3 ±0.1	4.1 ±0.2*
Body fat content	19.9 ±0.7	15.5 ±1.1*
Non-fat body mass	53.6 ±1.0	56.7 ±0.8*
Skeletal muscle mass	29.0 ±0.6	31.6 ±0.7
BMI	25.9 ±0.5	21.4 ±0.6*
Body fat percentage	27.2 ±0.9	20.8 ±1.0

Note: * – the differences are statistically significant to the data in the control group $p \leq 0.05$.

As a result of the 60-day intake of bars, there is a decrease in fat mass and the level of intracellular and extracellular fluid. Fat mass decreased by 23.5% from 19.9 ±0.7 kg to 15.5 ±1.1 kg. In studies, the fat-free body weight significantly increased in volunteers after 60 days of food intake from 53.6 ±1.0 kg to 56.7 ±0.8 kg, indicating a partial replacement of metabolically inactive tissues with active, particularly skeletal muscles and muscles of internal organs. The mass of skeletal muscles in volunteers after taking the product increased by an average of 9.0% – from 29.0 ±0.6 kg to 31.6 ±0.7 kg, which also indicates an increase in the degree of endurance of the body to physical exertion. According to Table 2, a significant decrease in body mass index (BMI) is important in volunteers from 25.9 ±0.5 to 21.4 ±0.6, ($p \leq 0.05$).

A significant decrease in the volunteers' total body water content, including the content of the intracellular and extracellular fluid, as well as an increase in protein levels, fat-free body weight, and skeletal muscle mass after using mare's milk bars indicates normalization of protein metabolism and synthesis of new structural proteins and tissues, replacement of metabolically inactive tissues with active components. A significant increase in the levels of mineral substances in the body of volunteers indicates the correction of violations of trace element metabolism and fluid metabolism.

Changes in body composition indicators in the control group after taking KDV fruit and nut bars were insignificant (Table 4).

Protein content increased by 7.6%, minerals – by 10.5%, fat – by 9.6%, and skeletal mass increased by only 2.8%. There is an increase in the total water content by 2.9% with an increase in the amount of intracellular fluid and a decrease in the extracellular fluid content. All of the above indicators were not reliable. The percentage of fat and body mass index increased.

Table 4 Analysis of the body composition of the control group (n = 15) before and after consumption of KDV fruit and nut bars (M ±m).

Indicators	Before reception	After reception
Body weight	72.5 ±1.0	76.6 ±1.2
Total water content	38.5 ±0.7	39.6 ±0.9
Intracellular fluid	27.0 ±0.5	28.8 ±0.8
Extracellular fluid	11.5 ±0.2	10.8 ±0.4
Protein content	11.8 ±0.6	12.7 ±0.6
Mineral content	3.8 ±0.3	4.2 ±0.4
Body fat content	21.8 ±0.8	23.9 ±1.5
Non-fat body mass	52.6 ±0.9	53.9 ±1.3
Skeletal muscle mass	25.3 ±0.5	26.0 ±0.7
BMI	26.7 ±0.6	27.8 ±0.7
Body fat percentage	30.1 ±0.9	31.2 ±1.2

The results of biochemical studies are presented in Table 5.

Table 5 Changes in biochemical blood parameters of the experimental group (n = 25) before and after taking FBB (M ±m).

Indicator Unit of measurement	Before reception	After reception
Total protein g/l	70.42 ±1.01	75.65 ±0.75*
Albumins %	45.70 ±0.72	49.70 ±0.55*
Globulins %	24.72 ±1.00	25.95 ±10.95
Albumin-globulin coefficient	1.85 ±0.10	1.92 ±0.21
Blood sugar mmol/l	5.60 ±0.21	5.20 ±0.14
Cholesterol mmol/l	4.05 ±0.40	3.80 ±0.35
Triglycerides mmol/l	0.83 ±0.08	0.84 ±0.09
HDL mmol/l	1.55 ±0.10	1.80 ±0.10
LDL mmol/l	2.7 ±0.20	1.9 ±0.20*
Atherogenicity coefficient	1.62 ±0.21	1.11 ±0.10
Iron mmol/l	19.60 ±0.20	22.5 ±0.43*
Total iron binding capacity mmol/l	48.5 ±3.20	58.6 ±4.30
Ferritin ug/l	215.36 ±20.31	454.29 ±31.44*

Note: * – the differences are statistically significant to the data in the control group $p \leq 0,05$.

As can be seen from the data presented in Table 3, after taking bars from volunteers after 60 days, there was a significant increase in total protein and albumin in the blood. The albumin index increased by an average of 4% compared to the data before taking the bars. The globulin index also increased by an average of 5% after taking the product.

The data obtained indicate the beneficial effect of bars on the state of protein metabolism in general and confirm the results of increasing the level of proteins in the body.

In the control group, there were practically no significant changes in the above indicators. There was a slight decrease in total protein and albumin in the blood serum, but it should be noted that these shifts were also not reliable.

Along with changes in the protein composition of blood serum indicators, after taking FBB, a decrease in blood sugar, total cholesterol, low-density lipoproteins, and atherogenicity coefficient was revealed by 7.1; 6.1; 26.9, and 31.5%, respectively. A decrease in low-density lipoproteins and atherogenicity coefficient against the background of a general decrease in cholesterol should be considered a positive result of the effect of FBB on lipid metabolism. This may be due to an increased intake of PUFA, anti-oxidant vitamins, and reduced content of animal fats in the diet with a high atherogenicity index (Table 3).

An increase in the blood level of iron and the iron-binding ability of blood serum, as well as a significantly increased level of ferritin, indicate the anti-anemic nature of FBB. This is due to the increased content of macro- and microelements, readily available proteins, vitamin C, folic acid, and B vitamins in the bars, which favorably affect the processes of hematopoiesis.

A decrease in the activity of transamination enzymes in the blood serum of the experimental group after 60-day consumption of FBB (Table 6). Thus, the activity of alanine aminotransferase and aspartate aminotransferase after taking the products decreased by 18.2 and 25.7%, respectively, but these changes were insignificant.

Table 6 Enzymatic activity in blood serum in the experimental group (n = 25) before and after taking FBB (M ±m).

Indicator Unit of measurement	Before reception	After reception
Alanine Aminotransferase (ALT) U/l	30.29 ±3.54	24.79 ±2.34
Aspartate Aminotransferase (ACT) U/l	41.49 ±9.43	30.81 ±2.57

Note: * – the differences are statistically significant to the data in the control group $p \leq 0,05$.

In the control group (n = 15), there was also no significant change in the activity of the above serum enzymes, but a decrease in the above enzymes by 4.2 and 6.3% were also detected for ALT and AST, respectively.

The assessment of hematological blood parameters before and after taking the products by the control group revealed certain shifts in the blood formula in comparison with the data before taking them (Table 7). As can be seen from the data presented in Table 7, volunteers had an unreliable increase in the blood level of hemoglobin, erythrocytes, platelets, and hematocrit after taking the products.

Table 7 Enzymatic activity in blood serum in the experimental group (n = 25) before and after taking FBB (M ±m).

Indicator Unit of measurement	Before reception	After reception
Hemoglobin, g/l	146.10 ±4.34	149.61 ±3.63
Platelets, 10^9, g/l	261.51 ±8.46	266.45 ±8.25
Red blood cells, 10^{12}, g/l	4.75 ±0.09	4.88 ±0.09
Hematocrit, g/l	0.42 ±0.01	0.46 ±0.009

The data obtained indicate an increase in the hematopoietic function of the volunteers' bodies against the background of taking FBB. This is due to the presence in the bars of high-grade protein, iron, vitamin C, folic acid, and B vitamins that stimulate the processes of hematopoiesis.

It is known that any physical activity accompanied by certain psycho-emotional stress leads to the initiation of free radical oxidation of lipids in the body **[23]**. With an increase in physical and psychological stress, the processes of lipid peroxidation (LP) intensify **[24]**, which can be demonstrated by increasing the level of primary and final products of lipid peroxidation and changing the activity of key enzymes of the antioxidant system **[25]**.

Pro- and antioxidant defence systems in a healthy body control the level of free radical formation and maintain the antioxidant status at a certain stationary level. Depending on the state of the body, and the influence of adverse environmental factors, the antioxidant defence (AD) system can regulate the formation and destruction of free radicals **[26]**.

Activation of LP is observed only at maximum loads, which is manifested in an increase in the content of LP products in the blood serum **[26]**, as well as a decrease in the functional activity of the antioxidant defence system **[27]**.

Considering the above, along with the assessment of biochemical parameters of blood, we studied the state of the LP-AD system in blood serum against the background of taking specialized food. The data obtained are shown in Table 8.

Table 8 Dynamics of changes in indicators of lipid peroxidation and enzymes of antioxidant protection systems in blood serum in the experimental and control groups before and after taking specialized foods (M ±m).

Period		DC mmol/l	MDA mmol/l	Serum catalase mmol/min/l
The experimental group (n = 25)	before reception	72.0 ±4.2*	42.6 ±3.3*	0.41 ±0.03*
	after reception	41.3 ±3.5	15.6 ±1.9	0.25 ±0.04
Control group (n = 15)	before reception	74.8 ±5.5	45.5 ±4.3	0.39 ±0.05
	after reception	64.3 ±3.4	36.1 ±3.4	0.29 ±0.02

Note: * – the differences are statistically significant to the data before and after taking the products $p \leq 0.05$.

As seen from the data given in Table 7, there was a significant increase in serum levels of malondialdehyde (MDA) and diene conjugates (DC) in the control group (persons who are not subjected to physical exertion) before taking specialized foods. Catalase activity also significantly increased 2.7 times.

Consumption of FBB for 60 days against the background of physical activity contributed to a decrease in the serum of the experimental group of final and intermediate lipid peroxidation products. In particular, the level of MDA and DC decreased by 38.7 and 24.6%, respectively, compared with the data before taking FBB. Catalase activity also decreased by 39.0%, compared with the results obtained at the beginning of the experiment.

The results of changes in the indicators of the LP-AD system indicate a specialized product's favorable effect on the body's antioxidant status.

The excessive accumulation of lipid peroxidation products revealed during experimental studies may indicate a decrease in the activity of the antioxidant defense system.

The results obtained, related to the assessment of physical performance in the experimental group and the indicators of the LP-AD system in the blood, differ from the results of the control group who did not exercise.

An equally important characteristic in assessing the impact of specialized products on the human body is the assessment of their immune status, which characterizes the state of the body's defence system **[30]**. Thus, after exhausting physical exertion, according to the available literature data, there is an increase in the number of leukocytes **[28]**, **[29]**, **[30]**. At the same time, there are a decrease in leukocyte functional activity and NK-cell depression **[31]**, and the number of T-lymphocytes and the level of immunoglobulins reduces **[32]**. Dopsaj et al. noted that people undergoing extreme physical activity could suffer from short-term immunosuppression and increased infection risk **[33]**.

Evaluation of the cellular and humoral components of the immune system allowed us to identify several specific changes after taking FBB by the experimental group (Table 9).

Table 9 Changes in immunological parameters in the experimental group (n = 25) before and after taking the special product (M ±m).

Indicator Unit of measurement	Before reception	After reception
Immunoglobulin G (IgG) g/l	10.87 ±0.57	11.11 ±0.50
Immunoglobulin A (IgA) g/l	2.10 ±0.18	2.28 ±0.16
Immunoglobulin M (IgM) g/l	1.22 ±0.11	1.78 ±0.12*

Note: * – the differences are significant when compared with the data before and after taking FBB.

The baseline data for IgG, IgA, and IgM immunoglobulins in the control group who did not experience physical activity were 9.01 ±0.78; 1.78 ±0.14; 1.01 ±0.10 g/l, respectively. The results obtained indicate that the state of humoral immunity is related to the intensity of physical exertion on the one hand, and on the other hand, the role of enriching the daily diet of volunteers with missing nutritional factors that determine resistance and endurance to increased physical exertion.

An increase in the level of all classes of immunoglobulins characterizing the state of humoral immunity indicates a good adaptation of the immune system. Repeatedly in scientific works, there has been a connection between a decrease in the indicators of humoral factors of immunity against the background of intense physical activity **[34]**, **[35]**. This led to an increase in the development of acute diseases **[36]**. It can be considered a syndrome of immune dysfunction **[37]**.

The contradictory information available in the scientific literature regarding the effect of physical activity on the immune system depends on the body's individual reaction, the type of physical activity, age, and other factors and conditions in which the state of immunity was assessed **[38]**. Scientific evidence indicates that intense physical activity has a depressing effect on the immune system **[39]**. Thus, Suzdalnitsky et al., studying the mechanisms of the development of immunodeficiency under intense loads, observed an increase in disorders in the cellular, humoral, and secretory links of immunity **[40]**. The most significant instability of humoral immunity as a consequence of various types of stress, including increased physical and psycho-emotional stress, was also noted in the works of other authors. The reduction of immunological resistance under intense psychophysical stress is based on disorders of neuroendocrine regulation, macro-, and micronutrient insufficiency, metabolic changes in the internal environment, and intoxication from foci of chronic infection **[41]**. It was noted that short-term stressors suppressed cellular immunity while maintaining humoral immunity. Meanwhile, chronic stressors were associated with suppressing both cellular and humoral indicators **[42]**.

The most significant immune disorders are observed with physical and psychoemotional loads **[43]**, hypothermia **[44]**, and disruption of adaptive mechanisms. Suzdalnitsky et al. stated that the human immune system should go through the phases of mobilization, compensation, decompensation, and recovery when adapting to physical exertion **[45]**. The earliest reflection of the breakdown of adaptation processes to physical and psychoemotional stress violates immunity **[46]**. Researchers agree that it is advisable to include dietary supplements in the diet of people subjected to constant physical exertion **[47]** and psychoemotional stress **[48]** to increase their physical endurance and mental stability.

When performing aerobic exercise (1000 meters) in the experimental group, after using FBB, there was a decrease in the concentration of lactic acid in the blood plasma by 23.1% compared to the initial data. After a two-month intake, against the background of this stress test, the volunteers showed a decrease in lactic acid levels by 40.7%, compared with the initial data. The content of pyruvic acid has not changed significantly. On average, the decrease in the level of pyruvate was in the range of 6.7-10.7% before and after taking FBB against the background of a stress test (Table 10). It should be noted that the changes in the concentration of lactate and pyruvate in the blood serum were not insignificant in the control group.

Table 10 Changes in the level of lactic and pyruvic acids before and after taking bars in blood plasma after a stress test (M ±m).

Indicator Unit of measurement	Control group (n = 15)		An experienced group (n = 25)	
	Before reception	After reception	Before reception	After reception
Lactate (mmol/l)	2.8 ±0.3	2.5 ±0.2	2.6 ±0.2	2.0 ±0.3
Pyruvate (ml/l)	0.032 ±0.01	0.030 ±0.03	0.030 ±0.01	0.028 ±0.02

The changes obtained indicate the activation of oxidative processes in all subjects after taking specialized products, while the changes in the experimental group were expressed to a significant extent.

Regular consumption for 60 days of FBB contributed to improving the performance and the anaerobic and aerobic links of the volunteers' energy system.

The results of the clinical evaluation of the effectiveness of FBB on the biochemical and immunological parameters of the volunteers' blood indicate an increase in antioxidant and immune statuses against the background of taking bars. The noted positive changes in blood parameters (the content of ferritin, serum iron, and the iron-binding ability of blood serum) indicate the antianemic properties of the product and its normalizing effect on the hematopoietic functions of the body.

Taking into account the beneficial effect of FBB on performance indicators, indicators of cellular immunity, and antioxidant status, this specialized nutrition can be recommended to various categories of the population experiencing increased physical activity to improve performance.

CONCLUSION

The results of the clinical evaluation of the effectiveness of FBB indicate their positive effect on performance indicators, the state of cellular immunity, blood parameters, biochemical parameters, as well as the antioxidant status of the body. There is a decrease in fat mass, intracellular and extracellular fluid levels, and a reducing the number of final and intermediate lipid peroxidation products. The blood level of hemoglobin, erythrocytes, platelets, hematocrit, and all classes of immunoglobulins increased. Considering the above, FBB with increased nutritional and biological value, enriched with unique ingredients, including dry mare's milk, can be recommended to various categories of the population experiencing intensive physical activity and staying in extreme environmental conditions to increase their adaptive capabilities and performance. The expansion of the range of snack products and the production and distribution of specialized snacks are seen as a promising direction and have social significance since it allows for improving the quality of life and health of people.

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