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DEVELOPMENT OF THE TECHNOLOGY OF FUNCTIONAL MEAT PRODUCTS WITH A HEALTH-IMPROVING EFFECT USING PLANT RAW MATERIALS AND ALGAE THAT ARE NOT TRADITIONAL FOR UKRAINE

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INTRODUCTION

Of all the factors that affect the human body, the most important is nutrition, which ensures physical and mental performance, health, and life expectancy, since food substances in the process of metabolism are transformed into structural elements of the cells of our body, ensuring its vital activity. Observations show the dependence of the occurrence of various diseases (ulcers, tumors, diseases of the gastrointestinal tract and other body systems) on the quality of food and the lack of vitamin complexes in it. At the same time, it is possible to cite examples of inverse dependence, when the level of disease in the population significantly decreased with the improvement of the quality of nutrition[1].

The level of human health depends 50 % on conditions and lifestyle, 20 % on genetic factors, another 20 % on environmental ecology, and only 10 % on medicine. That is, an important factor in shaping the health of the population is a balanced diet[2].

Among the main disorders in the diet of the population, the following are distinguished: deficiency of complete (animal) proteins, excessive consumption of animal fats, deficiency of polyunsaturated fatty acids, pronounced deficiency of dietary fibers, vitamins (hypovitaminosis, avitaminosis) and minerals[3].

Constant environmental problems, stress, fast pace of life, unhealthy diet and alcohol abuse lead to disease of both the liver and the whole body as a whole.

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[1] Renger F. Nutrition to Optimise Human Health – How to Obtain Physiological Substantiation? *Nutrients*. 2021. № 13. P. 2155. https://doi.org/10.3390/nu13072155

[2] Bharti J., Kumar Verma S., et al. Relationship of nutrition, food science and nutrional psychology to health. *Strad Research*. 2021. № 8. P. 81–89. https://doi.org/10.37896/sr8.10/008

[3] Bailey R. L., West K. P., Black R. E. The epidemiology of global micronutrient deficiencies. Ann. Nutr. Metab. 2015. № 66. P. 22–33. https://doi.org/10.1159/000371618

When formulating the principles of disease prevention among the population of Ukraine, it is necessary to keep in mind that the state of nutrition is the most important factor that neutralizes the effect of negative factors that contribute to the development and chronicity of food-dependent diseases. This approach is extremely relevant in modern environmental conditions[4].

In view of the above, the issue of creating food products for healthy nutrition is relevant. In this regard, we have developed semi-finished products with the use of plant raw materials unconventional for Ukraine in the recipe[5]: chia, quinoa, flax, amaranth, hemp, green microalgae chlorella and spirulina.

1. Statement of the problem and formulation of ways to solve it

Prevention of morbidity among the population by optimizing nutrition is observed in a number of economically developed European countries, in the USA and Canada. The relevance of this issue is emphasized by the adoption by the governments of a number of European countries (Netherlands, Norway, Denmark, Spain, Finland, Malta) of a healthy food policy.

The production of healthy food products is a relevant topic in Ukraine today, which satisfy the physiological needs of humans in essential substances and energy. One of the most popular among the population are healthy food products for athletes. The growth of sales of products of this segment in the world is due to the growing concern of the population about the problem of obesity[6]. Recently, consumers pay more and more attention to their health, physical activity and balanced diet. According to the results of the Datamonitor marketing research, about 28 % of the population are potential consumers of sports nutrition products that can help them achieve their sports goals and improve their health.

Among the categories of consumers of healthy food, the following are distinguished:

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[4] Tuck C. J., Vanner S. J. Dietary therapies for functional bowel symptoms: Recent advances, challenges, and future directions. *Neurogastroenterol. Motil.* 2018. № 30. P. 13238. https://doi.org/10.1111/nmo.13238

[5] Пешук Л. В., Будник Н. В., Іванова Т. М. Використання вторинної рослинної сировини в технології м’ясних продуктів. Природно-ресурсний та енергетичний потенціали: напрями збереження, відновлення та раціонального використання: колективна монографія / за ред. О. О. Горба, Т. О. Чайки, І. О. Яснолоб. Полтава: Видавництво ПП «Астрая», 2019. С. 205–212.

[6] Webb V. L., Wadden T. A. Intensive Lifestyle Intervention for Obesity: Principles, Practices, and Results. *Gastroenterology*. 2017. № 152. P. 1752–1764. https://doi.org/10.1053/j.gastro.2017.01.045

– professional athletes (to increase strength and endurance);

– people leading a healthy lifestyle (as an additional source of proteins and carbohydrates);

– women are an important target group for manufacturers of sports nutrition, which requires a special approach to the formulation of products, taking into account the peculiarities of the physiological processes of the female body;

– teenagers – now they become regular consumers of healthy food, the development of products specifically for this age group is necessary, as the nutritional needs of a young organism are significantly different[7].

– elderly people – with age, muscle mass decreases, bones weaken. Dan Benardot's new theory suggests that creating a basic exercise program for older adults, along with consuming protein-rich foods, can significantly improve their health[8].

– people with increased physical activity. There is also a high demand for healthy food products among people with jobs that require physical strength (construction workers, firefighters, rescue workers, military personnel, law enforcement officers).

Most often, healthy food products are used for the purpose of maintaining sports fitness (21 %), building muscle mass (18 %), improving the body (17 %), increasing the effectiveness of training (13 %)[9].

The main trend of the market of frozen semi-finished products in recent years has been the increase in the production of more technological products. If previously mainly cutlets and meatballs were produced, now frozen products with complex fillings, ready-to-eat natural products, and ready-made meals have appeared, which save consumers' time. The growth of the market is explained not only by the increase in capacity, but also by the emergence of new niches and segments.

Among the main factors causing high demand for meat semi-finished products:

1) an accelerated lifestyle, which motivates the purchase of semi-finished products, the practicality of which meets the modern requirements of society;

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[7] Kołota A., Głabska D. Analysis of Association between Adolescents' Food Habits and Body Mass Change in a Population-Based Sample. *Int. J. Environ. Res. Public Health*. 2022. № 19. P. 11772. https://doi.org/10.3390/ ijerph191811772

[8] Benardot D. Advanced sports nutrition. 2nd ed. Champaign, IL, Human Kinetics. 2012. P. 424.

[9] Chen F., Du M., Blumberg J., et al. Association among dietary supplement use, nutrient intake and mortality among U.S adults. Annals of Internal Medicine. 2019. № 170. P. 604–613. https://doi.org/10.7326/M18-2478

2) increasing the education of the consumer, who understands that modern methods of freezing make it possible to preserve biologically active substances as much as possible, in particular vitamins and minerals;

3) improving the quality of products (in the last 2 years, manufacturers have begun to use higher-quality ingredients for the production of frozen semi-finished products).

Today, the market of frozen products is actively developing, and the processing industry as a whole has a high potential for growth in consumption and market capacity[10]. The Ukrainian market of frozen semi-finished products has its own characteristics related to national stereotypes in the food culture of the majority of the population of Ukraine and the lifestyle of citizens[11].

The aim of the scientific work is theoretical substantiation and experimental proof of the possibility of using vegetable raw materials rich in protein, namely microalgae, chia, quinoa, flax, hemp and amaranth in the production of functional meat products, namely frozen semi-finished products. The object of the research is the production technology of frozen semi-finished products enriched with macro-microelements, in particular calcium, magnesium, zinc, iron thanks to natural native plant raw materials.

In accordance with the set goal, the following tasks were defined:

– analyze scientific and technical information from this field of research;

– justify the feasibility of using microalgae, chia, quinoa, flax, hemp and amaranth in the production of semi-finished products;

– evaluate the nutritional and biological value of these products; to conduct organoleptic, physico-chemical, functional-technological and structural-mechanical studies of the developed products before and after heat treatment;

– determine the content of calcium, magnesium, zinc, iron in products;

– conduct microbiological research;

– investigate the amino acid and fatty acid composition of products.

A promising way of developing the technology of functional food products is the combination of meat raw materials with vegetable raw

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[10] Пешук Л. В., Приходько Д. Ю. Розробка новітніх продуктів здорового харчування з використанням зелених водоростей. *Науковий вісник Полтавського університету економіки і торгівлі. Серія «Технічні науки»*. 2023. № 3. С. 28–32. https://doi.org/10.37734/2518-7171-2022-3-5

[11] Пешук Л. Нові тенденції та виклики сьогодення щодо виробництва та споживання продуктів харчування. *Матеріали науково-практичної конференції пам'яті професора Юрія Григоровича Григорова* (Київ, 17 травня 2021 р.). Київ, 2021. С. 44–48.

materials, namely microalgae, chia, quinoa, flax, hemp and amaranth, enriching the product with protein, macro- and microelement composition, with the aim of expanding the assortment, achieving the maximum technological effect, increasing biological and nutritional value of finished products and extension of shelf life thereby meeting the nutritional needs of supporters of a healthy lifestyle. In this way, we developed 7 recipes of semi-finished products.

In order to achieve high nutritional and biological value of functional meat products, ingredients were selected that allowed for a comprehensive approach to optimizing the nutritional value and technological characteristics of chopped meat semi-finished products. The developed recipes included chicken meat, turkey fillet, hemp oil, melange, onion, breadcrumbs, table salt, and black pepper. To give the product functionality, a combination of meat and vegetable raw materials was carried out: chia (Spanish sage, lat. Salvia hispanica), quinoa (lat. Chenopōdium quīnoa), flax (lat. Línum), hemp (lat. Cánnabis), amaranth (lat. Amaránthus), chlorella microalgae (lat. Chlorella vulgaris)[12] and spirulina (lat. Spirulina platensis), which is rich in vitamins A, C, B, PP, D, micro- macroelements necessary for the normal functioning of the human body.

Table 1

Comparative characteristics of the chemical composition of plant raw materials

Indexes, %	Turkey meat	Chia	Quinoa	Hemp flour	Flax flour	Amaranth flour	Chlorella	Spirulina
Moisture	70,40	4,90	13,28	11,50	8,00	11,35	2,60	1,80
Dry substances	29,60	95,10	87,72	88,50	92,00	88,65	97,40	98,20
Protein	20,42	15,62	14,10	20,10	23,00	16,13	56,0	69,0
Fats	8,02	30,75	6,10	32,50	35,00	6,72	9,0	7,0
Carbohydrates	-	43,85	64,2	-	27,0	60,96	28,0	20,0
Mineral substances	0,88	4,87	4,62	4,50	4,00	4,83	9,20	7,80

Table 1 shows that spirulina, chlorella, chia, and flax flour have the largest amount of dry matter. In terms of protein content, algae, flax and hemp flour are the best alternative as protein fortifiers for combining meat

[12] Бахмач В. О., Пешук Л. В., Чернушенко О. О., Савченко А. М., Петренко С. О. Використання інноваційних технологій та компонентів у емульсійних продуктах. *Вісник Національного Технічного Університету «ХПІ». Серія: Інноваційні дослідження у наукових роботах студентів*. 2022. № 1 (1363). С. 18–22. https://doi.org/10.20998/2220-4784.2022.01.03

and vegetable raw materials in the production of functional products and enriching them with macro-microelement composition.

Table 2

Comparative characteristics of the amino acid composition of raw materials, mg/100 g

Amino acids	Turkey meat	Chia	Quinoa	Hemp flour	Flax flour	Amaranth flour	Chlorella	Spirulina
Essential amino acids								
Valin	5000	5850	5000	5850	5000	3780	6440	4210
Isoleucine	3400	4480	4240	4920	3400	3700	5010	3640
Leucine	7600	8070	7120	4700	7600	5190	6840	6170
Lysine	4100	5890	6530	4700	4100	4750	5600	3400
Methionine + cystine	3380	2880	4320	3870	3380	8150	1500	1710
Threonine	3600	4280	3560	2680	3600	3540	5240	3310
Tryptophan	800	1600	1440	1670	800	820	2040	850
Phenylalanine + tyrosine	7600	6790	7290	7930	7600	7610	4200	3330
In total	**35480**	**39840**	**39500**	**36320**	**35480**	**37540**	**36870**	**26620**
Substitute amino acids								
Histidine	2950	3390	3480	2560	2000	3420	1500	2900
Alanine	6280	5950	5000	5080	5100	4350	4600	4700
Arginine	6960	12680	9330	10550	12500	10590	8000	4300
Aspartic acid	9530	10430	9580	11230	11000	8690	4300	6100
Glycine	5950	5820	5850	6830	4300	8830	3700	3200
Glutamic acid	1576	15810	15860	2200	1800	14990	5100	9100
Proline	4590	5760	6530	4430	4800	40,4	3000	1000
Serin	4350	6470	4830	5310	4900	4410	2100	3500
In total	**56370**	**66310**	**60460**	**67990**	**62600**	**59320**	**32300**	**34800**

Analyzing the comparative characteristics of the amino acid composition of the raw materials (table 2), it can be seen that all protein fortifiers have a sufficiently high content of essential amino acids to improve the protein content of the functional product, chlorella is especially valuable in this regard due to the content of valine, isoleucine, threonine, tryptophan and lysine[13].

Protein puffs with flax seeds differ from others in that they have a more pronounced lipophilic character. Their lipophilic properties are explained

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[13] Пешук Л. В., Новікова Н. В., Приходько Д. Ю. Водорості як «суперфуд» у технологіях м'ясних продуктів здорового харчування. *Таврійський науковий вісник. Серія: Технічні науки.* 2023. № 1. С. 96–103. https://doi.org/10.32851/tnv-tech.2023.1.10

by the presence of specific polysaccharides of flax seeds, which pass into the solution during cooking. These polysaccharides also affect such technological properties as viscosity, moisture-holding capacity, emulsifying and foaming properties[14]. Flax seeds, flour or protein isolate are most often used in product recipes, the amino acid profile of which is compared in Table 3.

Table 3

Amino acid composition of flaxseed products, % of total protein content

Amino acids	Seed	Flour	Protein isolate
Valin	4,6	3,6	5,6
Threonine	3,6	5,1	3,7
Isoleucine	4,0	5,0	5,2
Leucine	4,0	7,1	6,5
Lysine	4,0	4,3	5,5
Methionine Cystine	1,5	2,5	3,6
Phenylalanine	4,6	5,3	7,3
Tryptophan	1,0	1,7	1,3
Essential amino acids	**27,3**	**34,6**	**38,7**
Arginine	9,2	11,1	10,4
Tyrosine	2,3	3,1	3,0
Histidine	2,2	3,1	5,8
Proline	3,5	5,5	7,5
Serin	4,5	5,9	4,9
Glycine	5,8	7,1	4,8
Alanine	4,4	5,5	5,1
Aspartic acid	9,3	12,4	11,1
Cystine	1,1	4,3	6,3
Glutamic acid	19,6	26,4	24,6
Substitute amino acids	**61,9**	**84,4**	**83,5**

In order to determine the biological value of any product in accordance with the amino acid score method, the content of each essential amino acid of the product's protein should be consistently compared with the FAO/WHO scale. The amino acid balance of selected protein-vegetable fortifiers is indicated in Table 4.

[14] Kajla P., Sharma A., Raj Sood D. Flaxseed: A potential functional food source. *Journal of Food Science and Technology*. 2018. № 52. P. 1857–71. https://doi.org/10.1007/s13197-014-1293-y

Table 4

Amino acid balance of protein fortifiers for functional meat products

Amino acids	Content in 1 g of standard protein, mg/g	Chia		Quinoa		Hemp flour		Flax flour		Amaranth flour		Chlorella		Spirulina	
		Content in 1 g of protein, mg/100 g of raw material	AC_a – amino acid rate, %	Content in 1 g of protein, mg/100 g of raw material	AC_a – amino acid rate, %	Content in 1 g of protein, mg/100 g of raw material	AC_a – amino acid rate, %	Content in 1 g of protein, mg/100 g of raw material	AC_a – amino acid rate, %	Content in 1 g of protein, mg/100 g of raw material	AC_a – amino acid rate, %	Content in 1 g of protein, mg/100 g of raw material	AC_a – amino acid rate, %	Content in 1 g of protein, mg/100 g of raw material	AC_a – amino acid rate, %
Valin	50	58,5	117,00	50	100,00	58,5	117,00	50	100,00	37,8	75,60	64,4	128,80	42,1	84,20
Isoleucine	40	44,8	112,00	42,4	106,00	49,2	123,00	34	85,00	37	92,50	50,1	125,25	36,4	91,00
Leucine	70	80,7	115,29	71,2	101,71	47	67,14	76	108,57	51,9	74,14	68,4	97,71	61,7	88,14
Lysine	55	58,9	107,09	65,3	118,73	47	85,45	41	74,55	47,5	86,36	56	101,81	34	61,81
Methionine + cystine	35	28,8	82,29	43,2	123,43	38,7	110,57	33,8	96,57	81,5	232,86	15	42,85	17,1	48,85
Threonine	40	42,8	107,00	35,6	89,00	26,8	67,00	36	90,00	35,4	88,50	52,4	131,00	33,1	82,75
Tryptophan	10	16	160,00	14,4	144,00	16,7	167,00	8	80,00	8,2	82,00	20,4	204,00	8,5	85,00
Phenylalanine + tyrosine	60	67,9	113,17	72,9	121,50	79,3	132,17	76	126,67	76,1	126,83	42	70,00	33,3	55,5
Biological value, %		31,74		32,08		38,10		33,37		33,78		30,23		74,19	
KRAS, %		68,26		67,92		61,90		66,63		66,22		69,77		25,81	
Utility factor (U)		0,75		1,12		0,98		1,08		2,19		1,02		0,82	
In total		398,4		395,0		363,2		354,8		375,4		368,7		266,2	

In the process of developing recipes for functional semi-finished products, the mass fraction of plant raw materials varied from 3 to 20 %. After conducting preliminary tasting evaluations, it was decided to add vegetable raw materials in the amount of 15 %. At the same time, in recipes with flax flour, 5 % was replaced with a protein-mineral-carbohydrate additive (BMVD), and in recipes with algae, chlorella and spirulina were added in powder form in the amount of 3 %, which is associated with an increase in the specific smell characteristic of the selected plant raw materials, which is not typical for chopped semi-finished products, which can negatively affect consumer demand for this product.

The recipes of the developed semi-finished products are shown in Table 5. When preparing the recipes, names were not assigned to the experimental samples. Recipes were marked:

- Sample № 1 – with chia;
- Sample № 2 – with flax;
- Sample № 3 – with hemp;
- Sample № 4 – with amaranth;
- Sample № 5 – with quinoa;
- Sample № 6 – with chlorella;
- Sample № 7 – with spirulina.

Table 5

Recipes of developed semi-finished products

Raw	**Control (according to DSTU 4437:2005)**	**Sample № 1**	**Sample № 2**	**Sample № 3**	**Sample № 4**	**Sample № 5**	**Sample № 6**	**Sample № 7**
1	2	3	4	5	6	7	8	9
The amount of the main raw material, kg/100 kg								
Chicken meat	56	-	-	-	-	-	-	-
Turkey meat		56	56	55	55	55	73	73
Chicken eggs (melange)	8	8	8	8	8	8	8	8
Onion	10	10	10	8	8	8	10	10
Butter	5	-	-	-	-	-	-	-
Milk	10	-	-	-	-	-	-	-
Breadcrumbs	6	-	-	-	-	-	-	-
Hemp oil	-	6	6	5	5	5	6	6
Bread	5	-	-	-	-	-	-	-

Table 5 (ending)

1	2	3	4	5	6	7	8	9
Chia	-	15	-	-	-	-	-	-
Flax flour	-	-	10	-	-	-	-	-
Amaranth flour	-	-	-	20	-	-	-	-
Hemp flour	-	-	-	-	20	-	-	-
Quinoa	-	-	-	-	-	20	-	-
Chlorella	-	-	-	-	-	-	3	-
Spirulina	-	-	-	-	-	-	-	3
Amount of auxiliary raw materials, kg/100 kg of main raw materials								
Water	-	15	15	20	20	15	6	6
Salt	1	1,3	1,3	1,3	1,3	1,3	1,3	1,3
Ground black pepper	0,5	0,5	0,5	0,5	0,5	0,3	0,3	0,3

The technological process of the production of chopped semi-finished products consists of preparation of raw materials, preparation of minced meat, forming of semi-finished products, cooling or freezing, packaging, labeling and storage[15].

The set of indicators that determine the nutritional value and quality of semi-finished products include organoleptic indicators, which are determined by the sense organs. The main advantage of organoleptic analysis as a method of assessing product quality is the ability to relatively quickly determine the suitability of a product for consumption. Such indicators as color, taste, smell, consistency give a general idea about the product and indicate the quality of the selection of the main ingredients and their ratio. Appearance is determined in the finished product. Special attention is paid to the main indicators – taste and aroma. Based on the results of the tastings, the best samples were selected.

For each of the obtained samples, a physical and chemical study was conducted on the content of proteins, fats, ash and moisture in the product before and after heat treatment. The obtained research results are shown in figures 2 and 3.

An important indicator of the quality of semi-finished products is their microbiological condition, because it indicates the level of safety of these products. When determining the quality of meat products, it is necessary to study the microbiological indicators of finished products during their storage. The presence of Escherichia coli (coli-form) bacteria, pathogenic

[15] Пешук Л., Іванова Т. Січений м’ясний напівфабрикат «Мітлет»: пат. 123313 Україна: МПК 51 A23L 13/40, A23L 13/70. № u201708116; заявл. 04.08.2017; опубл. 26.02.2018, Бюл. № 4. 2 с.

microorganisms, including salmonella, sulphite-reducing clostridia is not allowed in the products[16].

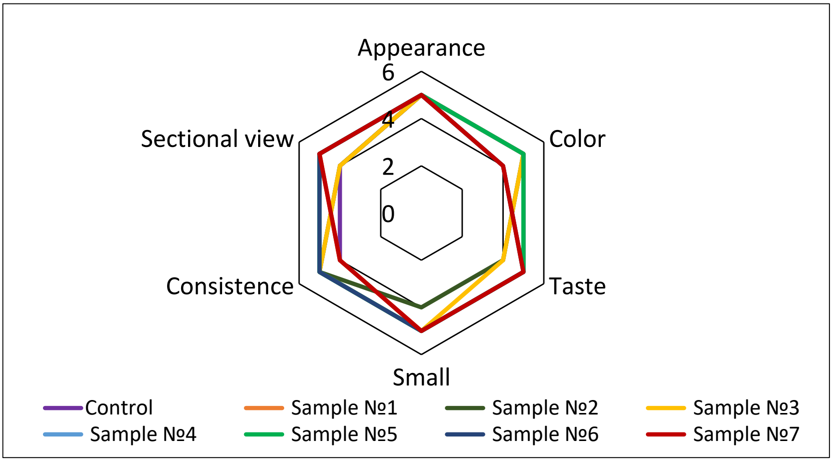

Fig. 1. Results of organoleptic evaluation of samples

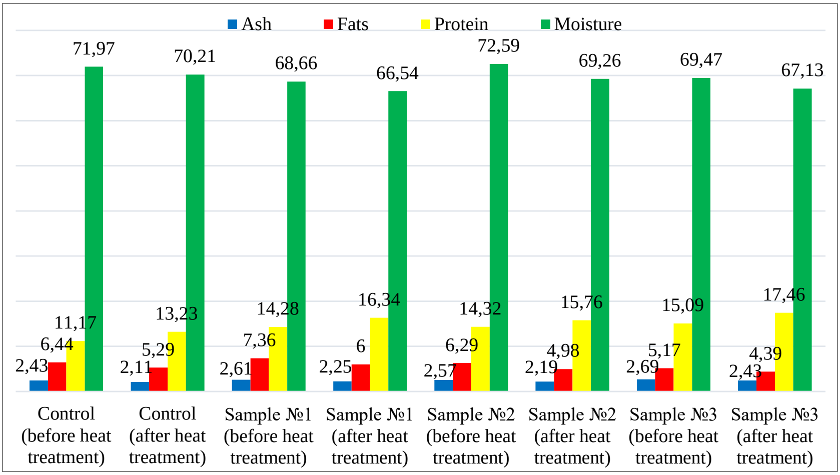

Fig. 2. Physico-chemical parameters of experimental samples

[16] Пешук Л., Зусько К., Грегірчак Н., Іванова Т. Спосіб виробництва м'ясних напівфабрикатів пролонгованого терміну зберігання : пат. 124831 Україна: МПК 51 A23L 3/00, A23L 13/00. № u201710755; заявл. 06.11.2017; опубл. 25.04.2018, Бюл. № 8. 2 с.

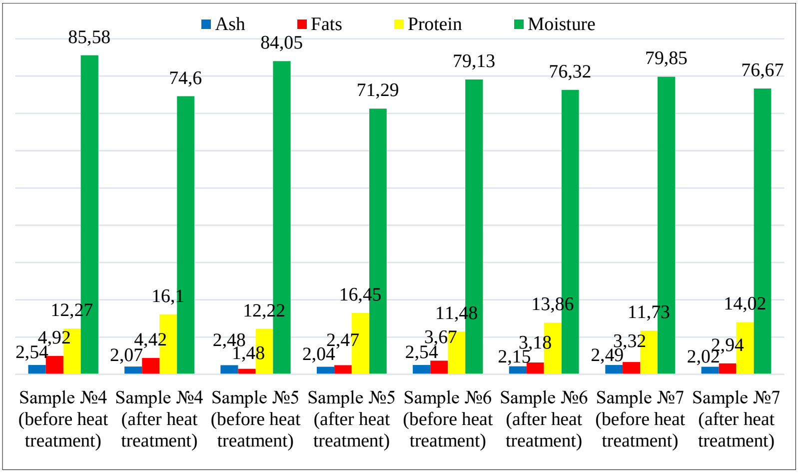

Fig. 3. Physico-chemical parameters of experimental samples

We conducted microbiological studies of samples of developed semi-finished products in raw form. Research was conducted in accordance with DSTU 4437:2005. Semi-finished meat and meat-vegetable chopped products. Specifications[17]. According to microbiological indicators, the developed semi-finished products met the established norms, the research data are shown in Table 6.

Table 6

Microbiological indicators of the developed semi-finished products

Variants of recipes	**MAFAM**	**Escherichia coli bacteria in 0,001 g**	**Salmonella spp. in 25 g**	**Listeria Monocytogenes in 25 g**
1	2	3	4	5
According to DSTU 4437:2005	$1\cdot10^7$	not allowed		
1 day after production (frozen)				
Control	$3{,}5\cdot10^2$	not found	not found	not found
Sample № 1	$4{,}1\cdot10^2$	not found	not found	not found
Sample № 2	$3{,}6\cdot10^2$	not found	not found	not found
Sample № 3	$3{,}2\cdot10^2$	not found	not found	not found

[17] ДСТУ 4437:2005. Напівфабрикати м'ясні та м'ясорослинні посічені. Технічні умови.

Table 6 (ending)

1	2	3	4	5
Sample № 4	$3,7\cdot10^2$	not found	not found	not found
Sample № 5	$3,9\cdot10^2$	not found	not found	not found
Sample № 6	$3,5\cdot10^2$	not found	not found	not found
Sample № 7	$3,6\cdot10^2$	not found	not found	not found
8 day after production (frozen)				
Control	$5,9\cdot10^4$	not found	not found	not found
Sample № 1	$5,5\cdot10^4$	not found	not found	not found
Sample № 2	$4,8\cdot10^4$	not found	not found	not found
Sample № 3	$4,6\cdot10^4$	not found	not found	not found
Sample № 4	$5,7\cdot10^4$	not found	not found	not found
Sample № 5	$5,3\cdot10^4$	not found	not found	not found
Sample № 6	$5,6\cdot10^4$	not found	not found	not found
Sample № 7	$5,4\cdot10^4$	not found	not found	not found
25 days after production (frozen)				
Control	$7,2\cdot10^6$	not found	not found	not found
Sample № 1	$7,4\cdot10^6$	not found	not found	not found
Sample № 2	$6,9\cdot10^6$	not found	not found	not found
Sample № 3	$6,8\cdot10^6$	not found	not found	not found
Sample № 4	$7,7\cdot10^6$	not found	not found	not found
Sample № 5	$7,3\cdot10^6$	not found	not found	not found
Sample № 6	$7,4\cdot10^6$	not found	not found	not found
Sample № 7	$7,2\cdot10^6$	not found	not found	not found

In all samples, no bacteria of the coliform group (coli-form) were detected in 0.001 g, pathogenic microorganisms, including bacteria of the genus Salmonella spp. in 25 g, S. Aureus in 1 g, sulfite-reducing clostridia in 0.01 g, L. Monocytogenes in 25 g. The next stage was a study of the developed semi-finished products on the content of macro- and microelements, in particular, on the content of calcium, magnesium, iron, and zinc in raw semi-finished products. The results of the research are shown in figures 4–7.

The results of the research on calcium content show that due to the use of chia (sample № 1) and amaranth (sample № 4) in the recipes, semi-finished products are enriched with the above-mentioned macroelement the most. Compared to the control sample, the calcium content for formulations № 1 and № 3 increased by two times compared to the control, and for formulation № 4 by 2,6 times.

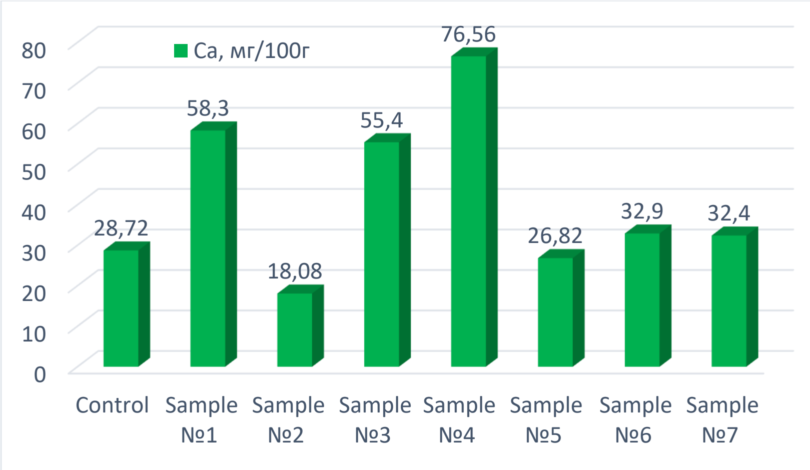

Fig. 4. Calcium content in semi-finished products, mg/100g

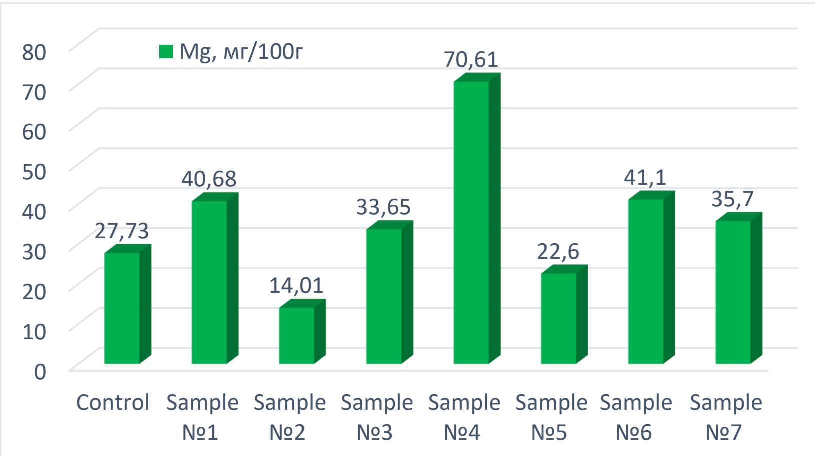

Fig. 5. Magnesium content in semi-finished products, mg/100g

The results of the research on the magnesium content show that due to the use of semi-finished amaranth flour in the recipes (sample № 4), the experimental samples are enriched with the above-mentioned macroelement the most. Magnesium content for recipe № 4 increased by 1,5 times, for recipe № 1 with chia and № 6 with chlorella – by ~ 50 % compared to the control.

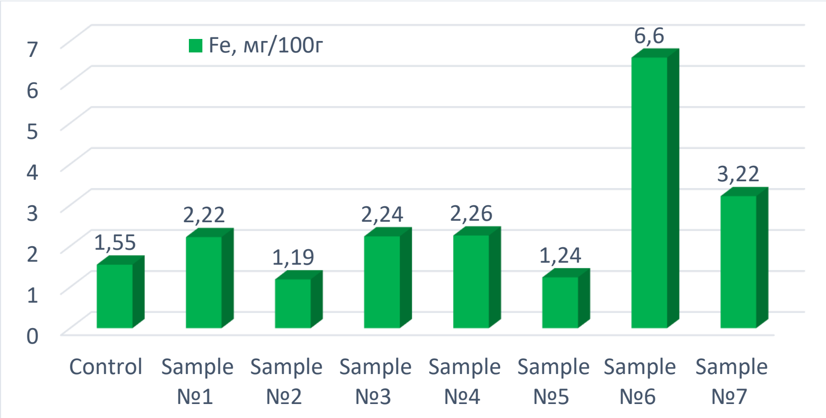

Fig. 6. Iron content in semi-finished products, mg/100g

The results of the iron content study show that due to the use of green microalgae chlorella (sample № 6) and spirulina (sample № 7) in the recipes, the semi-finished products are most fully enriched with this trace element. Compared to the control sample, the iron content in recipe № 6 increased by 4 times, and in recipe № 7 it increased by 2 times.

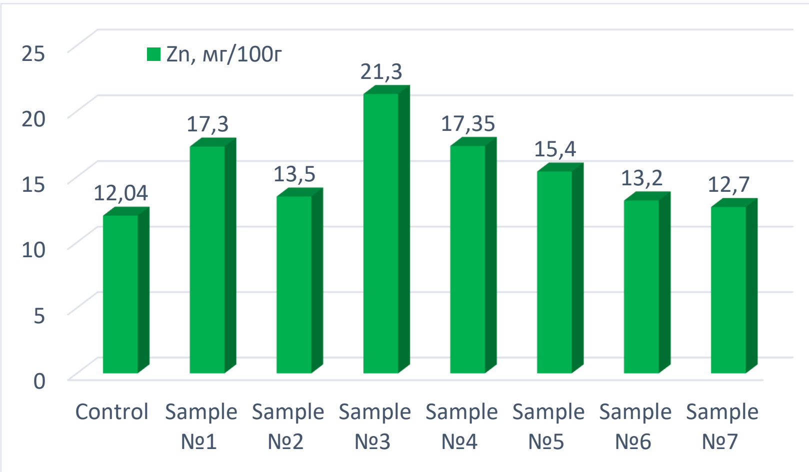

Fig. 7. Zinc content in semi-finished products, mg/100g

The use of semi-finished plant raw materials in recipes makes it possible to enrich the developed products with zinc from 10 to 76 %. The highest zinc content is characteristic of formulation № 3 (with hemp flour), formulation № 1 and № 4 (chia and amaranth flour).

In the Institute of Biochemistry named after O. V. Palladin of the National Academy of Sciences of Ukraine and the Institute of Food Resources of the National Academy of Sciences of Ukraine determined the amino acid composition of protein fortifiers and experimental sample No. 1 (chopped semi-finished product enriched with chia seeds) in comparison with the control sample. Data on the amino acid composition are given in Table 7.

Table 7

Comparison of the amino acid composition of the control and sample № 1 enriched with chia seeds

Amino acids	Control			Sample № 1		
	Quantity, mg	% per mg	SKOR in %	Quantity, mg	% per mg	SKOR in %
Valin	0,407	3,67	73	0,487	3,11	62
Isoleucine	0,114	1,03	26	0,473	3,02	76
Leucine	1,042	9,38	134	1,207	7,70	110
Lysine	1,368	12,32	224	1,080	6,90	125
Methionine	0,158	1,42	-	0,354	2,26	-
Threonine	0,894	8,05	201	0,647	4,13	103
Phenylalanine	0,239	2,15	-	0,608	3,88	-
In total	**4,222**	**38,02**	**-**	**4,856**	**31,0**	**-**
Alanine	0,310	2,79	-	1,185	7,56	-
Arginine	0,688	6,20	-	1,563	9,98	-
Aspartic acid	1,269	11,43	-	1,361	8,69	-
Histidine	0,781	7,03	-	0,389	2,44	-
Glycine	0,783	7,05	-	0,975	6,22	-
Glutamic acid	1,119	10,08	-	3,153	20,13	-
Proline	0,800	7,21	-	0,598	3,82	-
Serin	0,425	3,83	-	0,838	5,35	-
Tyrosine	0,517	4,65	113	0,527	3,36	139
Cystine	0,190	1,71	89	0,227	1,45	106
In total	**11,103**	**100,0**	**-**	**15,664**	**100,0**	**-**

Based on the results of the research, it can be stated that the amino acid composition of chia is rich in essential amino acids, which indicates the high biological value of this raw material. The introduction of chia seeds and hemp oil into formulation № 1 qualitatively changes the amino acid composition of this product compared to the control sample.

Fatty acids are carboxylic acids whose molecules contain from four to thirty-six carbon atoms. More than two hundred fatty acids have been identified in living organisms, but about twenty have become widely distributed. Depending on the presence of double bonds between carbon atoms, all fatty acids are divided into saturated, which do not contain them, and unsaturated, which include double bonds. The most common unsaturated fatty acids are palmitic (C16) and stearic (C18).

According to the modern classification of fatty acids, the number of C atoms from the end of the fatty acid chain to the nearest double bond allows it to be assigned to groups ω-3, ω-6, ω-7, ω-9.

The next stage of research was a comparative analysis of the fatty acid composition of the control with samples to which hemp oil was added in order to develop the technology of functional meat products from non-traditional raw materials, namely: chia, quinoa, amaranth, flax, hemp, chlorella and spirulina.

When studying the lipid composition of different types of microalgae, chlorella and spirulina were found to be the largest producers of polyunsaturated fatty acids, such as omega-3 and omega-6[18]. As you know, linoleic fatty acid (ω-6) enters the body with refined products, the use of which is daily for the majority of the world's population. Thus, in the diet, the ratio of omega-3 to omega-6 reaches an average of 1:20, while the optimal for the high-quality functioning of all life processes is 1:4, that is, omega-6 today exceeds the permissible norm by 5 times. This indicates the need to increase raw materials, the content of linolenic fatty acid (ω-3) in which will exceed the value of ω-6. Table 8 shows the fatty acid composition of the used green microalgae, which shows that they are a source of mono- and polyunsaturated fatty acids.

Chia is typical for Spain (it is called Spanish sage) and quinoa is an unconventional raw material for Ukraine. Homeland is Peru, Bolivia, Ecuador. As Ukrainians adopt "fashion" from the West, quinoa, which comes in black, white and red, is increasingly used in cooking[19]. Research on the determination of the fatty acid composition of raw materials unconventional for Ukraine – chia and quinoa – was carried out at the

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[18] Peshuk L., Simonova I., Shtyk I. Modern trend – health products with microalgae. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Food Technologies*. 2022. № 24 (97). P. 52–59. https://doi.org/10.32718/ nvlvet-f9709

[19] Maradini-Filho H., Pirozi M. R., Borges J. T., et al. Quinoa: nutritional, functional, and antinutritional aspects. *Crit Rev Food Sci Nutr.* 2017. № 57. P. 1618–30. 10.1080/10408398.2014.1001811

Research Institute "Ukrmetrderzhstandard" in the laboratory of chromatographic research, with the participation of Doctor of Technical Sciences Iryna Levchuk.

Table 8

Fatty acid composition of microalgae, g/100 g of fat

Fatty acid	Chlorella vulgaris	Spirulina platensis
Saturated, including	16,7	37,1
Myristic acid ($C_{14:0}$)	0,7	0,2
Palmitine acid ($C_{16:0}$)	14,4	35,4
Stearic acid ($C_{18:0}$)	1,6	1,5
Monounsaturated, including	21,7	5,7
Palmitoleic acid ($C_{16:1}$)	4,1	1,2
Oleic acid ($C_{18:1}$)	17,6	4,5
Polyunsaturated, including	27,7	16,7
Linoleic acid ($C_{18:2}$) ω6	11,9	12,2
Linolenic acid ($C_{18:3}$) ω3	15,8	4,5

Table 9

Fatty acid composition of oil extracted from quinoa seeds

Fatty acid	Content, %
Myristic acid ($C_{14:0}$)	0,46
Palmitine acid ($C_{16:0}$)	10,2
Palmitoleic acid ($C_{16:1}$)	0,81
Stearic acid ($C_{18:0}$)	0,91
Oleic acid ($C_{18:1}$)	25,64
Linoleic acid ($C_{18:2}$) ω6	49,81
Linolenic acid ($C_{18:3}$) ω3	6,47
Arachinic acid ($C_{20:0}$)	0,08 ± 0,02
Gadoleic acid ($C_{20:1}$)	0,49 ± 0,1
Behenic acid ($C_{22:0}$)	0,02
Erucic acid ($C_{22:1}$)	0,01
Lignoceric acid ($C_{24:0}$)	0,12
Nervous acid ($C_{24:1}$)	0,02

Table 10

Fatty acid composition of oil extracted with chia content

Fatty acid	Content, %
1	2
Myristic acid ($C_{14:0}$)	0,72
Palmitine acid ($C_{16:0}$)	7,2

Table 10 (ending)

1	2
almitoleic acid ($C_{16:1}$)	1,13
Stearic acid ($C_{18:0}$)	3,0
Oleic acid ($C_{18:1}$)	6,85
Linoleic acid ($C_{18:2}$) ω6	20,2
Linolenic acid ($C_{18:3}$) ω3	61,40
Arachinic acid ($C_{20:0}$)	0,05
Gadoleic acid ($C_{20:1}$)	0,36 ± 0,1
Behenic acid ($C_{22:0}$)	0,01
Erucic acid ($C_{22:1}$)	0,01
Lignoceric acid ($C_{24:0}$)	0,01
Nervous acid ($C_{24:1}$)	0,02

Table 11

Fatty acid composition of oil extracted from flax flour

Fatty acid	**Content, %**
Palmitine acid ($C_{16:0}$)	6,35
Palmitoleic acid ($C_{16:1}$)	0,13
Stearic acid ($C_{18:0}$)	6,49
Oleic acid ($C_{18:1}$)	20,88
Linoleic acid ($C_{18:2}$) ω6	14,69
Linolenic acid ($C_{18:3}$) ω3	50,70
Arachinic acid ($C_{20:0}$)	0,21
Behenic acid ($C_{22:0}$)	0,18

Analyzing the fatty acid composition of plant raw materials, the highest content of unsaturated fatty acids: linoleic fatty acid – in flax flour (50,7 %); oleic – in flax flour (20,9 %), linoleic – in quinoa (49,8 %), and chia (20 %). In addition, quinoa seeds are rich in palmitic and linolenic fatty acids (6,9 %).

Flax flour is a source of high-value proteins, polyunsaturated fatty acids ω-3 and ω-6, fiber and minerals (per 100 g: calcium – 255 mg, magnesium – 392 mg, phosphorus – 642 mg, iron – 5,73 mg, manganese – 2,48 mg, zinc – 4,34 mg and others), necessary for the high-quality functioning of the human body. Flour also contains vitamins of group B, K, PP[20].

The flour, which was used in the production of meat products, was obtained after extracting the oil by pressing. The resulting flour had a light cream shade and a weak aroma characteristic of the seeds. The flour

[20] Ganorkar P. M., Jain R. K. Flaxseed – a nutritional punch. *Int Food Res J*. 2013. № 20. P. 519–525.

contains a high content of protein (29,85 %) and ash (4,15 %). According to organoleptic indicators, it can be used in various, even discolored food products.

Based on the fatty acid composition of the plant material used, control and samples № 1 (chia), № 3 (quinoa) and № 4 (amaranth) were selected for further determination of fatty acids (Fig. 8).

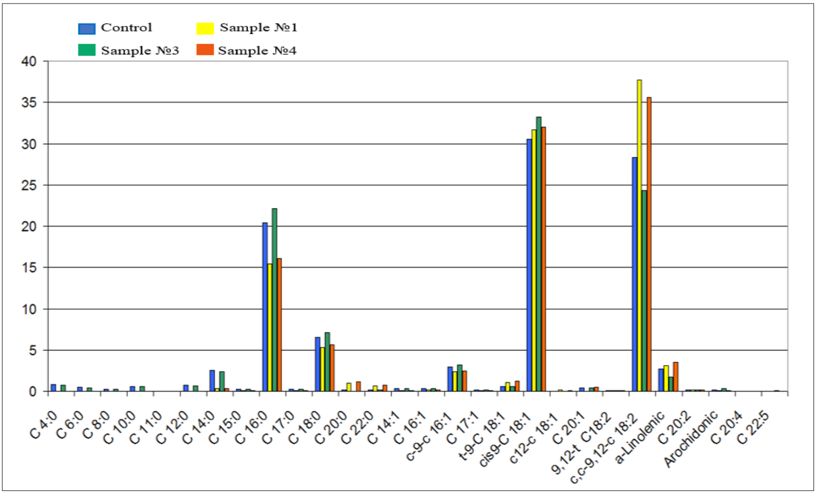

Fig. 8. Fatty acid composition of the studied samples of semi-finished products

Table 12

Fatty acid composition of the studied samples by group

Groups of fatty acids	Content, %			
	Control	**Sample № 1**	**Sample № 3**	**Sample № 4**
Saturated fatty acids	34,728	22,804	33,221	24,101
Monounsaturated fatty acids	38,245	35,502	35,197	36,461
Polyunsaturated fatty acids	26,641	41,178	31,455	39,432
ω-3	1,728	3,129	2,713	3,483
ω-6	24,312	37,674	28,286	35,595
Correlation ω-3:ω-6	1:14	1:12	1:10,5	1:10,2

The analysis of the fatty acid composition revealed the following trends:

– the content of saturated fatty acids in the developed samples is close to the recommended norm and is 22,8 % for sample № 1 and 24,1 % for sample № 4. The content of saturated fatty acids in food should be as low as possible and in no case exceed 30 % due to their participation in the development of atherosclerosis. According to this indicator, the control sample is inferior to the test sample;

– the content of monounsaturated fatty acids is reliably the same in the control and experimental samples;

– the content of polyunsaturated fatty acids is close to the balanced nutrition formula (10–20 %);

– the analysis of the fatty acid composition of the ω-3 and ω-6 family shows the superiority of the developed recipes over the control one. According to this indicator, sample № 4 has the best characteristics (the ratio of ω-3 to ω-6 is 1:10,2) and can be recommended for health food.

Figure 9 shows the content of PUFAs of the ω-6 and ω-3 family in control and experimental samples of semi-finished products.

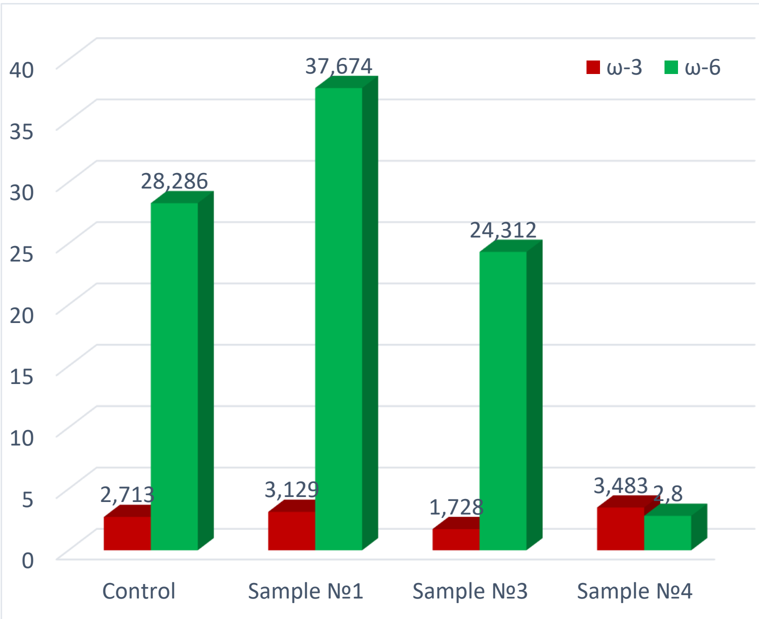

Fig. 9. The content of PUFAs of the ω-6 and ω-3 family in the experimental samples

Recently, the danger of the influence of trans isomers of fatty acids, the conditions of their formation and their content in various products have been intensively studied. This is due to the fact that they can be contained in any product where there is even a drop of vegetable fat.

The source of trans isomers in food products is hydrogenated fats. Hydrogenation is the process of adding hydrogen to unsaturated fatty acids at a temperature of 200 °C in the presence of catalysts.

In addition to increasing the risk of developing atherosclerosis and related diseases of the heart and blood vessels, trans fats reduce the sensitivity of pancreatic cells to insulin (type 2 diabetes), provoke the development of chronic inflammatory processes and obesity.

In the USA, Canada and many European countries, legal restrictions on the content of trans fats in products have been introduced. Labels must list the amount of trans fat. However, the news about the negative impact of trans fats made an impression on Denmark, which since 2003 has introduced a law limiting the content of trans fats to 2 % in ready-to-eat products and to 5 % for industrial fats, but the percentage of content of fats with trans isomers in the product is not 2 % of the total weight of the product, but of a part of the fats directly in it.

In Ukraine, there are no general standards for the content of trans fats, but they are gradually being introduced into the updated regulatory documentation for individual products. Thus, DSTU 4445:2005 "Fat Spreads and Mixtures"[21] (introduced from 01.07.2006) stipulates a norm for the content of trans fats, namely, the mass fraction of trans isomers of oleic acid in spreads and fat mixtures should not exceed 8 %. The content of trans-isomers in test samples of semi-finished products is shown in Figure 10.

Test sample № 1 contains 6 g/100 g of fat, of which 7,32 % are trans isomers. After carrying out the calculation, it was determined that the content of trans isomers in sample № 1 is 0,44 g/100 g of product. For sample № 4, the trans-isomer content is 0,061 g/100 g of product.

Analysis of the content of trans isomers in semi-finished products shows the superiority of the developed recipes over the control. According to this indicator, sample № 4 has better characteristics (1,37 % of the total fat content in the product is occupied by trans isomers) and can be recommended for a healthy diet.

[21] ДСТУ 4445:2005. Спреди та суміші жирові. Загальні технічні умови. Зі змінами та поправками.

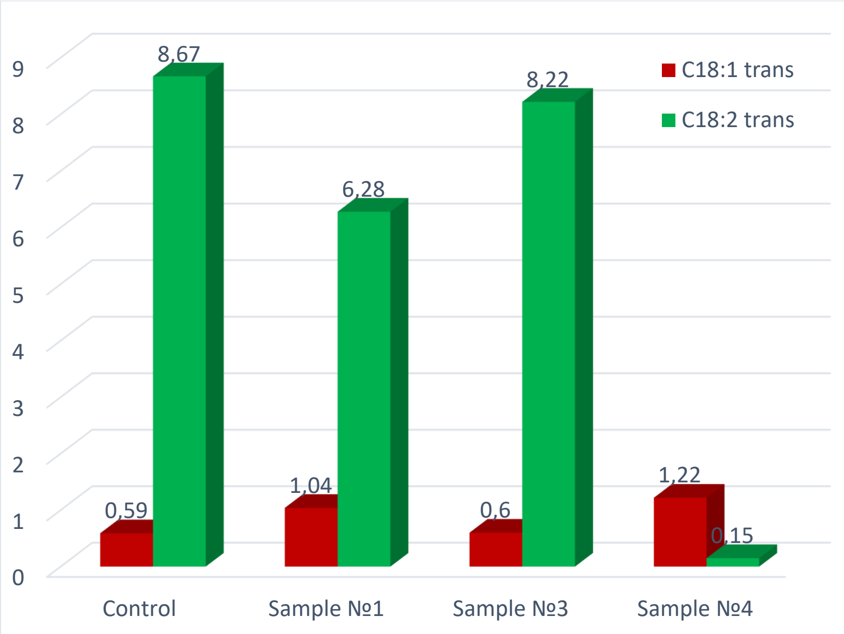

Fig. 10. The content of trans isomers in finished semi-finished products

CONCLUSIONS

The monitoring of vegetable protein fortifiers for the development and use of them in the technology of functional meat products was carried out. Based on the analysis carried out in the process of scientific research, a technological scheme for the production of semi-finished products using plant raw materials was developed: chia and quinoa in the form of whole grains, flour from hemp, amaranth, flax and powdered green microalgae chlorella and spirulina. The sequence of technological operations in accordance with the properties of raw materials makes it possible to obtain a product that is safe, high-quality and useful for consumers from the point of view of healthy nutrition. In this way, seven recipes of chopped semi-finished products were developed with the addition of native non-traditional raw materials for Ukraine. An analysis of the amino acid composition of the selected plant material was carried out, the potential biological value of the protein and the difference coefficient of the KRAS amino acid score were determined. An organoleptic evaluation of the developed samples was carried out, according to which all semi-finished products were distinguished by the quality indicators due to the consistency, appearance, color, taste and appearance inherent in chopped semi-finished products. To determine changes in chemical composition, experimental samples of semi-finished products were analyzed before and after heat treatment, according to the data of which it can be seen that the protein content increased in all samples compared to the control, and the moisture content decreased. According to microbiological indicators (MAFAnM, BGKP, mesophilic sulfite-reducing clostridia, staphylococci), the developed chopped semi-finished products are suitable for consumption within 7 days. The content of calcium, magnesium, iron and zinc was studied, which significantly improved in comparison with the control sample. The analysis of the fatty acid composition of the selected protein enhancers proved that the used vegetable raw materials are a rich source of mono- and polyunsaturated fatty acids. The analysis of PUFAs ω-3 and ω-6 shows the superiority of the developed recipes over the control. According to this indicator, sample No. 4 has the best characteristics (the ratio of ω-3 to ω-6 is 1:10,2). The obtained data of the conducted studies prove the relevance of using protein plant components, such as chia, quinoa, hemp, amaranth and flax flour, chlorella and spirulina algae, as raw materials for the development of functional meat products with an increased protein content, high indicators of micro-macroelements composition, the optimal ratio of fatty acids. The plant raw materials used for the research did not affect the deterioration of the taste properties of semi-finished products, which indicates the possibility of expanding the market of healthy native (organic) products by using plant components in optimal ratios with animal raw materials.

SUMMARY

Prevention of morbidity among the population by optimizing nutrition has been observed in a number of economically developed countries of the world in the last decade. First of all, this is related to many disorders in the diet, which lead to obesity, problems with the gastrointestinal tract, skin diseases and cardiovascular pathologies. The main problems of modern diets are a deficiency in the consumption of complete protein, an excess of refined food with an inappropriate ratio of PUFAs, a lack of dietary fiber and fiber, mineral and vitamin deficiencies. Thus, today's urgent task is to create a range of balanced products for healthy nutrition. We have developed seven recipes of chopped semi-finished products using poultry meat (turkey) and protein plant components, including chia seeds, quinoa, hemp flour, amaranth and flax, green microalgae chlorella and spirulina. An organoleptic evaluation of the quality of the obtained samples was carried out, an analysis of the amino acid, micro- macroelement and fatty acid composition was carried out, and the physicochemical and

microbiological indicators of the developed products were investigated. According to the conducted research, the relevance of using selected plant raw materials as components of meat products for the expansion of the healthy food market has been proven.

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