

## INNOVATIVE FUNCTIONAL FOOD PRODUCTS FOR THE WORKERS OF THE MINING INDUSTRY

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### Abstract

The aim of this work is the experimental determination of the formula and the appropriate technology of production of pasta with enriched nutrient composition based on adding a suspension of chicken meat and pumpkin seeds. There has been developed a functional product, designed to help prevent the development of pathologies that are of production and alimentary origin among the workers of the mining industry, whose work is characterized by constant physical and mental strain, increased blood pressure, reduced aerobic fitness and physical performance of the body.

The determination of the pasta formulation was carried out by experimental determination of proportions of possible contents of chicken meat and pumpkin seeds suspension using standard technological equipment and generators for ultrasonic intensification of technological processes. To establish the physicochemical parameters of the obtained product there were used the following methods: establishing the strength of pasta with the Stroganov device, the titrimetric method for the determination of protein content according to Kjeldahl method, the method of ion exchange chromatography for the determination of amino acid composition.

It has been experimentally established that the proportion of the suspension of chicken meat and pumpkin seeds in the manufacture of pasta products while maintaining the required consumer indicators can make up to 35%. The resulting research product per 100 g of the mass contains: 18 g of protein, vitamins B, A, E, minerals (iron, potassium, calcium, magnesium, and phosphorus). Ultrasound dispersion provides a sealing effect that reduces porosity and water absorption. High temperature drying with ultrasound irradiation saves time, energy, increases strength, eliminates the increase of acidity, and microbial spoilage.

There has been established the possibility of expansion of a functional products range at the expense of combinatorics of enriching additives from chicken meat and pumpkin seeds in the recipe of pasta. The use of ultrasound provides an increased amount of nutrients while maintaining the indicators that provide the opportunity for a long-term storage. The cost of production is competitive for the domestic market of Ukraine, which allows to count on the possibility that the mining industry will buy them for the centralised feeding of the workers.

**Key words:** *Functional food products, Physiology of labour, Recovery, Prevention of pathologies, Enriching additives, Ultrasonic effects of cavitation.*

## 1. Introduction

The use of the scientific and technical progress achievements opens up opportunities for manufacturers to create innovative functional food products with improved nutritional properties that will contribute to the rapid restoration and maintenance of optimal functional characteristics of all the physiological systems of the body of people engaged in heavy physical labour in extreme conditions of mining enterprises.

The concept "functional food products" and its objective implementation is constantly expanding. The emergence of functional food products is associated with an attempt to solve a purely medical problem concerning the treatment and rehabilitation of patients by a careful selection and application of optimum quantities of certain macro- and micronutrients within the theory of orthomolecular medicine founded by L. Pauling [1].

Further development and the formation of modern concepts of functional food products are related to the theory of a balanced diet, the founder of which was the Russian academician the necessary proportions of certain nutrients in the human diet, which depend on the activity of enzyme systems responsible for the assimilation of food, depending on the needs of the body in various substances and energy [2].

But, because the logic of human behaviour is determined by the principle of the permanent needs, growth and profits maximization, functional achievements in specific sectors of activity always fall in the sphere of mass consumption. Such was the case for functional products. Currently, functional food products, or products that are called functional by manufacturers, are actively used in the: preparations for sportsmen, and specialised nutrition for certain population groups like: adolescents, pregnant women, and the elderly and people engaged in intense mental or physical labour. Moreover, marketers are constantly trying to extend the audience of consumers of functional products for the most ordinary consumers, by advertising information about the positive impact of their use.

The major factor in the identification of functional products in accordance with the provisions of Scientific Concepts of Functional Foods in Europe is a strong physiological effect which is seen in a positive influence on the functional state of the physiological systems of the human body due to preventing or supplying the lack of nutrients in the human body. The consequence of the use of functional food products should be taking care and improving human health [3].

The aim of this work is the experimental determination of the formula and appropriate technology for the production of pasta with enriched nutrient composition based on adding a suspension of chicken meat and

pumpkin seeds. There has been developed a functional product designed to prevent the development of pathologies that are of production and alimentary origin among the workers of the mining industry.

## 2. Materials and Methods

The determination of the pasta formulation was carried out by experimental determination of proportions of possible contents of chicken meat and pumpkin seeds suspension using standard technological equipment and generators for ultrasonic intensification of technological processes.

To establish the physicochemical parameters of the obtained product there were used the following methods: establishing the strength of pasta with the Stroganov device, the titrimetric method for the determination of protein content according to Kjeldahl method, the method of ion exchange chromatography for the determination of amino acid composition, and spectrometric method for the determination of the content of mineral substances and vitamins.

## 3. Results and Discussion

### 3.1 Physiology of mining workers labour

In order our results to be clear, we have to explain physiology of mining workers labour. The labour of the workers employed in mining is characterised by constant physical and mental stress resulting in increased blood pressure, reduced aerobic fitness and physical performance of the body, and the development of pathological conditions.

Up to 50% of production operations in the mine are done by manual labour. The main indicators for the assessment of the severity of mining workers labour are: energy consumption, pulse rate, volume of oxygen consumption, blood pressure level. According to the results of studies on the physiology of mining workers labour it has been found out that the average level of energy consumption per shift among mining workers of the basic professional groups, i.e. coal face miners and drifters, is 4.4 - 6.4 kcal/min. Maximum performance of energy consumption is 7.1 - 7.4 kcal/min. if you perform a manual cleaning of the rock and coal loading on the conveyor [4]. The pulse rate and maximum oxygen consumption also depend on the type of performed work operations. Fluctuations in the heart rate over the shift range from 94 to 132 beats per minute, and oxygen consumption ranges from 39 ml min<sup>-1</sup>kg<sup>-1</sup> to 48.7 ml min<sup>-1</sup>kg<sup>-1</sup> [5]. Physiological observations have shown that significant energy consumption rates are 0.8 - 2.1 thousand kcal per shift, with an increase of body temperature by 0.3 - 0.4 °C and the systematic reduction of body weight by 0.9 - 1.4 kg lead to

the depletion of the body [6]. Combined with awkward work postures, poor working conditions lead to a rapid formation of neuromuscular system fatigue signs in 2 - 3 hours from the beginning of the work shift [4].

Thus, a comprehensive psychophysiological studies allow to note a common pattern of physiological changes among mining workers that are expressed by the tension of regulatory mechanisms of the cardiovascular system, hypertensive reaction, and rapid physical and mental exhaustion.

A high level of psychophysical activity, increased temperature of production zones at depths of 1000 - 1400 m, stipulate the increased demand of mining workers in proteins, vitamins A, C, PP, B, E. And also in minerals (iron, calcium, magnesium, phosphorus, iodine), due to the intense perspiration that reaches 4 litres or more per work shift [7].

Increased physiological needs of mining workers, who refer, according to the classification of the Ministry of health of Ukraine, to the fourth of five groups according to the severity of work, are set out in the relevant normative document [8], the main indicators are presented in Table 1.

The study of eating behaviour of mining workers points to a defective diet and inefficient regime of food intake. The main negative signs of feeding behaviour among mining workers who have chronic illnesses are:

- Insufficient frequency of food intake - at least three times a day;
- Refusal of food in the mine during the working shift;
- Insufficient intake of food products with a high content of proteins, polyunsaturated fats, minerals and vitamins (meat, fish, milk);
- Excessive consumption of confectionery and bakery products;
- Use of alcoholic beverages.

The structure of the food products consumption among mining workers is characterised by a deficit of meat and fish products, eggs (85.5 - 92.4%), severe deficit in dairy products, vegetables and fruits (74.8 - 81.6%) and excessive intake of fatty foods, potatoes and bakery products (115.8 - 189.5%). At the same time, the diet of the organized catering for miners at mining enterprises is unbalanced in nutrient content.

The contents of carbohydrates is 10% below the standard, the contents of fats and proteins exceeds the norms by 53.7% and 143%, respectively. Receipt of mineral substances is characterized by the deficit from 38.2 to 85.7% and imbalance. The content of vitamins A, B2, B6 and C is below the recommended one by 18.0 - 95.0% [9].

The solution to the problem of nutrition optimization for mining workers provides for adjustments to the existing negative eating behaviour algorithms and will have more chances of success with the active use of functional food products.

### 3.2 Defining orientation of the physiological effects, type and nutrient composition of the functional product

Based on the results of psychophysiological studies of mining workers labour, the diet and regime of eating the main criteria for functional optimisation of food products that have been chosen are as follows:

- Receipt of the required amount of nutrients by mining workers according to the specific working conditions;
- Providing nutrients to the functional product that stimulates influence on the health of the cardiovascular and neuromuscular system.

The specificity of the production and use of functional food products involves a sequence of actions or an algorithm for creating a functional product that consists of the following steps that determined the architectonics of the presented research:

- Analysis of needs in developing a functional product in various spheres of society and the definition of the target audience for which it is developed;
- Defining the list of required properties and physiological action of the functional product;
- Substantiation and choice of the type of product, its ingredient composition for modelling certain properties and physiological functions;
- Testing the options of the developed formulations and processing methods for determining the allowable proportion of ingredients that ensures the preservation of the basic consumer properties selected for the functional optimisation of the product;

**Table 1. Daily requirement of mining workers who belong to the group of hard physical labour according to the classification of the Ministry of Health of Ukraine**

Age (years)	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrates (g)	Minerals					Vitamins				
					Fe (mg)	Ca (mg)	P (mg)	Mg (mg)	I (mcg)	C (mg)	A (mcg)	E (mg)	B (mg)	
18-29	3900	108	54	128	566	15	1200	1200	400	150	80	1	15	5,6
30-39	3700	102	51	120	528									
40-59	3500	96	48	113	499									

- Development of technological schemes of functional products manufacturing;
- A comparative study of physicochemical indicators of the developed functional and traditional products;
- Expert evaluation of organoleptic indicators of the developed functional product;
- Study of the existing demand and the economic efficiency of product manufacturing;
- Development and approval of the technological documentation.

The type of the food product that must be subjected to functional optimisation is determined by the following consumer properties that are significant for mining workers nutrition organisation:

- Inclusion to the traditional diet;
- Low cost of the food product;
- Duration and simple storage conditions;
- Ease of cooking
- A high degree of the combinatorics of the basic ingredients of the food product.

According to the results of the analysis of conformity of products for mining workers diet with the established consumer properties, pasta was recognized as most appropriate for the functional optimisation.

The cost of pasta in the domestic retail market in Ukraine varies depending on its composition from 0.5 to 2.5 euros per kilo of packaged, ready for storage and cooking products. Pasta is one of the most common food products the sales volumes of which are constantly increasing. In 2016 the volume of pasta sales in Ukraine amounted to 89 million euros [10].

In accordance with DSTU 7043:2009 - Pasta: General specifications, pasta products are stored in covered warehouses, protected from atmospheric conditions with a relative humidity of not higher than 70% and a temperature not exceeding 30 °C. The recommended storage periods of pasta without additives are 2 years, and with egg ingredients - 1 year [11].

Ingredient composition of pasta is very simple. It consists of flour (hard or soft wheat) and drinking water. The simplicity of the ingredients leads to a limited nutrient composition in pasta without processing additives. The largest share in it belongs to carbohydrates (70 - 80%) and protein (10 - 13%). The structure of proteins is composed of a small part of the essential amino acids: lysine, methionine, and tryptophan. In pasta without processing additives there is about 1% of fat. 100 grams of pasta contain about 0.17 - 0.25 mg of vitamin B<sub>1</sub>, 0.04 - 0.13 mg of vitamin B<sub>3</sub>, 1.21-2.20 mg of vitamin PP. The energy value of pasta is 335 - 337 kcal/100 g. The benefits of pasta include quick cooking for 5 - 10 minutes and high organoleptic properties.

Simple technology for cooking pasta facilitates the process of enrichment of a food product with the defined ingredients. The study uses only natural ingredients. The analysis of possible combinations of food ingredients having in its nutrient composition a stimulating effect on the functioning of the cardiovascular and neuromuscular system has led to the conclusion of the necessity for the introduction of additives of the chicken meat and pumpkin seeds suspension.

For the experimental establishment of the functional formulation of the product there have been used ingredients that were purchased in food retail stores in the city of Kryvyi Rig. To determine the nutrient composition of the functional product there has been formed the average sample from five samples of white chicken meat and pumpkin seeds canopies purchased in various outlets.

Chicken is traditionally considered a dietary product. It contains approximately 50 - 80% of water, 16 - 22% of proteins, 3 - 20% of fat, most of which are unsaturated, as well as minerals, vitamins and extractives. Pumpkin seeds are a natural source of amino acids (especially arginine) and unsaturated fats that positively affect the cardiovascular system and all the body as a whole. The obtained results of the study concerning the physicochemical composition of white chicken meat and pumpkin seeds are shown in Table 2.

The high content of unsaturated fats in the selected ingredients for the functional optimisation of pasta provides a positive effect on the cardiovascular system, which is due to increasing the elasticity of blood vessels, decreasing blood pressure and cholesterol levels. Anti-inflammatory properties of polyunsaturated fats prevent the development of chronic illnesses [12].

The most important is a physiological effect of the amino acids that simultaneously with the construction of cells perform several important functions. Namely, arginine, represented in large amounts in pumpkin seeds and white chicken meat is determined by the positive effect on the cardiovascular and neuromuscular systems due to their ability to produce NO, which is an important molecular bioregulator. Receipt of arginine leads to the expansion of blood vessels, improving blood flow in the coronary arteries and a significant reduction in arterial blood pressure in the conditions of the high physical performance. For individuals with increased physical activity arginine enhances the action of insulin and increases the growth of blood capillaries in skeletal muscles. Arginine stimulates the production of growth hormone (somatotrophic hormone), promotes body fat reduction, muscle growth, increases the activity and physical endurance, and improves mood and concentration. Arginine also helps to cleanse the body from decay products of proteins. 100 g of white chicken meat and pumpkin seeds contain

**Table 2 - Physicochemical composition of white chicken meat and pumpkin seeds**

Indicators per 100 g of product	Chicken meat	Pumpkin seeds
Water, g	74.9	5.1
Carbohydrates, g	0	5.2
Fat, total, g	3.3	48.2
Saturated fats, g	0.9	9.1
Monounsaturated fat, g	1.6	18.2
Polyunsaturated fats, g	0.8	20.9
Proteins, total, g	21.8	31.2
<b>Essential amino acids, g</b>		
Valine	1	1.1
Isoleucine	1	1.1
Leucine	1.7	2.1
Lysine	1.9	1.1
Methionine + Cysteine	0.8	1
Threonine	0.4	0.7
Tryptophan	0.8	0.4
Phenylalanine+Tyrosine	1.6	2.1
<b>Substituting amino acids, g</b>		
Alanine	1.2	1.2
Arginine	1.4	5.2
Aspartic acid	1,9	2,1
Histidine	0,7	0,8
Glycine	0,9	1,4
Glutamic acid	2,9	5,1
Proline	0,6	1,1
Serine	0,8	1,4
<b>Mineral substances, mg</b>		
K	291	750
Ca	5	40
Mg	28	490
Na	345	5
P	270	1220
Fe	0.4	8
Mn	0.02	4
Se	0.03	0,08
<b>Vitamins, mg</b>		
A	0.09	0.01
E	-	2.2
C	-	1.7
B <sub>1</sub>	0.08	0.3
B <sub>2</sub>	0.02	0.2
B <sub>5</sub>	1.2	0.7
B <sub>6</sub>	0.8	0.1
PP	7.7	-

6.6 g of arginine that is 108% of the daily needs of an average adult. A positive impact on the functioning of the mining workers body will also belong to the aglutamic acid that participates in protein and carbohydrate exchange, stimulates oxidation processes, contributes to the neutralization and excretion of ammonia, and increases the body's resistance to hypoxia. It promotes the synthesis of acetylcholine and ATP, transfer of potassium ions, plays an important role in the activity of skeletal muscles, increasing their endurance. Glutamic acid belongs to neutrally mediated amino acids that stimulate the transfer of excitation in synapses of the central nervous system. 100 g of the selected as additives ingredients contain 8 g of glutamic acid, which is 58% of the daily requirement of an average adult [13].

On the whole, amino acid composition and a high content of minerals (K, Ca, Mg, Na, P, Fe) and vitamins (A, E, C, B, PP) in the selected ingredients must maintain a high level of functional ability of all the physiological systems in the mining workers body.

### 3.3 Testing the options of the developed formulations and processing methods for determining the allowable proportion of ingredients

Experimental production of pasta in the laboratory of food processing equipment in Donetsk National University of Economics and Trade named after Mykhailo Tugan-Baranovsky consists of the following stages:

- Preparation and dosing of ingredients;
- Dough kneading;
- Formation of pasta products;
- Drying.

The study included the establishment of the pasta products formulation of enriched nutrient composition for every 5 kg of the finished product. To prepare the appropriate quantity of traditional pasta, you need 5 kg of flour and 1.15 L of water.

For making pasta flour of durum wheat is used. In accordance with DSTU 7043:2009 flour should not exceed 15% [11]. Gluten content in flour that was used for making functional products was in the range of 30 - 32%, particle size of flour was 20 - 200 µm. The temperature of the flour was 20 °C. The flour was sifted through a metal sieve with holes the size of which was 1.4 - 1.6 mm. For cooking pasta there was used drinking water, temperature of which was of 40 - 50 °C.

Experimentally there was investigated the technological possibility of introducing three variations of the share of processing additives of 20 (1.23 kg), 35 (2.15 kg) and 50 (3.08 kg) percent of the total weight of ingredients in the formulation of pasta. The ratio of white chicken meat and pumpkin seeds is 50/50.

Processing additives as a suspension of minced white chicken meat and ground dried pumpkin seeds is cooked in a metal mixer with an attached to it universal emitter of ultrasonic waves. The influence of ultrasonic vibrations provides the finest dispersion of heterogeneous environment of the processing additives due to the effect of ultrasonic cavitation [14]. Preparation of the processing additive in a mixer under constant exposure to ultrasonic waves is 10 minutes. The result is a slurry with a high uniformity of particles with the size of 20 - 30  $\mu\text{m}$ .

The dough is mixed in a metal mixer for 14 minutes under the constant exposure to ultrasonic waves with a frequency of 20 kHz. The output is controlled by the characteristics that will ensure its effective formation and drying. Namely, the planned moisture of the dough is 30 - 31%, an acceptable level of homogeneity, adhesion and plasticity.

The results of the experiment established that the essential quality indicators for the further formation of pasta were achieved in experiments with a formulation containing 20 and 35 percent of processing additives. The dough containing 50 percent of the processing additive has not acquired the desired degree of homogeneity and plasticity.

At the next stage, by pressing and cutting there was obtained uncooked pasta of a ribbon-like type (with a width of 8 mm and thickness of 1 mm) for the further increased drying at an accelerated rate. Drying of pasta products was carried out in the upgraded oven with a built-in piezoelectric ultrasonic transducer. Appropriate drying technology is based on the use

of cavitation effects required for the sublimation of the liquid and of the active capillary effect, and to tear off the edge film material that is heated. Optimization contents of ultrasonic processing is that its energy in the form of vibration to the full depth penetrates into the colloidal substances of pasta and relieves mechanical tension. Additionally, ultrasound increases the intensity of the heat transfer rate 2 - 2.5 times due to turbulence and creation, as a result, of a considerably thinner layer of steam-air mixture on the surface of the material that is dried. This dramatically reduces the thermal resistance of the heat transfer from the drying air, contributes to the active protein denaturation and reduced drying time ([14], [15]).

The drying process consists of two stages. At first, the product is dried with the use of ultrasound in the upgraded oven when the air temperature is + 95  $^{\circ}\text{C}$ , humidity is 95%, the sound pressure level is 140 dB for 2 minutes. In the second stage, at the temperature of + 60  $^{\circ}\text{C}$ , humidity of 70% and the sound pressure level of 140 dB over 53 minutes to a moisture content of finished products of 11 - 12%.

Drying pasta with a processing additive of white meat chicken and pumpkin seeds slurry at a high temperature and humidity in the field of metered-dose ultrasound has enabled us to remove structural tension, to eliminate the acidification and microbiological spoilage, cracking, loss of shape and strength. The received pasta has a high density, smooth surface, which positively affects the duration of its storage and organoleptic qualities.

**Table 3. Amino acid composition of protein of pasta**

Amino acids, g	Pasta without processing additives		Pasta with the addition of lentils flour		Pasta with the addition of chicken meat and pumpkin seeds	
	in 100 g product	in 100 g protein	in 100 g product	in 100 g protein	in 100 g product	in 100 g protein
<b>Valine</b>	0.45	3.98 (79.6%)	0.60	4.94 (98.8%)	0.64	5.38 (107.6%)
<b>Isoleucine</b>	0.43	4.05 (101.2%)	0.64	4.44 (111.1%)	0.72	4.89 (122.2%)
<b>Leucine</b>	0.82	7.78 (111.1%)	1.00	7.57 (108.2%)	1.25	8.67 (123.9%)
<b>Lysine</b>	0.25	2.42 (44%)	0.43	3.33 (60.5%)	0.48	4.52 (82.2%)
<b>Methionine + Cysteine</b>	0.15	1.47 (42%)	0.18	2.04 (58.2%)	0.21	2.67 (76.3%)
<b>Threonine</b>	0.32	3.03 (75.6%)	0.41	3.68 (92.2%)	0.48	3.79 (94.8%)
<b>Tryptophan</b>	0.11	0.91 (91%)	0.12	0.96 (96.5%)	0.15	1.46 (146%)
<b>Threonine</b>	0.51	4.86 (81%)	0.63	5.05 (84.2%)	0.96	7.54 125.6%
<b>Content of protein, %</b>	10.4		13.8		18	

### 3.4 Physicochemical and organoleptic characteristics of the final functional product

To establish the compliance of the final product with its functional purpose there was carried out a comparative study of the physicochemical parameters of the traditional pasta and products offered by other researchers.

The level of physicochemical parameters of the obtained functional product, which are determined by the acting in Ukraine DSTU 7043:2009 - Pasta: General specifications, is within the set values: moisture - 12%, pH is 8.0, strength is 1.2 H. The level of microbiological contamination is  $4.5 \times 10^4$  of colonic units in 1 g.

When determining the biological value of the final product there was chosen a recipe that provides the contents of 35% of the processing additives of the total weight of the ingredients. It is established that the protein content in pasta enriched with functional additives of white meat chicken and pumpkin seeds is 18%, which is 7.6% more than ordinary pasta without additives and 4.2% more than in the patented pasta with the addition of lentils flour [16]. Comparative information about the protein content in pasta and its amino acid composition is given in Table 3.

By adding the offered processing additives the amino acid score grows in all positions. There remains a limited quantity of lysine, methionine + cysteine, threonine. Score of these amino acids grows compared to pasta without processing additives by 86.8%, 81.6%, and 25.1% respectively. Compared to pasta containing lentils flour additive the score increases respectively by 35.7%, 30.9%, and 29.9%.

Cooked pasta has the correct shape, elastic consistency and a pleasant taste. It was found that after boiling until tender, the protein content in pasta with the addition of white chicken meat and pumpkin seeds decreases by 22.8%, which is 9.6% less than in the pasta without additives.

### 4. Conclusions

- According to the results, there has been established the possibility of increasing the proportion of processing protein additives of white meat chicken and pumpkin seeds by 35% of the total weight of ingredients in pasta, due to the usage of the ultrasound dispersion and cavitation effects in the preparation process.

- Use of ultrasound in the drying process of pasta reduces the time by 20% and allows to achieve the necessary parameters of humidity, acidity, microbiology and strength required for a long-term storage.

- The calculation of the cost of the final product was carried out on the basis of costs for the preparation of 5 kg of the finished product. Taking into account the cost

of all the components, it gives grounds for setting the cost at the level of 1.5 - 2 euros per kilo of the packaged products. The cost of products is competitive for the domestic market of Ukraine, which allows to count on the possibility of procurement by the mining industry for using in the centralized nutrition of workers.

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