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The chemistry behind amaranth grains

Abstract

Due to their favorable chemical content and the application in developing functional food products, the use of pseudocereal species in human nutrition is constantly increasing. Amaranth is one of the three pseudocereals, next to buckwheat and quinoa, most frequently used in modern formulations of functional bakery, pastry and confectionary food products. Therefore, it is of great importance to summarize the reasons of its importance and the chemistry behind it. This review also describes the contents of macronutrients (such as starch, proteins, lipids), micronutrients (such as vitamins and minerals) and some of the antinutrients in amaranth grain, and compares them with other cereal and pseudocereal species, which are also commonly used in human nutrition.

Keywords: amaranth grain, chemistry and uses, macronutrients, micronutrients, antinutrients

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Introduction

Amaranth (*Amaranthus* spp., Greek "eternal") originates in South America, specifically Ecuador, Peru and Bolivia. Even NASA astronauts used amaranth as part of their diet in the universe. Botanically, amaranth belongs to the family of dicotyledonous plants *Amaranthaceae*, which includes more than 60 species, most of which are weeds. They can grow in width and in height, and there are both low and varieties that grow up to 4 meters high.[1,2] Three varieties of amaranth are the most important: *A. hypochondriacus* (Mexico), *A. cruentus* (Guatemala) and *A. caudatus* (Peru and other countries in the Andes). The variety *A.hypochondriacus* is examined the most widely and thoroughly.[3,4] Due to favorable agricultural, nutritional and functional characteristics, there is an increasing interest in the use of amaranth in nutrition in the last few decades. Amaranth is richer in proteins and lipids, but contains less starch, compared to common cereals. Amaranth grain is rich in phytochemicals (secondary metabolites), such as routine, nictoflorin and isoquercetin, which have a positive effect on human health. It does not contain gluten, so it can be used in the diet of celiacs. Also, the plant is resistant, adaptable and easy for breeding and growing.[2]

Amaranth grain is similar to quinoa grain because it possesses a central perisperm, surrounded by the embryo and the remains of the endosperm. The storage proteins are found in the embryo, and the starch cells are located in the perisperm.[3,4] The pericarp is very smooth and thin, and unlike the other two pseudocereals - buckwheat and quinoa, it is not necessary to remove it. This means that the grain in most cases can be used directly. The color of the grain varies from milky white to yellow, gold, red, brown and black, which depends on the content of the betalaine pigments.[1,2] Amaranth grains are very small, 1-1.5mm in diameter, lens shaped and weigh about 0.6-1.3mg per grain.[2,4] Amaranth flour can be used in the production of various types of breads, such as chapatti and tortilla, but not yeast bread. There is no gluten, so there is no ability to retain gases.[2] In order to produce bread and pasta, it can be added to wheat flour up to 20% (according to current achievements), without a product quality change.[1,2] However, some authors claim that it is possible to add 30-40%, some authors even 60-70% of amaranth flour in the formulations of bakery products.[2] Amaranth grain can be popped, similarly to the grain of corn. It can be used in the production of soy sauce, which is commonly used in Southeast Asia. In addition to the common application of barley malt, beer can also be produced from amaranth. Since amaranth grains containa relatively large starch content, strong alcoholic beverages can also be produced. A yellow amaranth oil can be obtained by refining process, and it contains about 8% squalene.[1]

Discussion

Carbohydrates

The total carbohydrate content of the amaranth grain is slightly lower than in the wheat grain. Starch represents the main carbohydrate component, constituting 48-69% of dry grain matter (depending on the variety), and is located in perisperm cells. It is stored in the form of extremely small starch granules, ranging from 0.8 to 2.5 μm, most often of uniform size, spherical, angular, and polygonal in shape. A very unusual feature is that they have almost crystalline structure. The content of amylose is very low, from 0.1 to 11.1%. Although the starch content is also subject to large variations, it is generally lower compared to common cereals.[2,4–10]. The content of dietary fibre in amaranth grain is slightly lower than in wheat, and is generally similar to quinoa and common cereals - about 20% of dry grain matter.[4,5] According to other authors, the content of total dietary fibers, soluble and insoluble, is between 9.8 and 14.5%, depending on the variety.[2] Only small quantities of mono- and disaccharides were detected in amaranth grain. Sucrose is dominant, but glucose, galactose, fructose, maltose, raffinose, stachyose and inositol are also detected.[2,8]

Proteins

Proteins are the second most common component of amaranth grains. It is believed that the amino acid composition of the amaranth protein is close to the ideal protein.[2,7,11–13] All varieties of amaranth are characterized by high protein content, from 13 to 18% d.m., which is generally higher than in cereals, and other pseudocereals. About 65% of the protein is in embryo and grain hull and 35% in starch perisperm. Unlike cereals, amaranth proteins consist of albumins (about 40%), glutenins (25-30%) and globulins (20%), and contain very small amounts of prolamins (2-3%), which are the main group of proteins in cereals, and are toxic for those suffering from celiac disease.[2,4–8,10,13–15] Amaranth does not contain gluten, therefore it is therefore suitable for the diet of celiac patients.[1,16] Albumins and globulins contain less glutamic acid and proline than prolamins, and are richer in essential amino acids, such as lysine, which makes amaranth proteins closer to the composition of animal proteins.[1,2,4–6,13,16]

Lipids

The content of lipids in amaranth grain is higher than in common cereals, 6-9%. According to some authors, the content of lipids in amaranth is 2 to 3times higher than in buckwheat grains and common cereals.[4,5] Amaranth lipids consist of fatty acids, triglycerides, sterols, phospholipids, glycolipids, tocopherols, and hydrocarbons.[2] Amaranth lipids are characterized by high content of unsaturated fatty acids, with a particularly high content of linoleic acid. Linoleic acid makes up over 50% of total fatty acids and therefore represents the most common fatty acid. The following are oleic (more than 25%), palmitic (about 20%) and linoleic (about 1%). Total unsaturation of amaranth lipids is greater than 75%. The most common phytosterols are chondrila sterol and clerosterol (42%).[1,2,4–10,16–19] Regardless of the high degree of unsaturation, amaranth oil is generally resistant to oxidation due to the protective effect of the present tocopherols.[4,5] Phospholipids make up about 5% of the lipid fraction, the most common are lecithin, cefalin and phosphoinositol.[2]

Vitamins

Generally, amaranth is not an important source of vitamins. However, it does contain more riboflavin (vitamin B2), folic acid (vitamin B9) and ascorbic acid (vitamin C) compared to common cereals. The content of total tocopherols (tocopherols and tocotrienols) in amaranth grains may vary significantly. Some authors point out the low content of tocopherols, while some report a high value.[1,2,4] The most common tocopherol is α-tocopherol. Some authors report significant concentrations of β- and γ-tocotrienols.[2]

Minerals

The mineral content is about two times higher than in common cereals. The content of calcium, magnesium, zinc and iron is particularly high. The calcium/phosphorus ratio is very suitable, being in the range 1: 1.9-2.7. Nutritionists recommend a ratio of 1: 1.5 (Ca : P). The high content of calcium in amaranth grain is particularly significant in patients suffering from celiac disease, due to the onset of osteopenia and osteoporosis in these individuals.[1,2,4,5,7,9,15]

Phenolic compounds

Amaranth grain contains following phenolic acids: protocatechuic, hydroxybenzoic, caffeic, and ferulic acid.[4,5,7] Polyphenolic substances, such as rutine, nicotiflorin and isoquercetin, were also detected. It is known that routine has an effect on preventing the aging process, quercetin inhibits oxidation processes, and nictoflorin participates in the preservation of memory functions.[2,20–24]

Squalene

The non-saponifiable lipid fraction of amaranth grain consists primarily of squalene. Squalene is a biosynthetic precursor of all steroids in plants and animals. It is a highly unsaturated open chain triterpene, which is widely used in the cosmetics industry (in skin care products) and as an industrial lubricant resistant to oxidation. The richest source of squalene is a small shark liver (*Squalus acanthus*), from which comes its name, as well as some other marine species. It is also present in some vegetable oils, such as olive oil (0.1-0.5%), but particularly high concentrations are detected in amaranth oil (3-8% and 0.3-0.4% of total grain weight).[1,4,6,8,16,25] Amaranth is the richest source of squalene in the plant world.[26]

Pigments

Amaranth grain contains pigments – betacyanins, belonging to the group of betalain pigments. Two types of these pigments are present in amaranth grain: amarantin and iso-amarantin.[1]

Antinutrients

The phytic acid is distributed uniformly in the grain, so its content cannot be reduced by removal of the external grain layers or by water extraction. It is already known that the phytic acid has the inhibitory effect on starch digestion, and the positive effect on lowering cholesterol in the blood.[1,6,12] However, phytic acid can produce complexes with proteins and mono- and divalent cations.[2] Tannins are present in high concentrations in the grain hull, so with grain peeling they are mostly removed. They can form complexes with proteins and digestive enzymes, thereby inhibiting protein digestion. Also, depending on the chemical composition, they can inhibit starch digestion.[1,6,12] Amaranth grains contain smaller amounts of protease inhibitors (trypsin and chymotrypsin) compared to common cereals. However, protease inhibitors have been found to have anti-cancer, antioxidant, and anti-inflammatory effects, as well as affecting the regulation of blood glucose levels. They can be inactivated by heat treatment.[1,2,6]

Saponins are surfactants, extremely bitter in taste. Chemically, glycosides are sapogenins, which have a steroidal or triterpenoidal structure. They can form complexes with proteins and lipids (for example with cholesterol). They can form complexes with zinc and iron, and thus reduce their absorption. Surfactants are able to react with lipid membranes of the small intestinal epithelial cell membranes, thereby mimicking the permeability of the membrane for different substances. However, saponins may also have positive effects, such as anti-cancer, anti-inflammatory and antimicrobial. Since they are present in very small quantities in amaranth grain (0.09-0.1% on dry grain matter) and they are characterized by very low toxicity, so that saponins in amaranth products do not pose any danger to consumers.[1,2,6,12]

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Conflict of interest

Authors declare that there is no conflict of interest.

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