

# Amaranth cake as a source of food isolate of vegetable protein for the meat processing industry

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**Abstract.** Recently, improving the nutrition structure of the population and reducing the harmful effects of animal products on the environment are important indicators in ensuring food security and achieving sustainable development goals. All over the world, the demand for vegetable substitutes for meat raw materials has increased significantly, contributing to the improvement of functional and organoleptic properties, but not taking into account the most important role of meat raw materials as the main source of high-grade protein, which requires the creation of combined products. The purpose of this work is to develop a technology for a food protein isolate based on the agricultural crop of amaranth to reduce the mass fraction of saturated fatty acids and partial enrichment with polyunsaturated fatty acids. The work used traditional methods for determining the mass fraction of protein, fat, moisture, as well as chromatographic methods for determining methyl esters of fatty acids. The work determined the general chemical composition of amaranth cake, which showed a mass fraction of moisture 6.48%, crude fat 6.29, crude protein 28.86%, starch 48.26%, crude fiber 6.82%, ash 3.29%. To reduce the mass fraction of fat in order to achieve the residual oil content of amaranth cake in the range of 1.0-1.5%, it is proposed to treat the raw material with CO<sub>2</sub>-gas. After treatment with CO<sub>2</sub> gas, studies of the total chemical composition of CO<sub>2</sub>-meal of amaranth cake showed a decrease in the mass fraction of fat to 1.31%. Important characteristics of the obtained amaranth food protein isolate are its neutral organoleptic characteristics and high functional and technological properties, which allow us to recommend it for use in the technology of most meat products, such as sausages, semi-finished products, etc. The novelty of this work is in the use of the CO<sub>2</sub>-extraction method to reduce mass fraction of fat.

## 1 Introduction

For the prevention of cardiovascular disease, the World Health Organization suggests the following nutritional guidelines: fat should provide 15 to 30% of calories in the diet, saturated fat should provide less than 10% of these calories, and cholesterol intake should be limited to 300 mg / day [1; 2; 3]. Many researchers in their papers note the significant role of various raw meat substitutes in the human diet, and note that the future generation of such products should focus on reducing the mass fraction of saturated fat and the total amount of additional food additives, as well as the overall reduction in the impact of the products of animal origin on the environment and improve the global ecology. But in most studies, the use of plant substitutes is aimed at changing the consistency, taste, aroma, enrichment with various nutrients, etc. [4; 5; 6]. Currently, traditional substitutes are mainly aimed at the formation of organoleptic properties and the improvement of physicochemical properties. However, this leads to the emergence of an increasing number of vegetarian products, while the significant role of meat as the main supplier of protein to the human body is not

taken into account. Also most works do not take into account that economic growth contributes to an increase in demand for animal products, i.e. meat products and there is a real problem of the expected compliance of an alternative analogue of meat raw materials with the main products of the meat industry such as meat, milk, eggs [7]. The problem of replacing meat protein has been around for many years for the halal and kosher market [8]. Unlike meat proteins, vegetable proteins are able to reduce the cost of a meat product due to their lower price [9]. This is what prompted many manufacturers to use non-meat proteins in formulations, i.e. vegetable proteins. The creation of industrial technologies for the production of concentrated protein products from plant raw materials is one of the main directions of increasing food and forage resources, improving the structure of the population's nutrition [10]. Most of the industrialized countries (USA, Japan, Belgium, Denmark, etc.) have already accumulated practical experience in the processing of soybeans to obtain soy proteins and a variety of high-quality food products based on them. As a rule, these industries operate within the conditions of environmentally friendly non-waste technology,

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producing, in addition to food highly concentrated proteins, also high-quality forage and biologically active preparations [11; 12; 13]. Despite the fact that soybeans are a popular source of complete protein [14], it is necessary to look for alternative crops, such as rapeseed, camelina, chickpeas, lupine, amaranth and others. Many of these crops are already being grown in Russia and their acreage is growing steadily, as evidenced by the latest crop market research. After the extraction of oil from plant materials, secondary products are formed - cakes and meal, the composition of which is characterized by high protein content (from 29 to 50%), and fiber (from 10 to 15%). Further processing of cake and meal consists in the development of feed additives for animals, however, these products can and should be considered as a potential raw material component for the production of proteins and dietary fiber for the food industry, in particular the meat processing industry [15]. The leading company in Russia for the production of amaranth oil is LLC Russkaya Oliva, Voronezh, Russia, where after pressing the oil, cake is obtained as a by-product in the form of embryonic flakes. Amaranth cake is the result of pressing amaranth seeds (embryo), because at its first stage the technological process provides mechanical separation of grain into a shell (high-protein flour, 40%) and a germ (amaranth oil and cake); it comes out in large plates and is characterized by a high mass fraction of fat, which is a limiting factor for obtaining a protein isolate. Due to the high mass fraction of fat, it has low mass fraction of crude protein, nevertheless, the cake is obtained as a protein fraction, which in its composition can be a valuable protein product [16, 17].

## 2 Methods and Equipment

The following products were selected as objects of research: amaranth cake, produced by LLC Russkaya Oliva (Volgograd region, Russia); minced meat systems based on pork and beef with partial replacement of the main raw materials.

To achieve the goal of the technology design of amaranth food protein isolate, the following main tasks were set: to evaluate the chemical composition of amaranth and amaranth cake; to establish the amino acid and fatty acid composition of amaranth and amaranth cake; to carry out the comparative characteristic of the solubility of amaranth protein under various conditions; to justify the use of CO<sub>2</sub>-extraction for processing amaranth cake; to propose a technological process for the production of food protein isolate based on amaranth cake- CO<sub>2</sub>.

The assessment of the quality indicators of the prime raw materials was carried out according to the following regulatory documents: GOST R 54705-2011 Oilcakes, meal and mustard powder. Methods for determining the

mass fraction of moisture and volatile substances can be found in [18]; GOST ISO 734-1-2016 Oilcakes and meals. Determination of crude fat content. Part 1. Method of extraction with hexane (or light petroleum ether) [19]; GOST ISO 734-2-2016 Oilcakes and meals. Determination of crude fat content. Part 2. Accelerated extraction method [20]; GOST 13979.2-94 Oilcakes, meal and mustard powder. Method for determining the mass fraction of fat and extractives [21]; GOST 13979.3-68 Oilcakes and meals. Method for determining the total mass fraction of soluble proteins (with Amendments No. 1, 2) [22]; GOST 10845-98 Grain and products of its processing. Method for determination of starch [23]; GOST 32040-2012 Feed, compound feed, compound feed raw materials. Method for Determination of Crude Protein, Crude Fiber, Crude Fat and Moisture Content Using Near Infrared Spectroscopy [24]; GOST 32933-2014 (ISO 5984: 2002) Feed, compound feed. Method for determination of crude ash content [25]; GOST 32195-2013 (ISO 13903: 2005) Feed, compound feed. Method for determination of amino acid content [26]; GOST 30418-96 Vegetable oils. Method for determination of fatty acid composition [27].

## 3 Results

To develop a food isolate of vegetable protein, in particular from amaranth, it is necessary to clarify the classification of the product, in accordance with generally accepted global rules.

The nutritional value of an ingredient and therefore of the whole amaranth product depends on the content of several chemical elements and compounds that provide nutritional functions. The development of food technology requires knowledge of the ingredients in the formulation that provide the required amount of a number of nutritional properties. Therefore, when formulating diets, ingredients are considered as the sources of nutrients. Thus, the quality and value of a particular ingredient will largely depend on the concentration of the respective nutrients in it. Description of the chemical composition of the amaranth cake is necessary for understanding the nutritional value of the product and further understanding the chemical, analytical and nutritional aspects of the cake (Table 1).

**Table 1.** The general chemical composition of amaranth cake

Test object	Mass fraction, %					
	Moisture	Crude fat	Crude protein	Starch	Crude fiber	Ash
Oilcake in the form of embryonic flakes	6.48	6.29	28.86	48.26	6.82	3.29

Studies of the chemical composition of amaranth cake showed that the mass fraction of moisture in the amaranth cake was 6.48%, crude fat 6.29%. The mass fraction of protein (crude protein) was determined by the Kjeldahl method and in our sample it was 28.86%. To

reduce the mass fraction of fat in order to achieve the residual oil content of amaranth cake within the range of 1.0-1.5%, as required by the food isolate technology, we need to treat the raw materials with CO<sub>2</sub>-gas, which is used to process various plant materials in order to reduce fatty acids in the products. Processing is carried out under high pressure, while carbonic acid and a gas-liquid explosion are formed in the cells, which provides fine grinding of the prime raw material and modification of the protein towards increasing the biological value [28]. After treating the amaranth cake with CO<sub>2</sub>-carbon dioxide, we carried out a comparative characteristic of the total chemistry of the amaranth cake and meal- CO<sub>2</sub>, in order to determine the achievement of the required residual oil content (Table 2).

**Table 2.** The general chemical composition of amaranth meal

Test object	Mass fraction calculated to absolutely dry matter (dry fat-free matter), %					
	Moisture and volatiles	Crude fat, (a.d.m.)	Crude protein, (a.d.m.)	Starch	Crude fiber, (d.f.f.m.)	Crude ash, (a.d.m.)
Amaranth meal-CO <sub>2</sub>	5.85	1.31	32.11	49.43	7.18	4.12

The quality of a protein depends on its amino acid composition and the proportion of essential amino acids. The obtained amaranth meal is planned for further production of food protein isolate and further use in formulations of meat products that will be subjected to heat treatment, which can lead to certain decrease in both the concentration and the digestibility or assimilation of several amino acids, especially lysine. A decrease in digestibility occurs as a result of the Maillard reaction, in which free amino acids bind to free carbonyl groups (for example, carbohydrates). The end products of the Maillard reaction are not biologically assimilable (Table 3).

**Table 3.** Amino acid composition of amaranth meal

Test object	Essential amino acids, mg/ g of protein							
	Val	Ile	Leu	Lys	Met+Cis	Tre	Tri	Fe n
Oilcake in the form of embryonic flakes	41.82	37.42	56.91	59.02	43.02	40.21	9.71	71.19
Amaranth meal-CO <sub>2</sub>	41.27	37.19	56.42	59.42	43.97	39.10	9.16	71.08

The results of the study of the amino acid composition of the amaranth cake and meal showed the presence of all essential amino acids, the mass fraction of phenylalanine prevails and is 71.08 and 71.19 in the meal and cake, respectively, we also note the high mass fraction of

lysine and leucine 59.02 / 56.91 for the cake and 59.42 / 56.42 for meal, respectively. An important characteristic of the lipid fraction of meal and amaranth is its fatty acid composition [17, 18], which we analyzed, the results of the study are presented in Table 4.

**Table 4.** Fatty acid composition of amaranth meal

Fatty acid symbols	Fatty acid names	Fatty acid concentration in the oil (weight %)	
		oilcake in the form of embryonic flakes	amaranth meal-CO <sub>2</sub>
C14:0	Myristic	0.19	0.21
C16:0	Palmitic	19.54	21.98
C18:0	Stearic	3.78	4.22
C18:1	Oleic	28.29	31.63
C18:2	Linolic	46.32	51.72
C18:3	Linolenic	0.71	0.80
C20:0	Arachidic	0.88	0.98
C22:0	Behenic	0.30	0.33
C20:1	Eicosenic	-	-
C22:1	Erucic	-	-
C23:0	Tricosanoic acid	-	-

Studies of the fatty acid composition showed the presence of oleic acid at the level of 28.29 wt% in the cake and 31.63 wt% in the meal, linoleic acid 46.32 / 51.72 wt%, respectively, as well as a high mass fraction of palmitic acid, which is 19.54 wt% for cake and 21.98 wt% for meal. Protein Dispersibility Index (PDI) is the most important indicator for determining the quality of vegetable protein, which shows that the higher the dispersibility coefficient is, the higher the biological and nutritional value will be, and is associated with the fact that food products, in particular meat, are subjected to heat treatment, which affects not only the change in the fractional composition of proteins, but also the change in the amino acid composition of the product (Table 5).

**Table 5.** Comparative characteristics of the solubility of amaranth protein before and after heat treatment

No	Test object	Crude protein, %	Solubility, %	PDI	NSI
1	oilcake in the form of embryonic flakes	28.86	73.17	69.30	70.32
	oilcake in the form of embryonic flakes after heat treatment	30.12	57.81	15.11	16.18
3	amaranth meal- CO <sub>2</sub>	32.11	84.23	78.21	77.91
4	amaranth meal- CO <sub>2</sub> after heat treatment	33.19	71.64	16.92	17.29

To determine the dispersibility coefficient, we determined the nitrogen content in the samples, then we placed 20 g of the product sample in the mixer and

added 300 ml of deionized water at 30 ° C, and then stirred at a speed of 8500 rpm for 10 minutes. After stirring, it was filtered and centrifuged for 10 minutes at centrifugal acceleration of 1000 g, after which the nitrogen content in the supernatant was analyzed. To determine Nitrogen Solubility Index (NSI) 5 g of the sample was mixed with 200 ml of water at 30 °C and stirred at a speed of 120 rpm for 120 minutes. The results of the comparative characteristics of the solubility of the protein cake and amaranth meal showed that the water-soluble fraction, manifested through the dispersibility coefficient, slightly differed from the total solubility, but after the thermal treatment, the protein structure underwent significant changes, and the total proportion of proteins increased, but the dispersibility coefficient decreased by 3-4 times, which was a consequence of a decrease in the mass fraction of the water-soluble fraction of proteins. Protein solubility in potassium hydroxide (KOH) is not a satisfactorily sensitive method for assessing the degree of heat treatment of a plant product, but it is effective in differentiating over-cooked products from properly processed ones. To determine the solubility in KOH, 1.5 g of cake and meal were mixed with 75 ml of 0.2% KOH solution and stirred for 20 minutes, then centrifuged at an acceleration of 2500 g for 20 minutes, then the soluble nitrogen in the liquid fraction was measured (Table 6).

**Table 6.** Comparative characteristics of the solubility of amaranth protein

No	Test object	Crude protein, %	Solubility in KOH, %
1	oilcake in the form of embryonic flakes	28.86	78.92
2	oilcake in the form of embryonic flakes after heat treatment	30.12	58.12
3	amaranth meal- CO <sub>2</sub>	32.11	84.91
4	amaranth meal- CO <sub>2</sub> after heat treatment	33.19	73.17

When implementing the technology of food protein isolate, it is necessary to ensure a high degree of purification of the prime raw material by removing all possible non-protein compounds. In general, most technological schemes include the following technological operations: extraction with water and alkali with pH control; sedimentation and neutralization; drying of the product. To obtain an isolate of edible amaranth protein, we propose a traditional technological scheme. The implementation of the technological scheme for the production of amaranth edible protein isolate will allow using traditional methods of processing non-traditional raw materials of plant origin, which will positively affect the cost of finished products using the finished isolate in the formulations.

## 4 Discussion

The performed studies of the chemical composition of amaranth cake showed that the mass fraction of moisture in amaranth cake was 6.48%, crude fat 6.29%,

comparable results are presented in the study by A.A. Fedorova, L.V. Antipova, N.A. Shmalko and others [29]. Also, the mass fraction of crude protein was determined in the work, which amounted to 28.86%, in the work of the authors [30] the situation was similar. The use of CO<sub>2</sub> gas for processing amaranth cake made it possible to achieve the residual oil content of 1.0-1.5%, while studies of the fatty acid composition showed the presence of oleic acid at the level of 28.29 wt% in the cake and 31.63 wt% in the meal, linoleic 46.32 / 51.72 wt%, respectively, as well as a high mass fraction of palmitic, which is 19.54 wt% for cake and / 21.98 wt% for meal, which is also confirmed by the data obtained in the work of A.I. Sanoeva and others, Cao Thi Hue and others [31; 32]. The obtained data made it possible to recommend the technology of CO<sub>2</sub> extraction for the processing of vegetable raw materials in order to reduce fatty acids in products.

According to the results of the study of the amino acid composition, a high mass fraction of phenylalanine was noted, which is 71.08 and 71.19 in meal and cake, respectively, a high mass fraction of lysine and leucine was also noted 59.02 / 56.91 for cake and 59.42 / 56.42 for meal, respectively, a similar situation is observed in the study of Sidorova Yu.S. and others [33]. The analysis of the protein solubility of oil cake and amaranth cake showed that the water-soluble fraction, expressed through the dispersibility coefficient, differed slightly from the total solubility, but after thermal treatment, the protein structure underwent significant changes, while the total proportion of proteins increased, but the dispersibility coefficient decreased by 3-4 times, which was the result of a decrease in the mass fraction of the water-soluble fraction of proteins, comparable results are presented in the study by I.M. Zharkova and others [34].

## 5 Conclusion

In conclusion, it can be noted that the research of the development of food protein isolate technology made it possible to obtain the necessary product that does not have any specific color and has neutral taste and smell.

Based on the study of the general chemical composition of the amino acid and fatty acid composition of amaranth and amaranth cake, the possibility of using it in the technology of protein production was proved and the use of CO<sub>2</sub>-extraction for processing amaranth cake was justified, which made it possible to achieve the required value for residual oil content in CO<sub>2</sub>-amaranth cake. The paper proposes the technological process for the production of food protein isolate based on amaranth cake- CO<sub>2</sub>.

For use in the technological process, the following methods of introducing it into minced meat systems are proposed: in the form of dispersions and the composition of brines in the production of semi-finished products and some types of sausages; in the form of a gel in the production of boiled and minced sausages; in the form of an emulsion in the production of cooked sausages; dry and hydrated.

## References

1. M.M. Danyliv, O.A. Vasilenko, O.N. Ozherelieva, N.M. Derkanosova, Production Engineering of the Low Fat Meat Products, *Advances in Engineering Research*, **1**, 129-135, (2018). doi:10.2991/agrosmart-18.2018.25
2. M. M. Danyliv, O.A. Vasilenko, O.N. Ozherelyeva and Yu.A. Shestakova, Improvement of sausage production technology, *IOP Conference Series: Earth and Environmental Science*, **341**, 012131 (2019) doi:10.1088/1755-1315/341/1/012131
3. J. Huang, L.M. Liao, S.J. Weinstein, R. Sinha, B.I. Graubard, D. Albanes, Association Between Plant and Animal Protein Intake and Overall and Cause-Specific Mortality, *JAMA Intern Med*, **180**(9), 1173–1184 (2020). doi:10.1001/jamainternmed.2020.2790
4. P. Franca, P. Duque-Estrada, A.J. Sá, Breno, A.P. Pierucci. Meat substitutes - past, present, and future of products available in Brazil: changes in the nutritional profile, *Future Foods*, **5**, 100133, (2022) doi.org/10.1016/j.fufo.2022.100133
5. J. Nezelek, C. Forestell, Meat Substitutes: Status, Potential Benefits, and Remaining Challenges, *Current Opinion in Food Science*, **47**(16), 100890, (2022). doi.org/10.1016/j.cofs.2022.100890
6. M. Murtaza, K. Ameer, *Food Processing Industrial Byproducts as Raw Material for the Production of Plant Protein Foods*, 109-129 (2022) doi:10.1007/978-3-030-91206-2\_4
7. Y. Zhu, T. Begho, Towards responsible production, consumption and food security in China: A review of the role of novel alternatives to meat protein, *Future Foods*, **6**, 100186, (2022) doi.org/10.1016/j.fufo.2022.100186
8. K. Nakyinsige, Y.B. Man, Z. Idrus, B. Fatimah, Halal meat: A niche product in the food market. *2nd International Conference on Economics, Trade and Development IPEDR*, **36**, 167-173, (2012).
9. E. Päivärinta, S.T. Itkonen, T. Pellinen, M. Lehtovirta, M. Erkkola, A.M. Pajari, Replacing Animal-Based Proteins with Plant-Based Proteins Changes the Composition of a Whole Nordic Diet-A Randomised Clinical Trial in Healthy Finnish Adults. *Nutrients*, **12**(4), 943, (2020). <https://doi.org/10.3390/nu12040943>
10. M. Murtaza, K. Ameer, *Food Processing Industrial Byproducts as Raw Material for the Production of Plant Protein Foods*, (2022) 109-129 doi:10.1007/978-3-030-91206-2\_4
11. M.L. Domoroschenkova, L.N. Lishaeva, Some aspects of the production and formation of the soy protein market at the present stage, *Food Industry*, **2**, 32-39, (2010)
12. P. Singh, R. Kumar, S.N. Sabapathy, A.S. Bawa, Functional and Edible Uses of Soy Protein Products, *Comprehensive Reviews in Food Science and Food Safety*, **7**, 14-28, (2008). doi:10.1111/j.1541-4337.2007.00025.x
13. U.M. Garba, S. Kaur, P. India, Protein Isolates : Production, Functional Properties And Application, *International journal of current research and review*, **6**, 35-45 (2014).
14. P. Qin, T. Wang, Y. Luo, A review on plant-based proteins from soybean: Health benefits and soy product development, *Journal of Agriculture and Food Research*, **7**, 100265, (2022). doi.org/10.1016/j.jafr.2021.100265
15. T.V. Renzyaeva, Protein products from rapeseed and camelina cake: obtaining, quality, biological value, *Achievements of science and technology of the agro-industrial complex*, **4**, 70-72, (2009).
16. S.V. Lymanska, L.A. Miroshnichenko, T.I. Goptsiy, O.S. Korneeva, Polymorphism of RAPD and ISSR markers in grain amaranth species, *Journal of Genetics and Breeding*, **21**, 189-197, (2017). doi 10.18699/VJ17.236
17. I.M. Zharkova, L.A. Miroshnichenko, A.A. Zvyagin, I.A. Bavykina, Amaranth flour: characteristics, comparative analysis, application possibilities, *Nutrition Issues*, **83**(1), 67-73, (2014). doi: 10.24411/0042-8833-2014-00010
18. GOST R 54705-2011 Oilcakes, meal and mustard powder *Methods for determining the mass fraction of moisture and volatile substances* (2011) <https://docs.cntd.ru/document/1200089995> Accessed 01 Jan 2013
19. GOST ISO 734-1-2016 *Oilcakes and meals Determination of crude fat content. Part 1. Method of extraction with hexane (or light petroleum ether)* (2016) <https://internet-law.ru/gosts/gost/63341/> Accessed 01 Jan 2018;
20. GOST ISO 734-2-2016 *Oilcakes and meals. Determination of crude fat content Part 2. Accelerated extraction method* (2016). <https://internet-law.ru/gosts/gost/63395/> Accessed 01 Jan 2018
21. GOST 13979.2-94 *Oilcakes, meal and mustard powder. Method for determining the mass fraction of fat and extractives* (1994) <https://internet-law.ru/gosts/gost/9601/> Accessed 01 Jul 1996
22. GOST 13979.3-68 *Oilcakes and meals. Method for determining the total mass fraction of soluble proteins (with Amendments No. 1, 2)* (1968) <https://internet-law.ru/gosts/gost/43141/> Accessed 01 Jan 2012
23. GOST 10845-98 *Grain and products of its processing. Method for determination of starch* (1998) <https://internet-law.ru/gosts/gost/8817/> Accessed 01 Jan 2000
24. GOST 32040-2012 *Feed, compound feed, compound feed raw materials Method for Determination of Crude Protein, Crude Fiber, Crude Fat and Moisture Content Using Near Infrared Spectroscopy* (2012) <https://internet-law.ru/gosts/gost/55122/> Accessed 01 Jul 2014
25. GOST 32933-2014 *Feed, compound feed. Method for determination of crude ash content* (2014) <https://internet-law.ru/gosts/gost/58204/> Accessed 01 Jan 2016
26. GOST 32195-2013 (ISO 13903: 2005) *Feed, compound feed. Method for determination of amino acid content* (2013)
27. GOST 30418-96 *Vegetable oils. Method for determination of fatty acid composition* (1996) <https://internet-law.ru/gosts/gost/56066/> Accessed 01 Jul 2015
28. G.I. Kasyanov, Technique and technology for the use of carbon dioxide in the sub- and supercritical state, *Bulletin of the Voronezh State University of Engineering Technologies*, **1**(59), 130-135, (2014)
29. A.A. Fedorov, L.V. Antipova, The use of cake from amaranth seeds in the production of combined meat products, *News of higher educational institutions. food technology*, **4**, 11-13 (2010)
30. Yu. F. Roslyakov, N.A. Shmalko, L.K. Bochkova, Prospects for the use of amaranth in the food industry, *News of higher educational institutions. North Caucasian region. Technical science*, **4**, 92-95 (2004)
31. A.I. Sanoev, Sh.K. Khidoyatova, N.I. Mukarramov, R.K. Rakhmanberdieva, M.Kh. Malikova, L.G. Mezhlumyan, Sh.Sh. Sagdullaev, S.D. Gusakova, Influence of the conditions of supercritical carbon dioxide extraction of

- amaranth cake on the yield of the extract and the content of squalene in it. *Chemistry of plant raw materials*, **2**, 315-322 (2020)
32. T.H. Cao, T.M.H. Nguyen, N.T. Le, E.V. Spiridovich, E. I. Alekseeva, V.H. Nguyen, Study of the biochemical composition of amaranth grain (based on Vietnamese raw materials), *Bulletin of the Astrakhan State Technical University*, **1**(59), 12-18 (2020)
  33. Yu.S. Sidorova, N.A. Biryulina, I.S. Zilova, V.K. Mazo, Amaranth grain proteins: prospects for use in specialized food products. *Nutrition Issues*, **3**(541), 96-106 (2022)
  34. I.M. Zharkova, Yu.A. Safonova, A.A. Samokhvalov, Study of the effect of processing parameters of amaranth grain before grinding on the properties of the resulting flour, *Bulletin of the Voronezh State University of Engineering Technologies*, **80**, 41-48, (2018).