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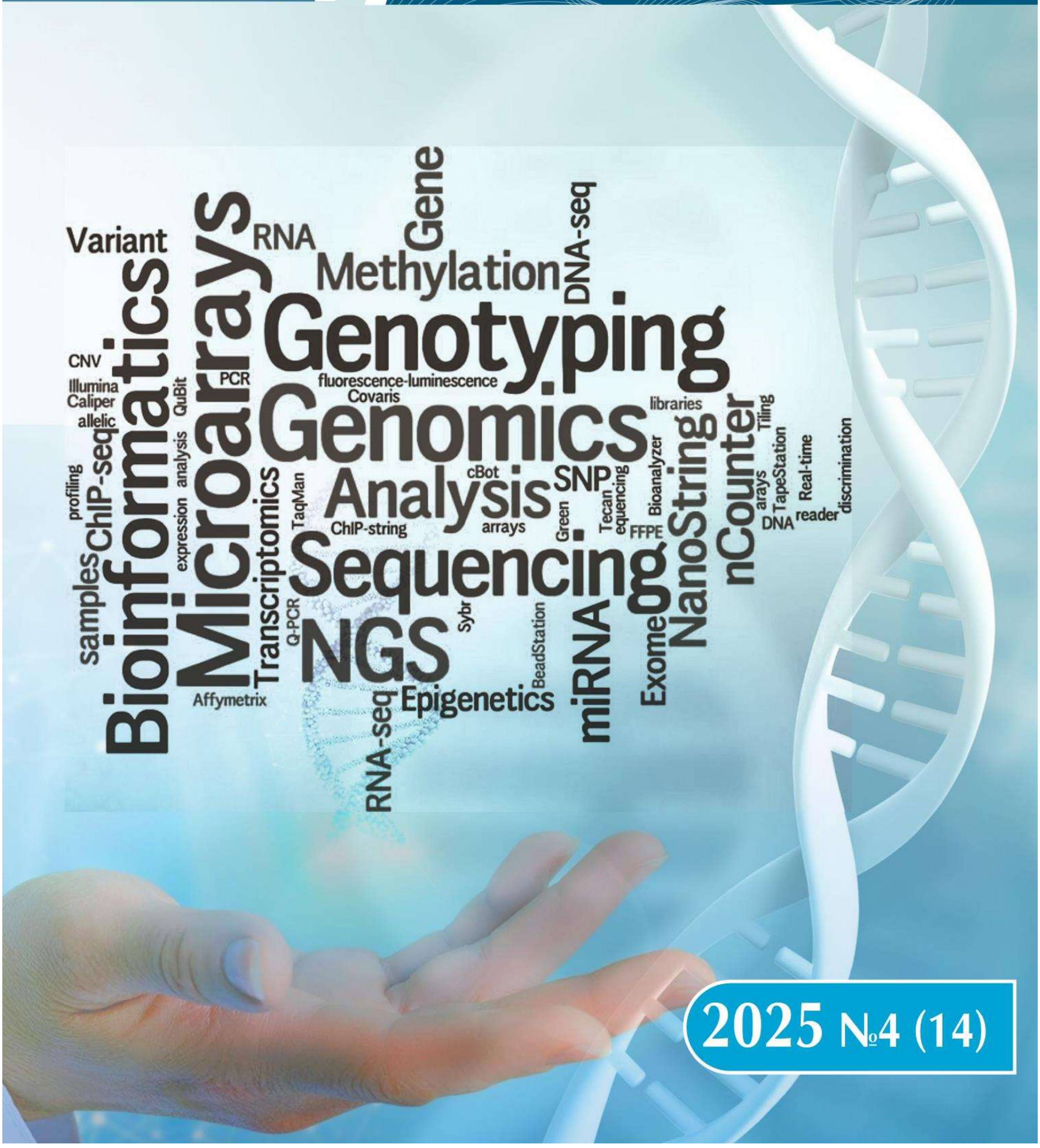

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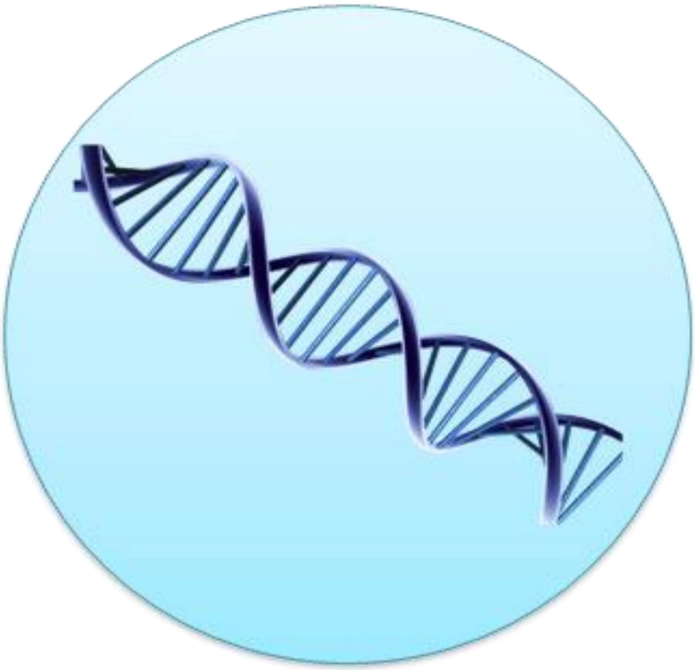

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MORPHOLOGICAL, PHYSIOLOGICAL CHARACTERISTICS AND BIOCHEMICAL COMPOSITION OF *CITRULLUS COLOCYNTHIS*

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Summary. This article presents information from scientific sources and research findings on the origin, distribution, systematics, botanical characteristics, and morphological, physiological, and biochemical properties of the bitter watermelon (Citrullus colocynthis). The article also summarizes data from several scientific literature sources regarding the bioactive compounds found in the fruit pulp-particularly cucurbitacins-as well as the organic and mineral substances present in the seeds of the plant. In addition, it provides information on the influence of environmental factors on seed germination of Citrullus colocynthis, the dormancy period in its seeds, and the optimal temperatures required for proper germination.

Keywords: *Citrullus colocynthis*, cucurbitacin, palmitic acid, stearin, olein, linolein, nondiabetic, hyperlipidemic, triglyceride, cholesterol

МОРФОЛОГИЧЕСКИЕ, ФИЗИОЛОГИЧЕСКИЕ ХАРАКТЕРИСТИКИ И БИОХИМИЧЕСКИЙ СОСТАВ CITRULLUS COLOCYNTHIS

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Summary. This article presents information from scientific sources and research findings on the origin, distribution, systematics, botanical characteristics, and morphological, physiological, and biochemical properties of the bitter watermelon (Citrullus colocynthis). The article also summarizes data from several scientific literature sources regarding the bioactive compounds found in the fruit pulp-particularly cucurbitacins-as well as the organic and mineral substances present in the seeds of the plant. In addition, it provides information on the influence of environmental factors on seed germination of Citrullus colocynthis, the dormancy period in its seeds, and the optimal temperatures required for proper germination.

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Introduction

Citrullus colocynthis is a perennial plant species that thrives in arid and semi-arid environments. Its primary center of origin is considered to be Asia and the Mediterranean basin, specifically the regions of present-day Turkey and Nubia. Over time, the species expanded its natural range to the western coasts of Africa, the Sahara Desert, the eastern territories of Egypt, and - via India - to the Caspian region and the northern coastal areas of the Mediterranean [1]. The plant has also been reported in several southern European countries, including the Greek archipelago and Spain. Growing naturally on sand dunes in hot and dry ecosystems, this species demonstrates remarkable tolerance to environmental stresses, such as drought, poor soil nutrient levels, strong winds, extreme temperatures, and sandstorms [2].

Table 1

Taxonomy of the plant *Citrullus colocynthis*.

Division:	Magnoliophyta
Class:	Magnoliopsida
Subclass:	Dilleniidae
Family:	Cucurbitaceae (Gourd family)
Genus:	*Citrullus*
Species:	*Citrullus colocynthis*

Morphology

The leaves of *Citrullus colocynthis* are angular and alternately arranged on long petioles. Each leaf is approximately 5–10 cm in length and is divided into 3-7 lobes [3]. In some cases, the central lobe may be ovate in shape. The leaves are generally triangular, with a rough and hairy surface and wide open sinuses. The upper surface of the leaf is light green, while the lower surface is pale green. Each *Citrullus colocynthis* plant produces about 15-35 fruits, with each fruit measuring 7-10 cm in diameter. The outer surface of the fruit is covered with a green rind marked with yellow stripes; in some instances, the fruits may be completely yellow. Ripe fruits are characterized by a thin but firm rind. Inside, the fruit contains soft pulp filled with numerous flattened, ovate seeds [4]. The flowers of *Citrullus colocynthis* are yellow or yellowish-green and occur singly in the leaf axils. The plant is monoecious, meaning that male and female flowers are borne on the same plant but at different positions. Both the calyx and the corolla consist of five fused parts, and each flower has a yellow, bell-shaped appearance. Female flowers can be easily distinguished from male flowers by their hairy ovaries. The seeds of *Citrullus colocynthis* are generally about 6 mm in size, smooth, flattened, and ovate in shape [3, 5, 6].

Fig. 1 Overall morphology of *Citrullus colocynthis.*

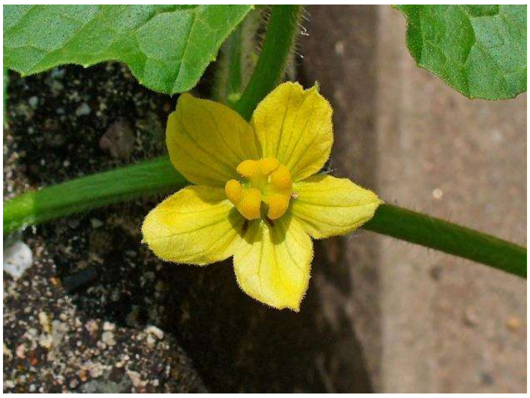

Fig. 2 Morphology of the flower of *Citrullus colocynthis.*

They are attached to a parietal placenta along the fruit wall. Seed color ranges from light yellow to dark brown. The root system is of the taproot type. From the main root, long, thin, angular, strong, and rough stems develop. These stems usually spread along the ground in a creeping manner, and with the help of tendrils arising from the leaf axils, the plant is capable of climbing over shrubs and other surrounding vegetation [7, 8].

Seed Dormancy and Germination of *Citrullus colocynthis*

Seed dormancy is an adaptive strategy to cope with unpredictable and variable environmental conditions, such as those characteristic of arid desert ecosystems [9]. Dormancy postpones seed germination until conditions conducive to seedling survival are present, thereby influencing the plant's life cycle and overall adaptability [9, 10, 11]. The type and degree of dormancy are shaped by environmental factors during seed maturation on the maternal plant [10], as well as by the conditions experienced by seeds while in their natural habitat [12, 13]. Furthermore, dormancy and germination responses are modulated by environmental factors encountered during seed imbibition (water uptake) [14]. Consequently, the timing of seed germination under natural ecological conditions is governed by the interplay of pre- and post-dispersal environmental cues [15].

Citrullus colocynthis ("bitter apple") is a perennial desert species belonging to the family Cucurbitaceae, characterized by annual aerial stems and a perennial rootstock. Its fruits are spherical, green with mottled patterns, and each fruit typically contains 100-200 seeds. The average seed mass is approximately 4.4 mg, which is comparatively large and heavy relative to seeds of most other desert species [16]. The plant propagates both sexually via seeds and vegetatively through root buds. Floristic records from the UAE suggest a primary flowering period from November to July [17, 18]; however, extensive observations indicate that *C. colocynthis* may flower and fruit throughout the year in sandy habitats. Fruit maturation lasts around one month during hot seasons and up to two months during cooler periods. Fruits developing on sand dunes are sometimes buried by shifting sands.

Seed germination rates of C. colocynthis are markedly higher at moderate to high temperatures (20-30 °C and 25-35 °C) than at lower temperatures (15-25 °C), consistent with patterns observed in many Cucurbitaceae species, in which warm conditions favor germination while cooler conditions inhibit it [19, 20]. For example, watermelon seeds exhibit robust germination at elevated temperatures but fail to germinate below 15 °C [20]. Similarly, "bitter apple" watermelon seeds germinate nearly 100% under optimal temperatures (20-40 °C) in darkness, but germination declines sharply at 15 °C [21]. In desert environments, temperature may function as a critical ecological cue, signaling suitable conditions for seedling establishment and growth [16].

Fig. 3 Appearance of the fruit seeds of *Citrullus colocynthis*.

High germination at elevated temperatures implies that young *C. colocynthis* seedlings are more likely to establish and develop successfully under warm conditions. Germination in relation to seasonal rainfall generally occurs at the beginning (October-November) or end (March-April) of the season. Early germination allows seedlings to reach maturity and fruiting, whereas delayed germination may increase the risk of seedling mortality if rainfall is insufficient. *C. colocynthis* can continue growth during hot summers, although its shallow root system limits access to deeper groundwater [22].

Our findings indicate that *C. colocynthis* seeds display strong negative photoblasty, which may represent an ecological adaptation to survival in sandy habitats where many fruits become buried [23]. With an average seed weight of 4.40 mg, *C. colocynthis* seeds are relatively large compared to other desert species [16]. Larger seeds produce more vigorous seedlings, providing a competitive advantage under resource-limited or highly competitive conditions [24]. High germination rates in darkness suggest that buried seeds can germinate successfully when other conditions are favorable. Seedlings from large seeds possess substantial metabolic reserves, enhancing survival and recovery during early developmental stages under nutrient limitation [25]. Moreover, seedlings originating from large seeds demonstrate increased tolerance to drought, sand burial, and root damage, allowing survival even in shaded or otherwise suboptimal microhabitats [26].

Chemical Composition of the Plant

Studying the chemical composition of *Citrullus colocynthis* is crucial for understanding its nutraceutical (bioactive food components) and therapeutic properties, thereby providing a foundation for exploring its medicinal potential in greater depth. All medicinal plants contain various bioactive compounds, including triterpenoids, steroids, alkaloids, tannins, flavonoids, essential oils, and glycosides, among others. These compounds are produced as a result of primary or secondary metabolism in living organisms and can directly influence human physiological functions [27].

According to data from the National Research Council of Canada, one of the country’s largest scientific research institutions, the water content of ripe *C. colocynthis* fruit reaches approximately 90%. In addition, the fruit contains about 30% protein, 10% carbohydrates, 4% inorganic compounds, and 3% cellulose [28]. Besides these nutrients, the plant contains various bioactive compounds such as alkaloids, essential oils, flavonoids, and glycosides [29]. The characteristic bioactive compounds of *C. colocynthis* include cucurbitacins (A, B, C, D, E, I, J, K, and L) and colocynthosides (A and B) [30].

Historically, the desert gourd (*C. colocynthis*) has been an integral part of traditional Arab medicine. Various studies have reported that extracts from its roots and callus tissues exhibit antidiabetic, anti-inflammatory, antioxidant, and anticancer properties [31, 32]. The seeds of *C. colocynthis* are oily, containing approximately 50% oil according to the National Research Council of Canada, along with other nutrients. The oil yield from *C. colocynthis* seeds is comparable to that obtained from sunflower and safflower seeds and exceeds that of soybean and cotton seeds [33]. Literature indicates that oil extracted from *C. colocynthis* seeds can be used not only for livestock feed but also for human consumption [34].

In addition to its high oil content, *C. colocynthis* seeds are rich in protein and contain all essential amino acids, making the seed protein of high quality and comparable to that of legumes [28]. According to available data, the oil content of *C. colocynthis* seeds is higher than that of several other oil-producing plants. The seed oil contains two major saturated fatty acids (SFAs): palmitic acid and stearic acid, ranging from 8.1-17.3% and 6.1-10.5%, respectively [33, 34, 35]. Moreover, oleic acid and linoleic acid are the predominant monounsaturated fatty acids (MUFAs). Linoleic acid content ranges from 50.6% to 60.1%, which is notably high compared to other oils and has significant medicinal applications. Due to the presence of linoleic and oleic acids, *C. colocynthis* seed oil is classified as a linoleic-oleic type oil and is considered comparable to oils derived from other oilseed plants [33, 35].

Amino Acids

Similar to its fatty acid composition, Citrullus colocynthis seeds are a rich source of protein, containing high amounts of essential amino acids such as methionine, arginine, and tryptophan [28]. The quality of the seed protein is slightly lower compared to soybean protein but is considerably higher than that of other oilseed plants. Numerous studies indicate that glutamine and arginine are the predominant amino acids in *C. colocynthis* seed protein, with concentrations of 19.8/100 g and 15.9/100 g, respectively. Other amino acids present in the seeds include glycine, alanine, leucine, aspartic acid, serine and phenylalanine [34].

Mineral Composition

Citrullus colocynthis fruits and seeds also contain substantial amounts of minerals. The seeds are particularly rich in calcium and potassium, with concentrations of 569 mg/100 g and 465 mg/100 g, respectively. Iron, zinc and phosphorus are also present in significant amounts. The considerable levels of calcium and niacin, especially in regions of southern West Africa where dairy consumption is low, promote the use of *C. colocynthis* as a dietary source [40, 41]. Biochemical analyses have further revealed that macroelements and trace elements such as Mg, Na, K, Fe, Ca, and Zn are present in notable amounts. The reported concentrations in seeds are as follows: Mg (0.002-2.1 mg/g), K (0.028-6.84 mg/g), Na (0.017-1.68 mg/g), Fe (0.00-0.499 mg/g), Ca (0.019-5.69 mg/g), Zn (0.0009-0.030 mg/g), Cu (0.001-0.051 mg/g), and Mn (0.0002-0.0974 mg/g) [33, 34, 36, 38].

Potassium, which is abundant in *C. colocynthis*, plays a crucial role in regulating physiological fluid and electrolyte balance in animal cells, as well as in muscle contraction and nerve impulse transmission. Potassium deficiency can lead to diarrhea, vomiting, hypokalemia in severe cases, muscle weakness, cardiac arrhythmias, circulatory problems, slowed reflexes, respiratory difficulties, and general fatigue. While many plants such as cabbage, broccoli, dates, figs, avocado, apricots, and almonds are recognized as natural sources of potassium, *C. colocynthis* seeds can also be considered a significant source of this essential mineral due to their relatively high potassium content.

Bioactive Compounds

Citrullus colocynthis is a perennial plant adapted to hot climates and is rich in nutrients as well as bioactive compounds that confer medicinal properties. The primary bioactive compounds are cucurbitacins, which are tetracyclic plant metabolites with oxygen-binding capacity and are responsible for the characteristic bitter taste of the fruit. Cucurbitacins are derived from a 19-(10-9β)-abeo-10α-lanost-5-en skeleton and, due to the presence of a methyl group, are not classified as steroids. Although cucurbitacins exist in 12 forms, the most prevalent in *C. colocynthis* is cucurbitacin E (2-O-β-D-glucopyranoside). Due to their cytotoxic properties, cucurbitacins play a vital role in the development of anticancer drugs. In addition to cucurbitacin E, forms A, B, C, and D are also widely distributed in C. colocynthis [23].

Flavonoids, as secondary plant metabolites, enhance antioxidant activity and neutralize free radicals. Some studies have identified flavonoid glycosides in *C. colocynthis*, including isovitexin, isosaponarin, and isoorientin. Cucurbitacin glycosides such as 2-O-β-D-glucopyranosyl (cucurbitacin L) and 2-O-β-D-glucopyranosyl (cucurbitacin I) have also been reported. Common flavonoids found in the fruit include catechin, quercetin, kaempferol, and myricetin [39].

In addition to flavonoids, *C. colocynthis* contains phenolic compounds with antioxidant properties. Approximately eight phenolic acids have been identified, including caffeic acid, chlorogenic acid, sinapic acid, ferulic acid, gallic acid, p-hydroxybenzoic acid, p-coumaric acid, and vanillic acid [30].

Conclusion

Citrullus colocynthis is a plant of significant interest due to its notable medicinal properties. The presence of diverse bioactive compounds underpins its therapeutic potential. Additionally, the seeds are rich in proteins and oils, with the major fatty acids being unsaturated, particularly linoleic and oleic acids. The seed proteins provide essential amino acids, including methionine, arginine, and tryptophan, which are vital for human nutrition. Comprehensive studies of C. colocynthis are essential not only for its pharmaceutical applications but also for its potential contributions to the food industry and livestock production.

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PHYSIOLOGY OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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Summary. Safflower (*Carthamus tinctorius* L.) is one of the drought-tolerant oilseed crops cultivated in saline and arid regions of Uzbekistan. This article presents an overview of the morphological structure of safflower, as well as its photosynthetic characteristics, water and mineral nutrient metabolism, hormonal regulation, stress tolerance, and molecular-genetic mechanisms. Safflower exhibits a C_3 type of photosynthesis and conserves water under drought conditions through stomatal closure and the maintenance of osmotic pressure. Owing to its deep root system, wax-coated leaves, and low transpiration coefficient, the crop consumes approximately 300-350 mm of water during the growing season. Its tolerance to salinity is associated with the compartmentalization of sodium ions within cells and enhanced proline synthesis. The seeds contain 35-40% oil and 15-21% protein, with a particularly high content of linoleic acid (omega-6). It has been demonstrated that safflower is a crop of considerable importance for the reclamation and utilization of saline and drought-affected lands under conditions of climate change.

Keywords: *Carthamus tinctorius* L., safflower, drought tolerance, photosynthesis, osmotic adjustment, antioxidant defense, molecular genetics.

ФИЗИОЛОГИЯ САФЛОРА (*CARTHAMUS TINCTORIUS* L.)

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Аннотация. Сафлор (Carthamus tinctorius L.) - одна из засухоустойчивых масличных культур, выращиваемых в засоленных и засушливых регионах Узбекистана. В данной статье представлен обзор морфологического строения сафлора, а также его фотосинтетических характеристик, водного и минерального