Processing of natural plant raw materials and their use as additives in the food industry

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Abstract. The article deals with the issues of deep processing of non-traditional plant raw materials – amaranth. The authors found that amaranth seeds of various types are a source of starch and protein, balanced in amino acid composition. A comparative assessment of the main nutrients and mineral composition of amaranth seeds with traditional crops showed that amaranth seeds are unique as raw materials for the production of biologically active additives. It is proved that a fine powder of whole-ground flour is possible to obtain by double mechanical processing of amaranth seeds with mandatory heat treatment before introduction into the recipe. It was experimentally revealed that the developed biologically active additive has a high nutritional value and functional properties, which are formed due to squalene content, essential amino acids and plant phospholipids.

1. Introduction
Amaranth is one of the unconventional sources of raw materials of plant origin. It is a long-known herbaceous plant whose fruits and leaves have a high nutritional value. Amaranth is widely used in the food industry [1].

Despite the ancient history of cultivation and practical use of plants of the amaranth family, research on the chemical composition of this unique plant began only in the eighties of the twentieth century. The closest attention of scientists was focused on the amino acid composition of various proteins and starch because of the unique structure of its granules and the ratio of amylose/amylopectin [2].

Much had been done in recent years on the use of amaranth in the agricultural industry. However, it is not fully applicable as a functional ingredient to meet the physiological needs as a food additive and a prophylactic treatment of many diseases [3].

There are known technologies for the isolation of certain valuable components from amaranth seeds, such as oil, squalene, starch, pectin. However, to see amaranth as being a promising focus of work it is necessary to conduct research on the development of specialized products based on seeds including biologically active additives to diet (dietary supplements or BAA), for example, in combination with plant phospholipids. When the concentration of phospholipids is high products containing a complex of physiologically active substances (dietary fiber, squalene, pectin, minerals, vitamins, including tocopherols, carotenoids) will expand the range of polyfunctional properties in the human body appropriate for phospholipids.

Thus, the development of innovative technologies for the production of dietary preventive nutrition products and biologically active additives based on amaranth seeds as non-traditional plant raw materials is timely and relevant.
2. Materials and methods

The composition of amaranth seeds (the content of moisture and volatile substances, lipids, minerals, proteins and amino acids, fiber, starch, sugars) was studied using modern physical and chemical analysis methods [4-10].

The mass fraction of fat was determined by various methods: centrifugation, exhaustive extraction with a highly volatile solvent, refractometric [5], and Folch’s method [6]. Generally accepted methods known in biochemistry were used to determine the protein content [7, 8]. The crude protein content was determined according to [GOST 13496.4-2019], recalculated taking into account the actual moisture content of seeds and oil content to a fatty substance according to the well-known method [9]. The amino acid composition of proteins was determined by the chromatographic method using an automatic amino acid analyzer [10]. The mass fraction of crude fat in amaranth seeds was determined by the extraction method, which consists in repeated extraction of lipids from the crushed material [GOST 10857-64].

3. Results

More than 100 species of amaranth are known [1], growing in warm-temperate regions, including 17 found on the territory of the Russian Federation. All of them are divided according to morphological and economic characteristics which made it possible to use them for food, feed and medicinal purposes. When creating a product with a wide range of functional effects on the human organism, the types and varieties of plants with high nutritional and physiological value of seeds were chosen: White-seeded, Pink-seeded and Black-seeded. The nutrient composition was studied comparing amaranth seeds with different colors of their shells (Table 1).

Table 1. The nutrient composition in amaranth seeds of various types, % on a dry matter basis

| Name of indicators | White-seeded | Pink-seeded | Black-seeded |
|--------------------|--------------|-------------|--------------|
| Proteins           | 15.50-18.10  | 13.54-16.30 |              |
| Lipids             | 5.97-8.23    | 5.80-6.80   |              |
| Starch             | 59.90-63.30  | 60.00-63.40 |              |
| Dietary fiber      | 6.90-8.90    | 8.70-10.90  |              |
| Mono-and disaccharides | 2.16-4.64  | 2.09-4.69   |              |
| Ash                | 2.80-3.60    | 3.00-3.82   |              |

As it can be seen from Table 1, carbohydrates largely predominate in amaranth seeds accounting for more than 72%. The content of dietary fiber, mono-and disaccharides, minerals and starch are at the same level, and their amount is almost independent of the fruit color. Light-colored seeds in comparison with dark-colored seeds are characterized by a higher protein concentration (13.54-18.50 %) with the increase in seed oil content (16.10-18.50 %).

The lipid composition of amaranth seeds of various types was studied to assess the biological effectiveness. They contain the most important biologically active components: squalene (6.14 – 8.70 %), tocopherols (0.10 – 0.18%), phospholipids (2.70 – 4.28%), sterols (3.70 – 4.60%) and carotenoids (0.45 – 1.12%) (Table 2).

Table 2. Composition of biologically active components of lipids in amaranth seeds of various types

| Type of seeds  | Mass share, % |
|----------------|---------------|
|                | unsaponifiable substances | tocopherols | phospholipids | squalene | sterols |
| White-seeded   | 10.90-12.70   | 0.10-0.18    | 2.70-2.85     | 8.30-8.70 | 4.60    |
| Pink-seeded    | 8.90-9.30     | 0.14-0.16    | 3.14-3.64     | 6.14-6.60 | 3.70    |
| Black-seeded   | 9.60-10.80    | 0.11-0.15    | 3.87-4.28     | 6.84-7.04 | 4.00    |
Due to the presence of squalene in the lipids of amaranth seeds, which is a natural immune response-modulating agent, products containing amaranth oil, and as a result, squalene in a physiologically significant amount can have an impact on the human organism, for example, anti-carcinogenic, anti-inflammatory, antitumorigenic, etc. Scientists consider squalene to be an antitumorigenic factor. It strengthens the immune system. In terms of the content of squalene (8.30-8.70%), sterols (4.60%), tocopherols (0.10-0.18%), white-seeded varieties are superior to pink-seeded and black-seeded varieties.

The research was conducted to compare the fatty acid composition of cottonseed oil and the lipids of amaranth seeds of various types. According to the data obtained, the fatty acid composition of amaranth lipids of various types has no prominent differences. In terms of palmitic acid content (19.2-21.2%), amaranth lipids are close to cottonseed oil (21.0%), but the amount of stearic and arachinic acids in cottonseed oil is minimal, compared to amaranth. The content of unsaturated fatty acids (74.6-76.4%) amaranth oil is approaching cotton (76.5 %), second only to the amount of oleic acid (1.3 times), if the content of linoleic (4.4-6.5%) and linolenic (0,8-1,2% versus traces in cottonseed oil) is increased.

The research into biochemical characteristic of amaranth seeds revealed the influence of species features of these fruits on a range of indicators which must be taken into account when you are choosing how to use this crop seeds. It was found that the seeds of light-colored types are characterized by the highest biological potential compared to dark-colored ones, due to the increased concentration of proteins and lipids containing polyunsaturated fatty acids, tocopherols with antioxidant activity, phospholipids, sterols, and squalene in a physiologically more significant amount.

The modern selected variety of amaranth "Ultra" (white-seeded) was chosen for the following research.

Taking into account that the biological value is assessed by the degree of compliance of the amino acid composition of food products with the human needs for amino acids to synthesize protein, their composition and ratio in amaranth seeds proteins of seed variety "Ultra" were studied, guided by the recommended FAO / WHO daily requirement for essential amino acids. The results are presented in Table 3. In terms of the amount of essential amino acids, proteins of amaranth seeds exceed the FAO/WHO food standard, which distinguishes this crop from the most common food crops of cereals and legumes.

Table 3. Essential amino acid content of amaranth seeds

| Amino acids             | FAO / WHO, gr/100gr | Amaranth, gr/100gr | Amino acid score, % |
|------------------------|---------------------|--------------------|---------------------|
| Phenylalanine+ tyrosine| 6.3                 | 7.0                | 111.1               |
| Lysine                 | 5.8                 | 6.2                | 106.9               |
| Leucine                | 6.6                 | 5.7                | 86.4                |
| Valine                 | 3.5                 | 4.3                | 122.9               |
| Methionine+ cystine    | 2.5                 | 4.2                | 168.0               |
| Isoleucine             | 2.8                 | 3.7                | 132.1               |
| Threonine              | 3.4                 | 3.6                | 105.9               |
| Tryptophan             | 1.4                 | 1.5                | 107.1               |
| Total of the essential | 32.3                | 36.2               |                     |

Lysine is known one of the most valuable essential amino acids valued for its powerful effect on the immune system which promotes proper calcium absorption, improves lipid metabolism; its lack leads to disorders of blood formation, a decrease in the number of red blood cells and hemoglobin in them, the depletion of muscle.
Methionine is involved in the formation of RNA and DNA, promotes the assimilation of selenium, and is part of hemoglobin. In terms of this amino acid content amaranth is 3 times superior to beans and wheat and twice superior to soy and corn.

Phenylalanine and trozine in amaranth seeds are 1.7 times higher than in corn, wheat and soybean. This amino acid regulates appetite, stimulates the activity of the thyroid gland and liver, forming a nucleus for the synthesis of thyroxine.

In terms of the amount of tryptophan, amaranth seeds are close to soy, surpassing wheat and corn by 1.3 and 1.7 times, respectively

The limiting amino acid is leucine (5.7%) for amaranth seeds. It should be noted for comparison that traditional crops (wheat, corn, beans, soy) exceed the FAO/WHO food standard for this amino acid (6.6%).

According to the research results, amaranth seeds have a distinctive feature in comparison to traditional food crops – a better balance in amino acid composition and, as a consequence, a better digestibility of proteins by human organism.

Compared with traditional food crops the amaranth seed variety "Ultra" has specific functional and technological properties, which determine the possibility of its use as a raw material for development a biologically active additive "Squalene-Lecithin". The research of the chemical and mineral composition of the nutrients of amaranth seeds in comparison to traditional crops has shown that amaranth seeds are an ideal source of raw material for the production of dietary BAA.

However, certain technological solutions are required to achieve the necessary degree of seeds grinding of this crop and to ensure high organoleptic parameters of the developed biologically active additive, taking into account all the features of the chemical composition and mechanical properties.

An effective way of processing of this non-traditional plant raw material for the production of biologically active additives is to process it in a specially designed activator. The amaranth flour was fried for 2-3 minutes at a temperature of 100-110{°}C to achieve the necessary organoleptic properties of the new additive. This roasting of flour leads to a slight darkening of the product due to the accumulation of melanoids and the formation of a pleasant nutty flavor, which contributes to the accumulation of dextrins reducing the loss of mono- and disaccharides, starch, as well as increasing the activity of amylolytic enzymes and sugar-forming ability.

To develop a recipe of the dietary BAA "Squalene-Lecithin", the previously developed phospholipid additive and amaranth flour which was fried according to the above mentioned technology were used as the main components. The ability of the dietary additive "Squalene-Lecithin" to normalize the nutritional status of a person was evaluated in accordance with the recipe choosing the optimal daily dosage (Table 4).

A new product with a full and preventive diet can be used as a dietary background or an additional element of nutrition to the main diet, as it is a source of a wide range of biologically active components in physiologically significant amounts. The inclusion of dietary additives "Squalene-Lecithin" in the daily diet in the amount of 12-18 g in one or two doses will meet the needs of the human body in squalene by 15-23%; phospholipids - by 43-65%; vitamin E - by 10-14 %; trace elements: copper – by 36-54%, manganese - 24-36%, iron-by 13-19%; in macronutrients: magnesium, phosphorus – by 8-12%; in essential amino acids: methionine and cystine – by 21-32%; isoleucine – by 17-25%, lysine – by 14-21%, threonine – by 13-20%, phenylalanine and tyrosine – by 14-22%, leucine – by 11-17 %; in non-essential amino acids: histidine – by 10-15%, serine - by 21.2-31.8%, arginine - by 11-16%.
Table 4. Composition of physiologically functional ingredients of dietary additive “Squalene-Lecithin”

| Name of physiologically functional ingredients | Daily need for methodological recommendations 2.3.1.19150-08 | Recipe of BAA | Provision of daily needs, % of the norm |
|-----------------------------------------------|-------------------------------------------------------------|--------------|----------------------------------------|
| Squalene, mg                                  | 400                                                         | 510          | 100 g 12 g 18 g                        |
| Amino acids, g                                |                                                             |              | 400 510 650 80 12 18 20 25 30          |
| leucine                                       | 4.6                                                         | 4.30         | 93.5 11.2 16.8                         |
| isoleucine                                    | 2.0                                                         | 2.80         | 140 16.8 25.2                         |
| valine                                        | 2.5                                                         | 3.20         | 128 15.3 23                             |
| Lisino                                        | 4.1                                                         | 4.70         | 115 13.8 21                             |
| threonine                                     | 2.4                                                         | 2.70         | 112 13.4 20                             |
| methionine+cystine                            | 1.8                                                         | 3.20         | 178 21.4 32                             |
| phenylalanine+tyrosine                        | 4.4                                                         | 5.30         | 120 14.4 21.6                          |
| histidine                                     | 2.1                                                         | 1.70         | 81 9.7 15                              |
| arginine                                      | 6.1                                                         | 5.60         | 92 11 16.6                             |
| the rite                                      | 8.1                                                         | 5.30         | 64 7.7 11.5                            |
| Phospholipids, gr.                            | 7                                                           | 25.20        | 360 43 65                              |
| Macronutrients, mg:                           |                                                             |              | 800 520 65 7.8 11.7                    |
| phosphorus                                    |                                                             |              | 400 260 65 7.8 11.7                    |
| magnesium                                     |                                                             |              |                                        |
| Trace elements, mg:                           |                                                             |              |                                        |
| copper                                        | 1                                                           | 3            | 300 36 54                              |
| iron                                          | 15                                                          | 15.8         | 105 12.6 18.9                          |
| manganese                                     | 2                                                           | 4            | 200 24 36                              |
| Vitamins, mg:                                 |                                                             |              | 15 12 80 9.6 14.4                      |

4. Conclusion

It was found that amaranth seeds of various varieties are a source of starch (61.40 – 61.70 %) and protein (14.90 – 17.25%) balanced in amino acid composition. Amaranth seeds exceed the FAO/WHO food standard in terms of the amount of essential amino acids.

Amaranth oil is unique due to squalene, its concentration depends on the type of seeds and varies from 6.37 % to 8.50 %. The lipids of amaranth seeds contain the most important biologically active components: such as sterols, carotenoids, tocopherols. It was found that the lipids of amaranth seeds were stabilized by tocopherols with high antioxidant activity.

It is established that the white-seeded variety of amaranth "Ultra" is characterized by improved organoleptic and physico-mechanical properties. The choice of the type of amaranth seeds as the main component for the development of dietary supplements "Squalene-Lecithin" is experimentally substantiated.

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