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AMARANTH: PERSPECTIVE RAW MATERIAL FOR FOOD-PROCESSING AND PHARMACEUTICAL INDUSTRY

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Abstract

Chemical composition of a new plant for Russia amaranth and its perspective use have been discussed. Amaranth contains a unique protein composition, starch with granule size not less than 1 micron, vitamins (A, B, C, E, P), carotinoids, substantial amounts of pectin, micro- and macroelements, calcium in great quantities, highly unsaturated oil, having squalene in its content (up to 8%) and a number of other bioactive substances. The role of these substances in functioning of organism and their use in non-conventional medicine have been discussed in brief.

At present plant raw materials are the major source for obtaining more than a third of all medicinal substances (MS) and practically all bioactive food additives (BAA) produced in the world. Such keen interest to BAA and MS is caused by disturbances in environment and, as a consequence, by growing intolerance to synthetic preparations and antibiotics, by-effects at their use, as well as by many other reasons.

The analysis of conference reports shows that most of them are discussing the use of nonconventional plants new for Russia either as the sources of bioactive substances for pharmacy, or as BAA components. Amaranth, which has been studied in more than thousand works for the last two decades, is one of these plants.

Amaranth (fig. 1) is a valuable fodder, medicinal, food, grain, vegetable and industrial crop. Amaranth foliage with productivity exceeding 1000 cent./hect. is used in stockbreeding as a green fodder, silage component and for obtaining protein-vitamin flour and concentrates. The balance of amino acids in Amaranth leaves approaches to that of Lucerne, but exceeds the latter in lysine content. Amino acid composition of amaranth protein is close to ideal and, as a consequence, has high food value (table 1).

Table 1. Food value parameters of different vegetable proteins.

Plant	Food value of protein in marks
Amaranth	75-78
Corn	44
Wheat	57
Sorghum	47
Barley	62
Pulse	67
Peanut	52
Soya	68
Kidney bean	55
Walnut	45
Cow milk	72

Fig. 1. The most common species of Amaranth *A.cruentus* in Russia.

Reasonably high seed productivity (up to 30 cent./hect.) makes it possible to obtain protein concentrate. According to the results of scientists from USA the use of amaranth seeds is especially effective for broiler breeding (fig. 2). In this case cholesterol content in meat is much lower (A.A. Lapin, S.S. Khirug etc.). Caloric value of amaranth seeds is higher than that of buckwheat.

The remarkable feature of amaranth is its ability to need much less water for one unit of dry synthetic mass as compared to other widespread crops (table 2).

Table 2. Water consumption for producing 1 g of dry biomass.

Crop	Water consumption for producing 1 g of biomass, g
Lucerne	840
Kidney bean	700
Oats	640
Wheat	550
Barley	520
Corn	370
Millet	300
Amaranth	260

Fig. 2. Plantations of four sorts of amaranth on a farm in USA.

Amaranth seeds are the source of excellent oil owing to the content of some useful properties - bactericide, antitumour, antiburn properties. In addition, this oil contains up to 8% of squalene – a marked olefin. High squalene content in oil allows its effective use as wound healing and regenerative substance in medicine and perfumery.

Amaranth seeds contain a unique starch with granules having smooth surface and approximate size of 1 micron. Starch granules of other crops are a number of times greater. Such granule size of starch makes it perspective for using in cosmetics (R. Saunders, R. Becker, 1984).

In some countries amaranth is widely used as food. Young amaranth leaves are rich in protein, carotin, micro- and macroelements (the content of the latter allows to call Amaranth a champion), vitamins (A, C, E, riboflavin, folic acid, rutin). Amaranth leaves are able to remove radionuclides and heavy metals from organism.

Some amaranth species with red leaves and large drooping panicles are used as decorative plants in gardening in many countries. Nowadays they can also be found on flower-beds in our cities.

In many respects the history of amaranth is tragic. For thousands of years before Columbus discovered America grain amaranth had been one of the basic foodstuffs for Indians. Its food value was as great as that of corn and beans. However, when the two latter crops were introduced into Europe and became widely spread, amaranth was prohibited by Spanish conquerors. That is why we should say, that Columbus discovered America, but closed the doors before amaranth.

In modern history Russian academician N.I. Vavilov became, after his trip to Mexico in 1930, one of the first scientists who attracted attention to amaranth. However, almost sixty years were needed for the plans on amaranth introduction to be put into practice.

The renewed interest to amaranth in the world is the benefit of the scientists of Rodale Centre in Pennsylvania. The centre collected a bank of amaranth seeds, worked out the technology of its cultivation and some processing methods.

At present amaranth is dealt with in many countries. In the shops of USA, Argentina and Poland you can buy biscuits, pasta, crisp bread, paste, sauce made from amaranth or with the use of its additives.

Regular biochemical investigations of amaranth as the source of most balanced and noncontiguous amino acids of protein for unhampered development of human organism, animals and poultry and laying biochemical foundations for introduction started to be carried out intensively in USSR by I. Magomedov in the middle of 80-s.

In recent years there have been no opponents of this crop, and new sorts have been grown and accommodate to CIS conditions (Sterkh, Legin', Skif, Ultra, Atstek, Atlant, Kremoviy ranniy, Valentina etc.). They were registered in many countries, but, unfortunately, their introduction in Russia is a slower process than in other countries. This takes place at the time when we are buying foodstuffs and fodder abroad, though there is a crop available which is able to supply additional qualitative forages and foodstuffs.

For successful use of plant potential, as we have noted many times, it is necessary to develop complex processing of amaranth seeds and leaves to meet the requirements of both food and fodder industry.

In Russia amaranth will become competitive to soya and corn only when one hectare of its plantation is able to substitute as much as one hectare of grain, industrial and medicinal crops. To accomplish this it is needed to complete the study of chemical composition and developed proper technologies for processing seeds and leave-stalk mass.

Until now the unique potentialities of amaranth in phytomelioration and recultivation of soils have practically not been used, though there have no equals in these spheres.

Finally, amaranth can be used in genetic engineering as perfect donor of genes for creating new transgenic plants with unique properties. The investigations in this direction have already started. As an example we can mention the latest works of Indian scientists on growing transgenic potatoes with introduction of gene responsible for albumin synthesis into amaranth.

After general characteristic let's pass to one of more specialized uses of amaranth. As we have already stated, in addition to unique protein, amaranth contains squalene used in medicine and perfumery and commonly extracted from shark liver, as well as vitamin P (rutin) in commercial quantities, the demand of which in Russian Federation is about 300 tons, which is currently imported to Russia. Amaranth is also a source of food color, irreplaceable qualitative starch and a number of other useful products.

Further we should speak about pectins in more detail.

In food industry pectins are used in gel-forming components in pastry production - zephyr, marmalade, jelly-like sweets, pastes, stuffings for caramels.

In canning industry pectines are used for improvement of consistence of marmalades, fruit jellies, confitures, for thickening mushed tomatoes and tomato sauce.

In dairy industry pectines are used as emulsifier in mayonnaises, sour cream, sour-dairy products, in creams for pies, soft grades of ice-cream and for preservation of milk.

In bakery pectines are used as an additive to batch for baking unstaling grades of bread.

Except for their gel-forming properties pectins are biologically active substances readily assimilated by organism. Due to the action of pectinase enzyme they are subjected to hydrolysis up to the formation of elementary components - sugar and tetragalactouronic acid. It has been proved by a number of researches that healthy people excrete only 3.5-5% of undigested pectine. The possibility of medical use of pectin has also been proved.

Of special interest is the ability of pectin substances to form insoluble complex compounds with polyvalent metals such as lead, cobalt, mercury, cadmium, chromium, zinc, iron etc. Pectines are capable of binding and removing strontium from organism. So, 1 g of pectin can bind 160 to 420 mg of strontium. At interaction of cobalt with pectin in the ratio 1:100 in insoluble complex more than 90% of the given metal can be bound.

Hence, pectins are capable of binding toxic and radioactive metals in insoluble, harmless complexes and remove them from human organism. Neutralizing action of pectins has found wide application in therapeutic and prophylactic nutrition to prevent intoxications caused by heavy metals, especially by inorganic compounds of plumbum, and also at work with radioactive substances and sources of ionizing radiations.

According to the recommendation of the Health Ministry of the USSR (1979) persons exposed to the action of inorganic compounds of plumbum and other metals, with the preventive purpose before starting their work were recommended to be given 2 g of pectin to enrich their tinned vegetable foodstuffs, fruit juices and drinks, or 300 g of natural fruit juices with flesh.

Taking into account the great food, biological and physiological significance of pectin and cellulose, it is recommended to use both of them in the diet of adults up to 25 g a day. The lack of these important food substances can cause various diseases, especially digestive ones.

World production of pectins makes up approximately 10000 ton a year. In the former Soviet Union about 600 of dry apple pectin were produced at three enterprises in Bar (Ukraine), Bendery and Kalininsk (Moldova) and at the factory of beetroot pectin production in Krasnodar with the annual capacity of 70 ton of pectin a year.

Thus, at present pectin is practically not produced in Russia. And the above listed factories use only 30%-60% of their production capacity due to insufficiency of pectin containing raw material (apple marcs) and obsolete equipment.

One of the ways of solving this problem is the search of accessible and cheap sources of pectin containing raw materials, introduction of new technologies for extracting, concentrating and development of food products containing pectins.

As perspective raw material the bagasse of Amaranth grass can be used. The latter is formed as a by-product at the extraction of rutin or other practically valuable substances, first of all in the production of protein from green mass. The realization of these preconditions will allow to obtain domestic pectin in sufficient quantities, so that there will be a need in development and certification of food production including jelly forming substances.

One of the most ancient cultural food plants - amaranth was widely used in non-conventional medicine of many countries of the world. The first mention of amaranth as a means of cleaning the stomach and intestines can be found in the works of medieval Armenian doctor of the 16th century Amasiatsy. The broth from tops of A. cruentus (Dubansky, 1918) was recommended as an effective means from cough. Later broths from the leaves of *A. retroflexus* and *A. lividus* were recommended to cure headaches and tumors, and their roots were used for jaundice treatment (Sakhobitdiniv, 1948). Bondarenko (1964) and Zolotnitskaya (1965) inform about antibacterial action of several amaranth species. Water tincture of leaves of *A. retroflexus* is recommended at colitis, intestinal colic, constipation, and even as gemostatic (Makhluk, 1967). The seeds of *A. lividus* are effective at tumors, warts (Hartwell, 1967) and at stings of the snakes (Chopra, 1956). Wulf (1969) recommended to use the leaves of *A. spinosus* as a diuretic means.

The chemical composition of overground part of Amaranth and its seeds allows to predict ample opportunities for its use as a source of a number of substations for manufacturing ready medicinal forms of various pharmacological groups.

So, some amaranth species contain up to 3% rutin or vitamin P (Khaziev, Ofitserov, 1990), which is used in production of askorutin, flakarbin, kversalol, anavenol, troxevasin or enters into the structure of various multi-vitamins. Flavonoides of plants, including rutin, form a group of vitamin P, having the ability (especially in combination with ascorbic acid) to reduce permeability and fragility of capillaries. Flavonoides, and there are about 4000 of them known, are responsible for colouring leaves, flowers and stalks of many plants. Flavonoides are contained more often as glycosides in many plants, but as medicinal preparations only two of them have become practically important: rutin and kvertsetin.

There are no other medicinal preparations, which are recommended to be used in treatment of such a great number of different diseases and at the same time they are practically not prescribed by doctors.

The preparations of vitamin P are applied for prophylactics and treatment of P hypo- and avitaminosis, at diseases accompanied with infringement of permeability of vessels, hemorrhagic dialysis, hemorrhages in eye retina, capillary toxicosis, radial sickness, endocarditis, rheumatism, glomerulonephritis, hypertension, arachnoiditis, allergic diseases, measles, scarlet fever, typhus, thrombocytopenic purpura, as well as for prophylaxis and treatment of capillary affection caused by using anticoagulants and salicylates (M.D. Mashkovsky) Moreover, flavonoides will soon become a regular medicinal preparation for treating cancer, cardiovascular and inflammatory diseases.

In nature flavonoides act in one team with vitamin C-ascorbic acid. Ascorbate prevents flavonoides from decomposing, thus enabling them to display their curative properties. In exchange they indues vitamin C with medical properties, which it did not have before. In order to prove this R. Atkins gives an example using the results of his research. Vitamin C and flavonoid of citruses separately did not have any effect in treating climacteric syndrome, whereas together they eliminated hot flushes in the majority of cases of 94 observed patients.

Rutin (3-rutinozide quartzetine or 3-ramnoglucosyl-3,5,7,3,4-pentaoxaflavone) is contained in leaves of rue (whence it has received its name) as well as in some other plants. For pharmaceutic purposes it is extracted from Japanese Sophora (Sophora japonica), belonging to the family of leguminous plants. It is a greenish-yellow fine-grained powder, tasteless and odorless, practically insoluble in water, but soluble in diluted solutions of caustic alkalis and spirit. Rutin is used in treatment of glaucoma (R. Atkins). In the process of rutin hydrolyses quercetine is produced.

The second perspective compound is pectin, which usage for removing radionuclides and heavy metals from organism is widely known. The complex of pectin with iodine has a prolonged bactericidal action and can be used as antiseptic (Mikheeva, Ofitserov, 1998). It is known, that soluble cellulose, containing basically pectin, authentically reduces the level of cholesterol and triglycerides in blood. Similar action has been demonstrated by amaranth pectin (Khirug, Lapin et al., 1998). Pectines of amaranth have also a protective action (Ashaeva, Khasiev et al. 1996).

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The leaves of Amaranth contain more than 10% Ca (Zelenkov, 2000) and can be used as a source of biogenic calcium and antacidic preparation (Ofitserov, Zelenkov, 2000).

Amaranth seeds contain substantial quantities of unique unsaturated compound - squalene, which role in organism is not quite clear. Squalene was first extracted as fat and oil substance from the liver of rather rare species of deep-water shark. The sharks use it for deep-diving to get along with very small amount of oxygen.

Squalene in small quantities is present in human body, mainly in skin. In Germany, Japan, Korea and other countries the additives of squalene are used in treatment of atherosclerosis, ischemic heart disease, at high level of cholesterol in blood, diseases of liver and skin disturbances.

Daily consumption of 860 mg squalene intensified the action of anticholesterol preparations reducing the concentration of LNP-cholesterol and increasing the content of LVP-cholesterol in blood (P. Chan). According to R. Atkins' data, squalene counteracts with carcinogenic substances, bacteria, fungi, shingles, Enstain-Barr virus, as well as such autoimmune diseases as leukemia. Mice subjected to fatal radiation dozes, stayed alive longer when they were given squalene (H. Storm et al.)

High content of squalene in our skin is a good enough proof of its importance for this organ. Squalene helps the skin to retain moisture making it smooth and elastic. But its major role is to protect skin from ultra-violet radiation and, taking into account its anticancer and immuno-stimulating properties, to protect from skin cancer. Undoubtedly, the extensive use of squalene in medicine, cosmetics and dietary nutrition is still ahead. Widening the spectrum of its use is directly connected with available sources for its extraction or chemical synthesis.

The value of olive oil is not only in the fact that it has a unique set of fat acids, but also in the presence of squalene. As it is proved by the results of numerous researches, Amaranth oil in the nearest future can become one of the basic sources squalene. The study of anti-burn properties of amaranth oil widens the areas of its application, alongside with its use in treatment of cancer, cardiovascular diseases and for correction of immune status.

On the basis of Amaranth oil, characterized by unique content of squalene, such medicinal forms as 10% emulsion of "oleogel" can be used for treatment and prophylaxis of duodenum ulcer as well as for healing wounds. High citoprotective action of Amaranth oil has been revealed. (Panasuk et al, 1996). Amaranth oil can be used to heal burns too (Miroshnichenco, 1994).

In nature there exist more than 600 plant pigments, but moreoften they are known to common public as beta (β) -carotin. People with high levels of β-carotin have impressing resistively to a lot of diseases: cancer, cardiovascular and degenerative diseases. Methods of synthesis of synthetic β-carotin have finally been developed and the factories for its production have been constructed. However, as R. Atkins writes "synthetic beta(β)-carotin has appeared to be the greatest failure since the time Trumen's victory over Dui".

Why is natural beta(β)-carotin rendering such impressing action as compared to a synthetic one? It is quite easy to answer. Carotenoids represent a complex of nutrients, which act better when they are together. Their therapeutic value is determined by the weakest link and overloading of one of them may result in disturbance of all the rest carotenoids.

The deficiency of β-carotin is found in the blood of patients suffering from AIDS (S.A. Branowitz et al., J.A. Omene).

β-carotin has protective action against many kinds of cancer, in particular, against the tumour of lung, stomach and mammary gland. (I.F. Dorgan et al.)

β-Carotin is able to protect the patients suffering from stenocardia. β-Carotin is known to increase the content of LVP-cholesterol performing protective functions (H. Gester).

In addition to β-carotin a few words should be said about two other carotenoids: moteine and zeaxanthin, which locate in yellow spot (vision centre on the back of retina) and perform protective functions. Because of their yellow colour these carotenoids mainly absorb blue light rays. Besides, chemical nature of moteine is more effective, as compared to that of β-carotin, for preventing free radicals damaging effect on fats inside eyes. Not only these two carotenoids are able to prevent cataract formation (P. Jaeques et al.), but also they can reduce by 57% the risk of yellow spot degradation – a damage of central vision causing approximately the third of all annual cases of blindness (R.R. Watson et al.). One of these carotenoids extracted from overground part of amaranth has been studied (R.Sh. Khaziev).

Amaranth pectin effect on isolated rat heart have been investigated by T. Desalen (1997).

The unique amino acid composition of proteins and starch of amaranth makes it perspective to use amaranth flour for preparing nutrient media to grow pathogenic microorganisms.

Amaranth flour is rather widely used for producing dietary products and products for medical nutrition all over the world.

Food calor of amaranth, the production technology of which was developed by V. Gins and P. Kononkov (1998), can be successfully used for making various vitamin dragee and medicinal forms.

Amaranth lectins which are being studied by several scientific groups might turn out to be useful in diagnostics.