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CHEMICAL INDICATIONS OF AMARANTH PLANT PRODUCTS AND THEIR USE

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Abstract
The widespread use of amaranth in various sectors of the national economy and in medicine is a promising direction and one of the current needs of today. This plant holds significant ecological potential, particularly in restoring the health of soils that are increasingly losing their quality, and even in addressing energy-related challenges. Amaranth thrives in saline soils with NaCl concentrations up to 10 mM and produces high yields. After being cultivated for 2–3 years in saline environments, amaranth can restore soil conditions to make it suitable for wheat cultivation. This heat-tolerant plant, capable of withstanding temperatures of 45–50°C, activates nitrogen-fixing microorganisms in the soil. Its strong root system improves the soil's micropore structure and helps restore humus at certain depths as a low-cost green manure. As a phytomediator, amaranth also contributes to the remediation of soils contaminated with heavy metals, radionuclides, and pesticides.

Keywords: Amaranth, chemical, vitamin, amaranth oil, malofeen, squalene, protein, vitamins, biologically active compounds, diseases.

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Introduction

In recent years, there has been growing scientific and practical interest in amaranth (Amaranthus spp.) due to its remarkable adaptability, nutritional value, and wide range of applications in agriculture, medicine, and food production [1,2]. Amaranth is recognized not only as a valuable source of high-quality proteins, essential vitamins, and biologically active substances, but also as an ecologically sustainable crop capable of thriving under adverse conditions, including high salinity and extreme temperatures [3,4,5].

Amaranth has a unique biochemical profile. It contains high levels of lysine-rich protein, dietary fiber, essential fatty acids, squalene, and compounds such as malofeen that have demonstrated potential health benefits. The seeds and leaves of the plant are rich in calcium, iron, magnesium, and vitamins A, C, and E, making them highly beneficial in addressing malnutrition and chronic diseases [6,7].

Apart from its nutritional and medicinal value, the amaranth plant also contributes to environmental remediation. Its deep root system improves soil structure, enhances microbial activity, and aids in the phytoremediation of heavy metals and other pollutants. As a green manure crop, it restores soil fertility and increases organic matter content [8].

Given these characteristics, the cultivation and processing of amaranth hold significant promise for sustainable agriculture, food security, and the development of bio-based products. This paper explores the chemical composition of amaranth-based products and examines their potential uses across various fields, highlighting their role in human health, environmental sustainability, and industrial applications [9,10].

Materials and methods

This study was conducted to investigate the chemical composition and potential applications of various products derived from the amaranth plant (*Amaranthus spp.*), with a focus on nutritional, medicinal, and ecological properties.

Amaranth seeds and leaves were collected from experimental agricultural fields located in saline-prone areas of the Fergana Valley, Uzbekistan. The plants were

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cultivated under controlled conditions to ensure consistency in environmental factors such as temperature, irrigation, and soil salinity.

Amaranth was grown in both saline (NaCl concentration up to 10 mM) and non-saline soils. Soil analysis was conducted prior to planting to determine salinity levels, pH, organic matter content, and essential macro- and micronutrients. Growth performance, biomass accumulation, and root development were monitored throughout the growing season.

Chemical Analysis

- Protein Content: Determined using the Kjeldahl method.
- Fatty Acid Composition: Assessed via gas chromatography (GC) after extracting oils using cold press methods.
- Vitamin Analysis: Vitamins A, C, and E were quantified using high-performance liquid chromatography (HPLC).
- Squalene and Malofeen Content: Identified through spectrophotometric and chromatographic analysis.
- Mineral Content: Calcium, iron, magnesium, and phosphorus levels were measured using atomic absorption spectroscopy (AAS).
- Biologically Active Compounds: Total phenolic content and flavonoid concentrations were determined using the Folin–Ciocalteu and aluminum chloride colorimetric methods, respectively.

To evaluate amaranth's phytoremediation potential, soil samples were collected before and after cultivation and analyzed for heavy metals (Pb, Cd, Zn) using inductively coupled plasma mass spectrometry (ICP-MS). Additionally, microbial activity and organic matter restoration were assessed post-harvest.

Results and discussion

Amaranth cultivation is gaining increasing attention in Uzbekistan due to its multifunctional role in agriculture, livestock, and food production. It holds particular importance in enhancing the efficiency of animal husbandry, poultry, and aquaculture, thereby supporting the growing demand for affordable, high-quality meat, milk, eggs, and fish for the population.

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Amaranth is an excellent feed supplement for livestock and poultry. Studies have shown that incorporating up to 25% of amaranth green biomass into animal feed significantly accelerates growth. For example, lambs and calves grow 1.5 to 2 times faster, while nutrias and rabbits exhibit a 2–3-fold growth acceleration. Cows fed with amaranth show a marked increase in milk yield and fat content, and piglets have demonstrated a live weight gain of up to 60 kg within four months. These effects are attributed to the high concentrations of vitamin C and carotenoids in the plant, which contribute to improved animal health and productivity [11,12].

Amaranth has attracted the attention of agricultural researchers and practitioners due to its high protein content, rich yields, and abundance of vitamins and mineral compounds. It is not only a food and forage crop but also a valuable medicinal plant. Its leaves, seeds, and press cake are extensively used in livestock feeding. The unique combination of rare nutrients and record-level protein content supports rapid and healthy development in young animals, enhances weight gain, and significantly improves both the quantity and quality of dairy production. Moreover, amaranth ferments well with maize to produce high-quality silage. While maize contributes sugar, amaranth provides protein, thus enhancing the nutritional value of the silage throughout the year [13,14,15].

Another noteworthy aspect of amaranth is its potential for pectin extraction. After oil is cold-pressed from its seeds, the residual biomass contains high levels of biologically active pectin compounds, which may serve as valuable dietary supplements.

Ongoing studies in Uzbekistan have focused on oil yield, squalene concentration, and pectin extraction from locally cultivated amaranth varieties. Notably, amaranth has also emerged as an effective agent in biogas production. The plant acts as a fermentation stimulant, accelerating the breakdown of organic material and significantly increasing biogas yield—up to three times more efficient than cattle manure.

Although many organic substrates can be used for biogas, identifying the most effective ones remains a subject of active research. The biogas production process is complex and depends on the chemical composition of the substrate [16,17,18].

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The A. Arbuzov Institute of Fine Chemical Technologies in Kazan has conducted in-depth research into fermentation stimulants and identified the green mass of amaranth and the plant growth regulator "Malofeen" as effective biogas catalysts. In livestock experiments, gas accumulation in the rumen of cattle fed with amaranth was observed, indicating potential for high biogas production. Scientific investigations have since confirmed that amaranth green biomass significantly enhances methane concentration in the emitted gas—by 10 times or more. The amaranth mash (wet pulp) has proven to be a valuable material that stimulates gas release and boosts fermentation efficiency.

Due to these exceptional properties, amaranth is now being recognized in Uzbekistan as a promising crop with both agricultural and economic value. A notable technological advancement involves the use of a cold-pressing machine, imported from Germany by the company "AEN Engineering GmbH & Co. KG", to extract oil from locally cultivated amaranth seeds [19,20]. Analysis revealed that the oil contains high levels of squalene and other biologically active compounds. Initial research showed that the squalene content in Uzbek amaranth oil is 8–10 times higher than that of shark liver oil. The oil contains approximately 12% squalene, while the residual press cake may contain up to 42%, which was regarded as a significant scientific discovery by Professor S. D. Gusakova of the Institute of Plant Substances, Academy of Sciences of Uzbekistan.

Further analysis of amaranth oil cultivated in Andijan using gas chromatography revealed a rich profile of Omega-3 and Omega-6 unsaturated fatty acids. These findings position amaranth oil as a unique and valuable medicinal product, offering great potential for local pharmaceutical and nutritional applications.

Conclusions

The study confirms that amaranth (*Amaranthus spp.*) is a highly valuable and multifunctional plant with broad applications in agriculture, animal husbandry, medicine, and renewable energy. Its high nutritional content—rich in proteins, vitamins, minerals, squalene, and biologically active compounds—makes it an exceptional food and feed resource.

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Amaranth demonstrates strong adaptability to saline and arid conditions, contributing to soil restoration and environmental sustainability. Its ability to enhance livestock productivity, improve milk and meat quality, and support the rapid growth of young animals underlines its economic significance in feed production. Additionally, its silage compatibility with maize and the presence of valuable pectin compounds in residual biomass further enhance its utility.
Importantly, amaranth also exhibits excellent potential in bioenergy generation. Its green mass significantly stimulates biogas production, offering a cost-effective and eco-friendly alternative to traditional energy sources. High squalene content in amaranth oil, surpassing that of marine sources, opens up new avenues for its use in pharmaceutical and nutraceutical industries.
Given these findings, amaranth cultivation and processing should be prioritized in Uzbekistan and similar agro-climatic regions to promote sustainable agriculture, food security, and bio-based economic development.

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