AMARANTH PROCESSING TECHNOLOGIES FOR THE PRODUCTION OF HEALTH-IMPROVING FOOD

Natalia Stetsenko*, Galyna Simakhina, Iryna Goyko, Alla Bashta
National University of Food Technologies, Kyiv, Ukraine
**Corresponding author: stetsenkono@nuft.edu.ua*

One of the goals of sustainable development is responsible consumption, in particular, the transition to a significant reduction in waste volumes through the use of measures to prevent its formation, its reduction, recycling and reuse. Such approaches should be implemented in the processing of plant raw materials in modern food technologies, in particular in the production of food products for health and preventive purposes. One of the ways to improve the quality of nutrition of modern people is to introduce food additives with high taste and nutritional qualities into the diet, which include processed amaranth seed products. Researchers are actively developing technologies for the complex processing of amaranth seeds to obtain a number of food and medicinal products from them: products of mechanical and thermal processing, amaranth oil, squalene, CO_2-extracts, protein additives and pectin. Products of mechanical processing of amaranth seeds, such as whole-grain flour, are obtained by grinding the seeds on roller mills or disintegrators without removing the seed coat. Extrusion processing helps to reduce the trypsin content and increase the digestibility of the protein, as well as improve the organoleptic properties of the resulting product. Vegetable forms of amaranth and its leafy part are considered as a potential source of coloring pigments, protein and vitamins. The valuable biochemical composition of various parts of the plant creates broad prospects for the use of amaranth in modern food technologies.

Keywords: amaranth, complex processing, healthy food, sustainable development, amaranth seeds

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Introduction

One of the goals of sustainable development is responsible consumption, in particular, the transition to a significant reduction in waste volumes through the use of measures to prevent its formation, its reduction, recycling and reuse (Herrero et al., 2021). Such approaches should be implemented in the processing of plant raw materials in modern food technologies, in particular in the production of food products for health and preventive purposes. New developments are beginning to actively change the field of food technology (Liu et al., 2022): Industry 5.0 (Demir et al., 2019), innovative processing technologies, short supply chains, artificial intelligence, blockchain (Kamilaris et al., 2019) are just some of the many trends and technologies that affect modern systems for processing agricultural raw materials into food products and that will contribute to healthy and sustainable food production.

One of the ways to improve the quality of nutrition of modern man is to introduce into the diet food additives with high taste and nutritional qualities, which include products of amaranth seed

processing. Amaranth (*Amaranthus L.*) is a valuable industrial, feed, food and medicinal crop (Jimoh et al., 2022). Amaranth is an ideal and useful product for humans, in which seeds and vegetative mass are consumed. Amaranth attracts the attention of agricultural specialists due to its high yield, which is on average 1500-1700 centners of green mass per hectare and from 10 to 53 centners of amaranth seeds per hectare. This crop has the ability to adapt to different environmental conditions. Therefore, climate changes, which are already observed on the planet and may become much greater, determine the attention to the choice of amaranth for mass cultivation. Currently, this crop is classified as niche, that is, those for which there is a situational or constant increased commercial or social demand in the product market.

Materials and Methods

The work used general scientific methods of analysis and synthesis. A calculation method was used to determine the biological value of amaranth seed protein (Stetsenko, N.O., & Frolova, N.E., 2024).

The Register of Varieties Suitable for Distribution in Ukraine currently includes 15 varieties of amaranth. 8 varieties are used for grain, 4 varieties are used for silage, 2 are used for landscaping, and 1 variety (Kharkiv 1) is considered medicinal. The National Botanical Garden named after M. M. Grishko of the NAS of Ukraine, the Institute of Feed of the NAAS, and the Kharkiv State Agrarian University named after V.V. Dokuchaev are engaged in the breeding and seed production of amaranth in Ukraine. The following varieties belong to the grain direction: Aztec, Zhaivir, Lera, Orchid, Polishchuk, Studentsky, Sem, Ultra.

Amaranth belongs to the C4 group of plants – photosynthesis and consumes more carbon during the growing season, which also gives amaranth a certain opportunity to compete with weeds. Therefore, growing amaranth is important in the global decarbonization strategy. Amaranth requires 2-3 times less water to form a unit of organic matter than wheat and corn, which makes the crop adapted to various climatic conditions of Ukraine. In addition, amaranth is known as a green manure for restoring soil fertility.

Amaranth with the harvest brings out several times less natural minerals than wheat or corn, but has the same revenue from sales. In addition, the crop does not require the application of mineral fertilizers.

Among the advantages of growing amaranth can also be noted (Topwal, 2019):

• the plant desalinates slightly saline soils;

• amaranth has a root system capable of going down to 7 m (pulls minerals to the surface for subsequent crops in crop rotation);

• it is an excellent component of cover crop mixtures, which are the basis of regenerative;

• grows on poor soils, for example, on the sands of the Kherson region;

• leaves behind a lot of nitrogen (up to 47% protein in leaves);

• is able to compete with corn as a raw material for silage and biogas plants, at least halving the number of areas that are intensively used.

Results and Discussion

Researchers are actively developing technologies for the complex processing of amaranth seeds to obtain a number of food and medicinal products from them: products of mechanical and thermal processing, amaranth oil, squalene, CO_2-extracts, protein supplements, and pectin (Figure 1).

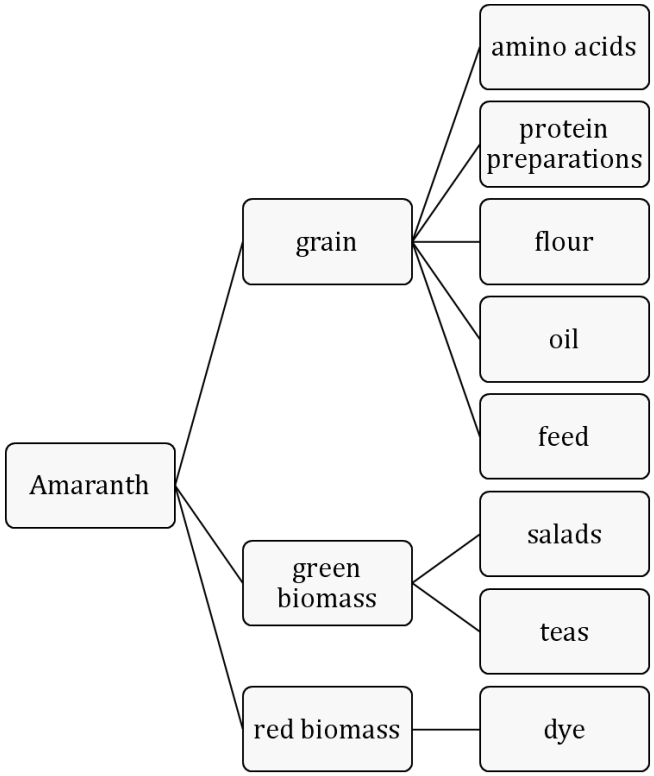

Figure 1. Options for processing plants of the Amaranth family for use in the food industry

Amaranth seeds are of greatest interest to food industry professionals. They are valued for their high protein content with a balanced amino acid profile, the valuable fatty acid composition of amaranth oil, which contains the unique biologically active substance squalene, and the high content of vitamins, minerals, and other micronutrients (Figure 2). Products of mechanical processing of amaranth seeds, such as whole grain flour, are obtained by grinding the seeds in roller mills or disintegrators without removing the seed coat. Taking into account the peculiarities of the fractional composition of amaranth seed proteins, protein concentrates, isolates and protein-polysaccharide complexes are produced, which have high digestibility, water solubility and emulsifying ability. To obtain processed products from thermally treated amaranth seeds, it is proposed to extrude or roast them. Extrusion processing helps to reduce the trypsin content and increase protein digestibility, and also improves the organoleptic properties of the resulting product.

We evaluated the amino acid composition of amaranth seed flour and compared it with the composition of wheat flour (table 1). The results obtained indicate that the amino acid composition of amaranth flour is better approximated to the composition of the ideal protein. Especially important are the high values of lysine and leucine content, which increase almost 2 times. Calculation of the balance of protein composition of two plant species showed that amaranth protein is absorbed 32.6% better than wheat protein (table 2). This determines the basis for the use of amaranth grain in the creation of health-promoting products with improved protein composition.

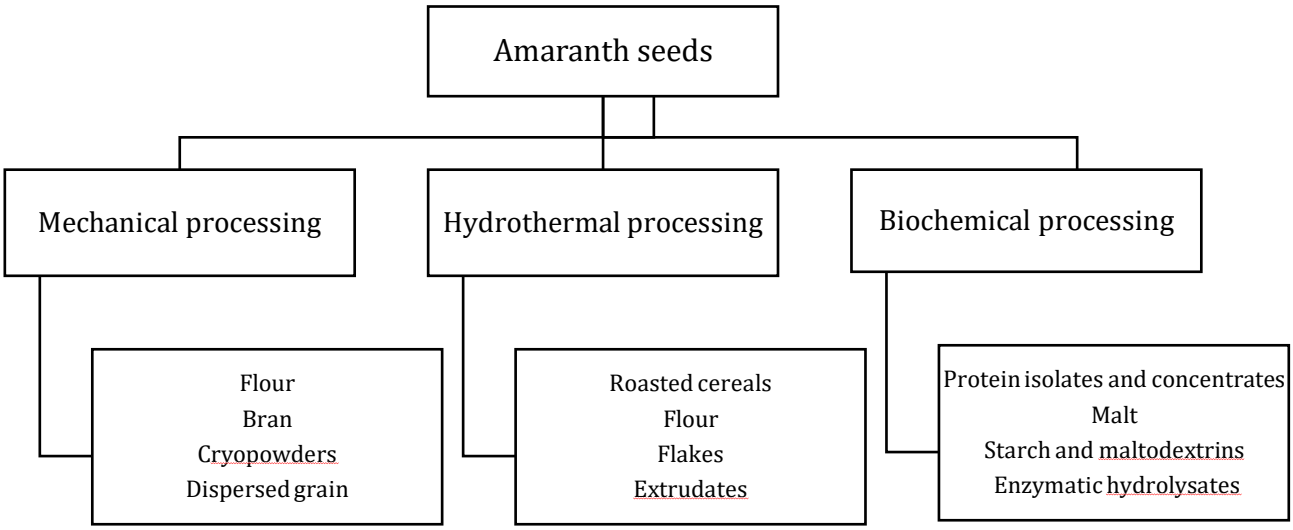

Figure 2. Methods of industrial processing of amaranth seeds

Table 1. Amino acid composition of amaranth and wheat flour

Amino acid	Amino acid composition, mg/100 g protein		Amino acid scor, %	
	amaranth flour	wheat flour	amaranth flour	wheat flour
Leucine	7.2	3.5	102.9	50.0
Isoleucine	3.7	7.2	92.5	180.0
Methionine + cystine	3.2	4.3	91.4	122.8
Lysine	6.2	3.1	112.7	56.4
Tyrosine + phenylalanine	7.1	8.1	118.3	135.0
Threonine	3.4	3.1	85.0	77.5
Valine	4.6	4.7	92.0	94.0
Tryptophan	1.15	1.2	115.0	120.0

Table 2. Indicators of the biological value of amaranth and wheat protein

Indicator	Amaranth flour	Wheat flour
Total protein content, %	15.3	10.3
Rate of the first limited essential amino acid, %	85.0	50.0
Protein utility coefficient, %	83.7	51.1
Complete part of amino acid composition, %	30.6	18.0
Coefficient of excess amino acid composition, %	7.0	34.3

Amaranth flour is also valuable because it is completely gluten-free (de la Barca et al., 2010). This is a real find for people suffering from celiac disease, and it opens up the opportunity for them to consume foods rich in protein (Piga et al., 2021).

Amaranth oil occupies a special place among the products of complex processing of amaranth seeds; its fatty acid composition contains up to 77% unsaturated fatty acids, mainly represented by polyunsaturated acids (Gamel et al., 2007). Squalene in the human body rejuvenates cells, and also inhibits the growth and spread of malignant tumors. Squalene is able to increase the activity of the body's immune system several times, ensuring its resistance to various diseases. During active sports, it contributes to better transportation of substances in the blood, and, therefore, significantly accelerates metabolism (Sun et al., 1997).

The leaf part of amaranth is considered as a potential source of color pigments, protein and vitamins. Amaranth leaves contain a large amount of protein, carotenoids, vitamins C, B_1, B_2, B_{12}, E, flavonoids with P-activity (rutin, quercetin) and pectin, which in its complex-forming ability is not inferior to apple pectin. Such a valuable biochemical composition of different parts of the plant creates broad prospects for the use of amaranth in modern food technologies (Kraujalis et al., 2013). Amaranth leaf mass is used as animal silage and in the production of biomethane. Therefore, the development of the crop will be an important step in the country's bioenergy strategy. The plant mass of this crop is advisable to use in the processing of cyanobacteria into biogas, as well as in the processing of leaf litter into high-quality fertilizer in the composting process. Such technologies are environmentally safe, low-waste, and also provide solutions to environmental problems (Sitkey et al., 2013).

Let's summarize the therapeutic and prophylactic properties of amaranth and its value for the production of health-improving food products (table 3).

Table 3. Properties of amaranth, which are important for the production of health-improving food products

Direction of action	Properties of amaranth
Cardiovascular system condition	Improvement of cholesterol metabolism, improvement of the condition of blood vessels and capillaries
Gastrointestinal tract function	Dietary fibers, in particular fiber and pectin substances, improve the functioning of the gastrointestinal tract
Visual organs condition	Positive effect due to the presence of carotenoids
Immune system condition	Stimulating effect due to the presence of squalene and other biologically active substances
Antioxidant system function	Improvement due to the presence of vitamins, antioxidants and polyphenolic compounds
Gluten-free diet	The absence of gluten in the composition of the seeds allows the creation of food products for patients with celiac disease or gluten enteropathy

Conclusions

Amaranth seeds are processed into flour, oil, flakes, extrudates, protein isolates, and concentrates, which are used in the food industry in the production of bread and bakery products, cereal bars, enriched meat products, and vegetable milk substitutes.

Vegetable forms of amaranth and its leafy part are considered as a potential source of coloring pigments, protein and vitamins. Amaranth foliage contains a large amount of protein (up to 38.3%), carotenoids, vitamins C, B1, B2, B12, E, flavonoids with P-activity (rutin, quercetin) and pectin, which is not inferior to apple pectin in its complexing ability.

Such a valuable biochemical composition of different parts of the plant creates broad prospects for the use of amaranth in modern food technologies.

Conflict of interest

The authors state no conflict of interest.

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