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DEVELOPMENT OF THE NEWEST HEALTHY FOOD PRODUCTS USING GREEN ALGAE

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Abstract. *Globalization is changing people's diets. In today's conditions, the attention of consumers to the quality of food products is increasing. This shows a change in priorities in favor of safe food products from natural domestic raw materials. New food products with algae can become an important physiological source of essential micronutrients and, provided a varied balanced diet, can meet 50% of human needs in essential micronutrients. An important source is the microalgae Chlorella vulgaris and Spirulina platensis. New types of meat products with chlorella will allow, on the one hand, to normalize the intake of vitamins and mineral elements in the human body, and on the other hand, contribute to the removal of heavy metals, pesticides, radionuclides, giving the developed products radioprotective properties. This opportunity can be provided by «superfoods», which are rapidly gaining popularity. Microalgae Chlorella vulgaris and Spirulina platensis contain all the necessary elements and a wide range of uses, which gives them full potential for mass consumption. Therefore, these superfoods are promising raw materials not only for sports, diet and herodiet nutrition, but in general as a food additive and component of any dishes, the assortment of which is very small today. Therefore, in order to achieve the goal, the technology of chopped meat semi-finished products was improved with the use of microalgae Chlorella vulgaris and Spirulina platensis in the amount of 1.5% and 3%, as well as their combination 1:1. The study of the vitamin and mineral content of the developed samples was conducted. The conducted studies confirm and prove the expediency and perspective of using microalgae in many sectors of Ukraine.*

Key words: *microalgae, Chlorella vulgaris, Spirulina platensis, blend of oils, technology, chopped semi-finished products.*

Statement of the problem in a general form. Currently, food products derived from microalgae are marketed as health foods and are commercially available as capsules, tablets, powders, and liquids. They are also mixed with candy, gum, snacks, pastas, noodles, breakfast cereals, wine, and other beverages. Microalgae species such as Spirulina plantesis, Chlorella sp., Dunaliella terticola, Dunaliela saline and Aphanizomenon flos-aquae have become widely used due to their high protein content and nutritional value. Recently, however, it is chlorella and spirulina that dominate the global microalgae market as they gain popularity in supermarkets and health food stores. Microalgae are important sources of long-chain polyunsaturated fatty acids and are therefore used in the food industry as additives. They are able to synthesize representatives of the omega-6 family, which include linoleic acid, γ-linolenic acid and arachidonic acid, as well as omega-3 (linolenic, eicosapentaenoic and docosahexaenoic acids). The last two are associated with a reduction in complications from cardiovascular disease, arthritis and hypertension; show appropriate hypolipidemic activity to lower triglycerides and increase high-density lipoprotein cholesterol. Alternative forms of such additives include liquid for beverages, powder for flour-based products (bread, cookies, pasta), oil (butter, mayonnaise), and tablets and capsules for food additives [1, 2].

Over the past five years, the amount of food and beverages containing micro- and macroalgae has increased significantly. Worldwide, 13,090 new food products containing algae or their derivatives were released, of which 5,720 were in Europe. The inclusion of algae in the product took different forms (whole dried biomass or purified ingredient) and their function in the formulation (colorant or functional ingredient). Analyzing the state of the food additives market, the preference is given to microalgae. In Ukraine, this raw material is currently undervalued and is just beginning to gain momentum, although in European and Asian countries, algae is used not only as a food additive, but as a component of the daily diet on a par with other products. In addition, microalgae contain a variety of bioactive components that have anticarcinogenic, antioxidant, antihypertensive, and hepatoprotective agents [3, 4].

Analysis of recent research and publications. Cultivation of microalgae is currently a promising direction because the range of their use is quite wide – it includes the production of food, animal feed, fertilizers, as well as the production of biofuel. The idea of cultivating microalgae on an industrial scale arose in Germany in the middle of the last century, to obtain edible oil from diatom algae. Soon, the green microalgae Chlorella and Scenedesmus attracted the attention of scientists. However, at that time, the technological features of growing these microalgae were at a low level, so attempts to cultivate them were temporarily suspended. The revival of research in the field of industrial cultivation of microalgae began in

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the late 1960s, and interest in them continues to this day. The cultivation of microalgae on an industrial scale has a history of half a century. The obtained biomass is used in agriculture, food industry, perfumery, pharmacology, medicine and other sectors of the national economy. Currently, there are about 40,000 species of microalgae (more than 5,000 species in Ukraine), but representatives of the Chlorella, Dunaliella, Scenedesmus, and Spirulina families are considered the most promising [5, 6].

Chlorella vulgaris and Spirulina platensis are currently the most common microalgae cultivated and widely used in many countries of the world. Of course, most of these microalgae on the Ukrainian market are of foreign production, mainly China, Japan and the USA, but Ukrainian producers are also engaged in the cultivation of Chlorella vulgaris – the enterprise «Хлорела Україна» LLC and TM «Жива Хлорела» FG «У Самвела», which represent the assortment microalgae in powder and liquid (suspension) form. The manufacturer of Spirulina platensis is the company «Фуд Факторі» under the TM «Spirulinka», which manufactures a frozen suspension of microalgae.

Chlorella vulgaris and Spirulina platensis in their composition have a high content of complete protein (50–70%), which is due to the presence of all essential amino acids that cannot be synthesized in the human body, vitamins (A, group B, PP, E, C) and macro- and trace elements (Ca, Mg, K, P, Na, Fe), unsaturated fatty acids and pigments (chlorophyll, phycobilins, carotenoids) [7, 8].

Algae belong to the consumption culture of Japan, Korea, and China, where they are used on an equal footing with other products that are familiar to us, America and European countries use them mainly as food additives. Microalgae are added to salads, first courses, bakery and pasta products, sauces, ice cream, candies, chips and snacks, smoothies and lemonades are prepared on their basis. Thus, with the help of superfoods Chlorella vulgaris and Spirulina platensis, it is possible to improve the technology of almost any product, enrich its nutritional and biological value, by fortifying the mineral and vitamin composition [9-11].

Forming the goals of the article. The aim of the work is to improve the technology of chopped semi-finished products using natural biologically valuable components containing microalgae Chlorella vulgaris and Spirulina platensis, for product fortification without changing its organoleptic indicators.

Presentation of the main research material. Modern principles of creating high-quality food products are based on the selection and justification of certain types of raw materials in such ratios that would ensure the predicted quality, consumer and functional properties and maximum balance of food components according to the chemical composition of the finished products. In order to expand the assortment and, at the same time, improve the quality of products to the control recipe, according to DSTU 4437:2005 Semi-finished meat and meat-vegetable minced meat products, microscopic unicellular green algae Chlorella vulgaris and Spirulina platensis were added in the amount of 1.5–3% in the form powder To balance the fatty acid composition, a mixture of oils was taken, which will allow to adjust food rations with essential nutrients, to achieve the required ratio of ω–6 : ω–3 fatty acids and to expand the range of meat semi-finished products.

The main raw material for the production of experimental samples was chicken meat, since it is the most affordable for the Ukrainian consumer. Flax flour was added to the recipe to improve the nutritional value of the product, as it contains 34% protein, B vitamins (B1, B2, B3, B5, B6, B9), macro- and microelements (Ca, K, Fe, P, Zn, Cu, Se), polyunsaturated fatty acids (omega-3 and omega-6). Hydration of flax flour was carried out 1:2. To give the product functional properties, a balanced fatty acid composition, a blend of oils (walnut, avocado and linseed) was added in a ratio of 3:2:1, respectively.

To compare the analysis of the fatty acid composition of oils, sunflower oil was chosen as the most popular in Ukraine according to DSTU 4492:2005 Sunflower oil. Specifications. The fatty acid composition of the oils selected for blending is shown in Table 1. In the resulting blend of walnut, avocado, and linseed oils (3:2:1), the ratio of ω–6: ω–3 fatty acids is 3:1, which indicates its balanced compared to sunflower oil.

Walnut and linseed oil have a high content of alpha-linolenic acid (omega-3) and linoleic acid (omega-6), avocado oil – oleic, and also has a high smoking temperature (270°C), which indicates the preservation of all its beneficial properties substances after heat treatment. Flax flour and microalgae were added to the minced meat after the hydration process to evenly combine all components in the recipe.

Algae Chlorella vulgaris and Spirulina platensis are rich in vitamins of group B, vitamin C, E, A, PP. It is important that all these vitamins are found in microalgae in their natural form – they are easily absorbed and will have an effective effect on the human body, since nature itself took care of their digestion and dosage. The vitamin composition of experimental samples of semi-finished products is shown in Table 3.

The developed chopped semi-finished products have an advantage in comparison with the control in terms of all the above vitamins. Samples № 2 (using Chlorella vulgaris) and sample № 4 (using Spirulina platensis) have the highest amount of vitamin A. According to the content of vitamins E, the experimental samples exceed the control sample by 30...187%, sample № 2 has the best results. According to the values of other vitamins, the developed

Table 1

Fatty acid composition of oils

Fatty acid	Fatty acid content of oils, g/100 g of product			
	Sunflower	Walnut	Flax	Avocado
Saturated, including	12,1	7,0	11,4	14,1
Myristic ($C_{14:0}$)	0,1	0,5	0,1	0,1
Palmitine ($C_{16:0}$)	6,5	4,8	6,1	13,5
Stearic ($C_{18:0}$)	5,5	1,7	5,2	0,5
Monounsaturated, including	29,5	22,1	19,4	61,3
Palmitoleic ($C_{16:1}$)	5,0	0,1	0,1	5,4
Oleic ($C_{18:1}$)	24,5	22,0	19,3	55,9
Polyunsaturated, including	63,5	76,9	68,9	17,0
Linoleic ($C_{18:2}$) ω6	62,5	68,0	15,6	16,1
Linolenic ($C_{18:3}$) ω3	1,0	8,9	53,3	0,9

Table 2

Recipes of chopped semi-finished products

Raw	Recipes					
	Control (according to DSTU 4437:2005)	№ 1	№ 2	№ 3	№ 4	№ 5
The amount of the main raw material, % /100 kg						
Chicken meat	65	61	57	61	57	59
Flax flour	4	4	4	4	4	4
Water for hydration of flour	6	6	6	6	6	6
Egg	11	10	10	10	10	10
Onion	8	8	8	8	8	8
Blend of oil	6	6	6	6	6	6
Chlorella vulgaris	-	1,5	3	-	-	1
Spirulina platensis	-	-	-	1,5	3	1
Water for the hydration of algae	-	3,5	6	3,5	6	5
Spices, % to the main raw materials						
Salt	1,3	1,3	1,3	1,3	1,3	1,3
Ground black pepper	0,2	0,2	0,2	0,2	0,2	0,2

Table 3

Vitamin composition of chopped semi-finished products and algae

Sample	Vitamin content, mg/100 g of product					
	A	B_1	B_2	PP	E	C
Chlorella vulgaris	170	2,38	5,02	24,5	14,5	10,4
Spirulina platensis	160	2,32	3,67	12,8	5,0	10,1
Control	0,08	0,11	0,15	4,85	0,23	0,85
Sample №1	2,62	0,15	0,22	5,25	0,45	1,01
Sample №2	5,17	0,19	0,29	5,32	0,66	1,17
Sample №3	2,54	0,14	0,20	5,08	0,30	1,0
Sample №4	5,05	0,18	0,25	4,96	0,37	1,15
Sample №5	3,47	0,16	0,23	5,10	0,42	1,06

semi-finished products exceed the control sample by: 27...73% (B1), 33...93% (B2), 18...38% (C).

In addition to a wide range of vitamins, microalgae have a relatively high content of minerals in their composition, the deficiency of which is felt by every second resident of Ukraine. data on the content of minerals in the test samples are given in Table 4.

According to the data of the mineral composition, sample № 2 and sample № 4 turned out to be the best. The sample with the use of Chlorella vulgaris in the amount of 3% (sample № 2) has the highest indicators for the content of Ca, Mg, K (increased by 32 mg/100 g of product) and Fe, the value of which increased 4 times compared to the control sample. In samples № 1, № 4, and № 5, the value of Fe increased by 2 times. The sample using Spirulina platensis 3% (sample № 4) has the highest Na and P values (the content of the element is 10 mg/100 g of product

Table 4

Mineral composition of chopped semi-finished products and algae

Sample	The content of mineral substances, mg/100 g					
	Ca	Mg	K	P	Na	Fe
Chlorella vulgaris	150,0	318,0	1540,0	58,0	186,0	167,0
Spirulina platensis	131,5	191,5	1500,0	118,0	250,0	58,0
Control	30,1	31,1	213,3	160,8	66,5	1,6
Sample № 1	31,4	36,4	230,2	166,9	67,3	4,1
Sample № 2	32,9	41,1	245,5	163,8	66,7	6,6
Sample № 3	31,1	33,7	231,1	167,5	67,9	2,4
Sample № 4	32,4	35,7	243,7	171,1	68,5	3,2
Sample № 5	31,6	36,0	233,7	167,1	67,1	3,8

higher than the control). In the experimental samples, compared to the control, the content of magnesium increased by 8...32%, potassium by 9...15%, iron by 50...313%.

Conclusions from the mentioned problems and prospects for further research in the given direction. Microalgae Chlorella vulgaris and Spirulina platensis are promising raw materials for their mass use in various industries, and food production is no exception. The easiest way to use microalgae in food technologies is to improve products familiar to the Ukrainian consumer by adding these superfoods to their composition. It is algae in the form of a suspension or powder that is the best option for this, as they contain microalgae with a broken cell wall, which contributes to the maximum assimilation of all useful elements [12].

In this way, we improved the technology of chopped semi-finished products. The vitamin and mineral content of the produced samples was studied. After analyzing the obtained data for each sample, sample No. 2 with the use of Chlorella vulgaris in the amount of 3% turned out to be the best according to the vast majority of indicators. It received the highest values for the content of vitamins A, B1, B2, PP, E, C and minerals Ca, Mg, K and Fe. Thus, on the basis of the obtained data, it has been proven that the use of microalgae in the technology of meat semi-finished products is expedient for improving quality indicators and expanding the assortment without worsening their organoleptic properties.

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Розробка новітніх продуктів здорового харчування з використанням зелених водоростей

Анотація. *Глобалізація змінює раціони людей. В умовах сьогодення посилюється увага споживачів до якості продуктів харчування. Це показує зміну пріоритетів на користь безпечних харчових продуктів з натуральної вітчизняної сировини. Нові харчові продукти з водоростями можуть стати важливим фізіологічним джерелом основних мікронутрієнтів і за умови різноманітного збалансованого раціону на 50% задовольнити потреби людини в основних мікроелементах. Істотним джерелом є мікроводорості Chlorella vulgaris і Spirulina platensis. Нові види м'ясних продуктів з хлорелою дозволять, з одного боку, нормалізувати надходження в організм людини вітамінів, мінеральних елементів, а з іншого сприяють виведенню важких металів, пестицидів, радіонуклідів, надаючи розробленим продуктам радіопротекторних властивостей. Цю можливість нам можуть надати «суперфуди», які стрімко набирають популярності. Мікроводорості Chlorella vulgaris і Spirulina platensis мають у своєму складі всі необхідні елементи та широкий спектр використання, що дає їм повноцінні можливості масового вживання. Тож ці суперфуди є перспективною сировиною не лише для спортивного, дієтичного та геродієтичного харчування, а в цілому як харчова добавка та компонент будь-яких страв, асортимент яких насьогодні дуже незначний. Тому для досягнення поставленої мети – проведено удосконалення технології м'ясних січених напівфабрикатів з використанням мікроводоростей Chlorella vulgaris і Spirulina platensis в кількості 1,5 % та 3 %, а також їх поєднання 1:1. Проведено дослідження вітамінного та мінерального вмісту розроблених зразків. Проведені дослідження підтверджують і доводять доцільність і перспективність використання мікроводоростей у багатьох галузях України.*

Ключові слова: *мікроводорості, Chlorella vulgaris, Spirulina platensis, купаж олій, технологія, січені напівфабрикати.*