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## THERAPEUTIC AND PREVENTIVE PROPERTIES OF AMARANTH SEEDS

***Actuality.*** *Numerous studies conducted over the past decades have proven the high therapeutic efficiency of the squalene hydrocarbon, obtained for the first time as part of shark liver lipids. A significant content of squalene was also found in amaranth seed oil and its therapeutic and preventive properties were shown. However, amaranth seeds contain a large amount of not only squalene, but also other physiologically active compounds (proteins, phospholipids, vitamins, trace elements, dietary fibers), which also have therapeutic properties.*

***The aim of the study.*** *Present information about the therapeutic and preventive properties of all components of amaranth seeds.*

***Material and methods.*** *An analysis of scientific publications in the PubMed, Google Semantic Scholar systems, as well as from domestic sources was carried out. A total of 250 sources were analyzed, of which 38 are cited in this work.*

***Research results.*** *The article presents information about the curative and preventive properties of amaranth seeds, due to the presence of a significant amount of protein that is complete in terms of amino acid composition, free of gluten and with a significant content of tryptophan. Amaranth protein oligopeptides have hypotensive and immunostimulating activity. Amaranth lipids are represented by amaranth oil with a high content of the hydrocarbon squalene and phospholipids. Amaranth starch belongs to the group*

*of resistant starches and has prebiotic properties. The dietary fibers of amaranth seeds have prebiotic properties and stimulate the growth of probiotic bacteria. Squalene has antioxidant, antihypoxant, anti-inflammatory properties and exhibits hepatoprotective and cardioprotective activity.*

***Conclusion.*** *Amaranth seeds are a source of a large number of compounds with high nutritional and therapeutic activity, which indicates the relevance of its widespread use.*

***Key words:*** *amaranth, squalene, nutrition, treatment, prevention.*

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## ЛІКУВАЛЬНО-ПРОФІЛАКТИЧНІ ВЛАСТИВОСТІ НАСІННЯ АМАРАНТУ

***Актуальність.*** *Чисельні дослідження, проведені за останні десятиріччя, засвідчили високу терапевтичну ефективність вуглеводню сквалену, отриманого вперше у складі ліпідів печінки акул. Значний вміст сквалену було виявлено і в олії з насіння амаранту і показано його лікувально-профілактичні властивості. Однак, насіння амаранту містить велику кількість не тільки сквалену, а й інші фізіологічно активні сполуки (протеїни, фосфоліпіди, вітаміни, мікроелементи, харчові волокна), які також мають терапевтичні властивості.*

***Мета дослідження.*** *Представити інформацію про лікувально-профілактичні властивості усіх компонентів насіння амаранту.*

***Матеріали та методи.*** *Проведено аналіз наукових публікацій в системах PubMed, Semantic Scholar Google, а також з вітчизняних джерел. Всього проаналізовано 250 джерел, з яких 38 процитовано в даній роботі.*

***Результати дослідження.*** *У статті представлена інформація про лікувально-профілактичні властивості насіння амаранту, обумовлені наявністю у значній кількості повноцінного за амінокислотним складом протеїну, позбавленого глютену і зі значним вмістом триптофану. Олігопептиди амарантового протеїну проявляють гіпотензивну і імуностимулюючу активність. Ліпіди насіння амаранту представлені амарантовою олією з високим вмістом вуглеводню скваленy і фосфоліпідів. Амарантовий крохмаль відноситься до групи резистентних крохмалів і має пребіотичні властивості. Харчові волокна насіння амаранту мають пребіотичні властивості, стимулюють ріст пробіотичних бактерій. Сквален проявляє антиоксидантні, антигіпоксантні, антизапальні властивості та виявляє гепатопротекторну і кардіопротекторну активність.*

***Висновок.*** *Насіння амаранту є джерелом великої кількості сполук з високою харчовою і терапевтичною активністю, що свідчить про актуальність його широкого застосування.*

***Ключові слова:*** *амарант, сквален, харчування, лікування, профілактика.*

**Actuality.** Numerous studies conducted over the past decades have proven the high therapeutic efficiency of the squalene hydrocarbon, obtained for the first time as part of shark liver lipids. A significant content of squalene was also found in amaranth seed oil and its therapeutic and preventive properties were shown. However, amaranth seeds contain a large amount of not only squalene, but also other physiologically active compounds (proteins, phospholipids, vitamins, trace elements, dietary fibers), which also have therapeutic properties.

**The aim of the study.** Present information about the therapeutic and preventive properties of all components of amaranth seeds.

**Material and methods.** An analysis of scientific publications in the PubMed, Google Semantic Scholar systems, as well as from domestic sources was carried out. A total of 250 sources were analyzed, of which 38 are cited in this work.

**Research results**

1. Biological characteristics of amaranth.

Amaranth belongs to annual herbs of the amaranth family (Amarantus). In total, there are at least 60 species, 15 of which are found in Ukraine. Amaranth comes from Central America (Mexico), from where it was brought to Europe in the 16th century (Soriano-García et al., 2018).

Amaranth is considered a weed, but a certain number of species are grown for use as a food seasoning, as well as in traditional medicine as an anti-inflammatory agent (Shodiev, Rasulova, 2022).

The people of Central America (Aztecs) used amaranth to obtain seeds as an important food component (Laparra, Haros, 2016).

The most valuable are amaranth seeds, which differ significantly from the grain of cereal crops in their small size and, especially, their chemical composition (table 1).

Amaranth seeds contain less starch (30-35 %), much more dietary fiber (over 30 %) and fat (8-9 %). Moreover, a unique feature of fat (amaranth oil) is the high content of the unique hydrocarbon squalene (6-8 %). Amaranth seeds differ significantly from cereal grains in their high protein content (18-25 %), and amaranth seed protein is among the complete proteins in terms of the content of essential amino acids (Gabás-Rivera et al., 2014; Gylling, Miettinen, 1994; Miettinen, Vanhanen, 1994).

Table 1

**Chemical composition of amaranth seeds**

| Indexes | Contents % |
|---|---|
| Protein | 18-25 |
| Starch | 30-35 |
| Lipids | 9-15 |
| Dietary fibers are water soluble | 10-12 |
| Dietary fibers are insoluble | 15-20 |
| Squalene in fat | 5-8 |
| Phospholipids | 1,5-2,5 |
| Tryptophan in protein | 2,0-2,5 |
| Lysine in protein | 5,0-6,2 |

Amaranth seeds contain a significant amount of vitamins, polyphenols, macro- and microelements, in particular calcium, organic phosphorus, zinc and manganese (Gunina et al., 2018).

2. Therapeutic and preventive properties of amaranth seed proteins.

Amaranth seeds are 2-3 times higher the protein content than cereal crops (wheat, rye, barley, corn, rice). After remove fat from degreasing the amaranth seeds with acetone protein content in the molding is 30 % (Montoya-Rodríguez et al., 2014).

Amaranth proteins contain all essential (irreplaceable) amino acids, most of which correspond to the FAO WHO indices. The content of tryptophan even exceeds the FAO indices by 3-4 times, which enables the body to convert tryptophan into serotonin, which has antidepressant properties (“hormone of happiness”) (Gylling, Miettinen, 1994).

Under the conditions of partial enzymatic proteolysis of amaranth proteins, oligopeptides are formed, which exhibit hypotensive properties (Silva-Sánchez et al., 2008), and also prevent blood clot formation, which is very

important for the prevention of strokes and heart attacks (Sabbione et al., 2015).

The use of protein extrudates or protein isolates from amaranth seeds in food contributes not only to the normalization of protein metabolism in the body, but also stimulates the growth of probiotic bacteria (Martínez-Villaluenga et al., 2020), increases the formation of short-chain fatty acids, in particular butyric acid ($C_4H_8O_2$), which is used not only as an energy substrate, but also performs a number of regulatory functions.

It has been established that amaranth proteins and the oligopeptides formed from them reduce the content of cholesterol and low-density lipoproteins in the blood plasma, which has a positive effect on the prevention of atherosclerosis (Montoya-Rodríguez et al., 2014).

There are data on the anti-inflammatory effect of amaranth proteins (Ibrahim, Mohamed, 2021), possibly due to their ability to stimulate the growth of probiotic bacteria and inhibit the growth of opportunistic bacteria.

It is possible that, in addition to proteins, amaranth dietary fibers, phenolic compounds, and squalene also participate in the regulation of endogenous microbiota (Ciudad-Mulero et al., 2019).

It is also very important that amaranth seeds proteins do not contain the gluten fraction that affects the development of celiac disease (Mansueto et al., 2014). Therefore, amaranth seeds are recommended for consumption by patients with celiac disease (Inglett et al., 2015).

3. Prebiotic properties of amaranth seed carbohydrates.

The total amount of carbohydrates in amaranth seeds is 55-65 %, and up to 35 % is starch, 25-30 % dietary fiber and less than 5 % mono- and oligosugars (Miroshnichenko et al., 2009; Lamothe et al., 2015).

Amaranth seed starch is represented mainly by amylose, which is resistant to the action of α-amylases of saliva or pancreatic juice (Lou-Bonafonte et al., 2018). Resistant starches have prebiotic properties and stimulate the growth of probiotic bacteria that produce short-chain fatty acids.

Food fibers of amaranth seeds are represented by both water-soluble polysaccharides (approximately one third) and water-insoluble ones, which include fiber (Paśko et al., 2009). The peculiarity of dietary fibers is that they are not hydrolyzed by digestive enzymes of the macroorganism, but are easily broken down by enzymes produced by bacteria, in particular, probiotics. The process of enzymolysis of dietary fibers occurs mainly in the large intestine and ends with the formation of lactic acid and short-chain fatty acids, in particular, propionic and butyric acids. Thanks to this, the pH of the intestinal contents is equal to 5-6, and this makes it possible to prevent the absorption of toxic ammonia ($NH_3$), which is formed in the intestines from amino acids under the action of conditionally pathogenic bacteria.

It is important to emphasize that amaranth seeds have a low glycemic index due to the presence of resistant starch and dietary fibers (Yelisyeyeva et al., 2012). This can make it possible to use amaranth seeds for diabetics. Moreover, amaranth seeds contain a lot of the trace element manganese, which takes part in the regulation of carbohydrate metabolism (Yelisyeyeva et al., 2012).

4. Therapeutic and preventive properties of squalene.

Amaranth oil belongs to the linoleic type of oils (table 2) and contains more than 40 % of linoleic acid ($C_{18:2}$, ω-6). Unlike ordinary sunflower oil, amaranth oil contains 1-1.5 % linolenic acid ($C_{18:3}$, ω-3), and more than 15 % palmitic acid ($C_{16:0}$), while sunflower oil contains no more than 5 % palmitic acid.

The main difference between amaranth oil and all vegetable oils is the high content of squalene hydrocarbon ($C_{30}H_{50}$) − more than 8 %. In olive oil, squalene is less than 0.8 % (Popa et al., 2015).

Table 2

**Fatty acid composition of amaranth oil**

| Fatty acid | Abbreviated formula | Contents, % |
|---|---|---|
| Myristic acid | $C_{14:0}$ | 0,12 |
| Palmitic acid | $C_{16:0}$ | 16,36 |
| Stearic acid | $C_{18:0}$ | 3,62 |
| Oleic acid | $C_{18:1}$ ω-9 | 22,16 |
| Vaccenic acid | $C_{18:1}$ | 1,10 |
| Linoleic acid | $C_{18:2}$ ω-6 | 42,47 |
| Linolenic acid | $C_{18:3}$ ω-3 | 1,10 |
| Arachinic acid | $C_{20:0}$ | 0,81 |
| Eicosenoic acid | $C_{20:1}$ | 0,83 |
| Erucic acid | $C_{22:1}$ | 1,38 |
| Squalene | $C_{30}H_{50}$ | 9,08 |

The characteristics of squalene are presented in table 3 (Senbagalakshmi et al., 2019).

Table 3

**Chemical and physicochemical indicators of squalene**

| Indexes | Value | Indexes | Value |
|---|---|---|---|
| Molecular weight | 410,73 g/mole | Iodine number | 381 g/100 g |
| Melting point | −75 °C | Peaks in the infrared spectrum | 2788, 1668, 1446, 1380, 1180, 1150, 964, 835 $cm^{-1}$ |
| Boiling point | +203 °C | | |
| Specific weight | 0,858 g/ml | Solubility | Hexane, benzene, chloroform, ether, alcohol |
| Viscosity at 25 °C | 12 cP | Solubility in water | 0,124 mg/l |

It has been established that squalene manifests itself as an antioxidant, binding reactive oxygen species (ROS), such as $O_2^-$, $^{\cdot}OOH, NOO^{\cdot}$, and activating the antioxidant defense system (superoxide dismutase, catalase, glutathione peroxidase, heme oxygenase) (Motawi et al., 2010; Gunes, 2013).

Squalene is able to bind oxygen molecules and transport them through cell membranes to mitochondria, where fatty acids are oxidized to $CO_2$ and $H_2O$ with the formation of ATP (Gunes, 2013; Şakul et al., 2019). It is believed that squalene can replace oxygen by accepting electrons in the tissue respiration system, which ensures the implementation of oxidative phosphorylation (that is, the formation of ATP), and squalene itself is transformed into the saturated hydrocarbon squalane ($C_{30}H_{62}$) (Chanput et al., 2010).

Biosynthesis of squalene occurs in animal and plant organisms, as well as in microbes (bacteria, yeast, fungi) (Senbagalakshmi et al., 2019). Squalene is considered as an intermediate product in cholesterol biosynthesis pathways (Xu et al., 2004).

Squalene biosynthesis also takes place in the human body, mainly in the liver (Senbagalakshmi et al., 2019). From the liver in the composition of very low-density lipoproteins (VLDL), it is transported into the blood, and further through the receptors for VLDL, it enters the cells (Chanput et al., 2010).

The antioxidant properties of squalene ensure its positive effect on the state of polyunsaturated fatty acids (PUFA), which play a significant role in the structure of biomembranes and in the implementation of anti-inflammatory and reparative processes (Dhandapani et al., 2007).

Experimental studies on various models of such diseases as myocarditis, hepatitis, dermatitis have shown sufficiently high therapeutic efficiency of squalene (Farvin et al., 2006; Yuxi et al., 2009; Gunes, 2013; Sivakrishnan, Muthu, 2014; Lou-Bonafonte et al., 2018).

Squalene significantly increases the effectiveness of anti-cancer drugs, eliminating to a certain extent their negative side effects on the state of healthy cells and organs (Rao et al., 1998; Senthilkumar et al., 2006; Quiroga et al., 2015).

Squalene is widely used as a vaccine adjuvant (Suli et al., 2004). There is some evidence of its influence on the state of the immune system, in particular on the function of macrophages and lymphocytes (Spanova, Daum, 2011).

Based on the fact that the main transporter of squalene is VLDL, which contains a significant amount of triglycerides with a high content of oleic acid (more than 50 %), we proposed a dietary supplement "Squalene-Olivka", which contains squalene from amaranth oil together with high-oleic sunflower oil "Olivka" (contains more than 80 % oleic acid) (Levitsky, Potapova, 2015). Due to the high content of oleic acid, the dietary supplement "Squalene-Olivka" stimulates the biogenic biosynthesis of long-chain PUFAs of the ω-3 series: eicosapentaenoic ($C_{20:5}$, ω-3) i and docosahexaenoic $C_{22:6}$, ω-3). From these acids, physiologically active eicosanoids and docosanoids are formed in the body, which perform anti-inflammatory and reparative functions (Levitsky et al., 2023).

Squalene has a positive effect on the condition and physiological functions of PUFA of the ω-3 series, which determines the high therapeutic effectiveness of the "Squalene-Olivka" dietary supplement.

**Conclusions**

**1. The presented data show that amaranth is not a weed, but a very valuable food and medicinal plant.**

**2. Amaranth seeds contain 2-3 times more protein than the grain of cereal plants, and amaranth protein is close to the "ideal protein" in terms of amino acid composition.**

**3. Amaranth proteins are free of gluten, which gives reason to recommend its consumption for the prevention and treatment of celiac disease.**

**4. The high content of tryptophan in amaranth proteins, from which serotonin is formed, gives reasons to recommend the consumption of amaranth for the prevention and treatment of depressive states.**

**5. The high content of squalene in amaranth oil, which has antioxidant, antihypoxant and anti-inflammatory properties, gives reasons to recommend its use for prevention and treatment, as well as for the rehabilitation of the sick and wounded.**

**6. Amaranth suds has prebiotic properties.**

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