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NUTRITIONAL BENEFITS OF BIOACTIVE COMPOUNDS FROM WATERMELON: A COMPREHENSIVE REVIEW

Abstract. According to the latest statistics, the major problem that predominates in the contemporary world today is chronic disorders, which account for deaths greater than 40 million annually. Further, 74% of all deaths in the world are due to cardiovascular disorders (CVD), cancer, chronic respiratory diseases, and diabetes-related kidney disease. It is well-established that chronic inflammation is associated with oxidative stress and thrombo-inflammatory manifestations. This helps to propagate and develop these disorders, while it has also been observed that switching to healthy dietary habits plays a vital anti-inflammatory role in the prevention of these chronic disorders, improving thus life quality.

Keyword: *Fruits, watermelon, flesh, healthy fruit, antioxidant, nutritional composition, bioactive content, amino acids.*

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ПИЩЕВАЯ ПОЛЬЗА БИОЛОГИЧЕСКИ АКТИВНЫХ СОЕДИНЕНИЙ ИЗ АРБУЗА: ВСЕОБЪЕМЛЮЩИЙ ОБЗОР

Аннотация. Согласно последним статистическим данным, главной проблемой современного мира являются хронические заболевания, которые ежегодно становятся причиной более 40 миллионов смертей. Более того, 74% всех смертей в мире связаны с сердечно-сосудистыми заболеваниями (ССЗ), раком, хроническими респираторными заболеваниями и болезнями почек, связанными с диабетом. Хорошо известно, что хроническое воспаление связано с окислительным стрессом и тромбо-воспалительными проявлениями, которые способствуют развитию и прогрессированию этих заболеваний. Однако наблюдается, что переход к здоровым пищевым привычкам играет важную противовоспалительную роль в профилактике данных хронических болезней, что способствует улучшению качества жизни.

Ключевые слова: фрукты, арбуз, мякоть, полезный фрукт, антиоксидант, питательный состав, биологически активные вещества, аминокислоты.

Introduction. Fruits and vegetables play a vital role in healthy dietary patterns, as they possess a wide variety of micronutrients with antioxidant, anti-inflammatory, and antithrombotic properties. The consumption of diverse fruit species relates to a lower chance of acquiring certain diseases, particularly cancer and cardiovascular disease, due to the potential for bioactivity.

Citrullus lanatus (CL), commonly known as a watermelon, seems rich in bioactive and healthy fruit. Watermelons belong to the Cucurbitaceae family of tropical fruits (Kyriacou, Leskovar, Colla, & Rouphael, 2018) and are one of the world's most cultivated fruits of significant economic importance. Watermelons are primarily grown in Asia (79.5%), Africa (7.5%), and America (6.9%). Although fruit production and consumption are gradually expanding in the Mediterranean basin, China produces 67% of the total quantity (FAO, 2018), reaching 60.9 million tons per annum (FAO, 2020) with the highest consumption rates.

Watermelon consumption is increasing due to its refreshing taste, sweetness, appealing color (red, yellow, and pink), and high-water content. As a fruit, it is low in calories, salt, cholesterol, and fat fruit (Nishat et al., 2024; Yadav, Prasad, Singh, & Singh, 2022; Żyżelewicz & Oracz, 2022), and thus a popular and widely consumed fruit (Dammak et al., 2019), due also to being thirst-quenching and nutritious, with an abundant content of nutrients, minerals, and phytochemicals (Yadav et al., 2022) With numerous biological benefits that are linked to healthy eating and improved human health (Manivannan, Lee, Han, Lee, & Kim, 2020; Tlili et al., 2023). Subsequently, several health benefits from the intake of watermelon have been reported, such as improving cardiovascular health, high blood pressure in hypertensive patients, decreasing LDL (low-density lipoproteins) oxidation, and fighting against age-related degenerative diseases and certain types of cancer (Bianchi, Provenzi, & Rizzolo, 2020; Dammak et al., 2019; Tlili et al., 2023).

Nevertheless, an increased demand from consumers for watermelon and fruits has increased the byproduct production. Several food processing facilities generate serious amounts of peels and seeds as byproducts (Boukid, Pera, Parladé, & Castellari, 2022; Samota et al., 2023). There is an increasing concern about agri-food byproducts generated by the fruit and vegetable sectors, as they can jeopardize food security and cause economic and environmental issues (Sagar, Pareek, Sharma, Yahia, & Lobo, 2018; Silva, Gonçalves Albuquerque, Alves, Oliveira, & Costa, 2018).

Search strategy. A comprehensive literature survey was performed using scientific databases such as Google Scholar, Web of Science, and Scopus. Data were gathered from scientific publications in English from 2018 to 2024 using the following keywords: watermelon, byproducts, nutritional composition, bioactive compounds, health, and food application. The inclusion criteria were based on the contents such as (i) the design of the experimental study, (ii) health benefits, and (ii) food application.

Nutritional composition, bioactive content, and associated health benefits of watermelon. Watermelon has a plethora of micronutrients crucial for the physiological functions of the human body (Nkoana et al., 2022). A chunky rind and a fleshy middle (i.e., pulp) containing lycopene and beta-carotene contributing diverse colors characterize watermelon (Yıkmış, 2020). Oberoi and Sogi (2017) found that watermelon fruits produce 55.3% juice, 10.4% pomace and 31.5% rind. Several studies have evaluated the nutritional composition of flesh, juice, rind/peel, rind powder, and watermelon.

Antioxidant and anti-inflammatory properties and associated health-promoting effects. Citrullus lanatus is an excellent functional food, and its various sections are great sources of a variety of antioxidant bioactive, such as vitamins, phenolic compounds, and carotenoids (Alemika et al., 2018; Imran et al., 2020; Jibril et al., 2019; Mirahmadi et al., 2020). According to Tlili et al. (2023), as well as citrulline, a non-essential amino acid with significant antioxidant effects (Dawoud, Malinski, Malinski, & Malinski, 2020).

Potential food application of watermelon byproducts that improve food functionality and health-promoting effects. Watermelon and its byproducts can be applied in some food products such as cookies, dairy, and meat products and can be considered environmentally friendly for food packaging systems. Moreover, the chemical composition of watermelon byproducts (rind and seeds) exhibits a potential source of nutrients and bioactivity to be utilized as functional ingredients for developing novel valuable products in several applications with a relevant impact on the food industry.

The unique composition of watermelon, including its minerals, vitamins, and phytochemicals, reportedly has specific therapeutic and pharmacological significance (Banurek and Mahendran, 2011; Jiang et al., 2020; Nkoana et al., 2021; Ubbor and Akobundo, 2009; Zhao et al., 2021). Watermelon seeds are rich in proteins, oil, and unsaturated fatty acids, such as stearic, palmitic, linoleic, and oleic acids. It is also a rich reservoir of natural organic sugars including glucose, sucrose, and fructose and it contains carotenoids such as β-carotene (Khan et al., 2020). Watermelon fruits are comprised of phytochemical compounds, such as cucurbitacins and their glycoside derivatives which exhibit a peculiar medicinal significance in terms of potent biological activities, such as hepatoprotective, anti-inflammtory, anti-tumor, antimicrobial and anthelmintic effects (Biswas et al., 2017; Nkoana et al., 2021).

In Sudan, watermelon is used for the treatment of various ailments including gastrointestinal disorders, rheumatism, inflammation, and gout. In South Africa, the leaves and fruits of the watermelon plant are employed in conventional healing and alternative medicinal therapies to treat hypertension (Aderiye et al., 2020; Nkoana et al., 2021; Rashid et al., 2020). Furthermore, the roasted seeds of watermelon are utilized by consumers as an appetite stimulant and to alleviate constipation (Biswas et al., 2017). In recent years, the interest of consumers in natural plant-derived food products as alternatives to pharmacological drugs for the treatment of human diseases and ailments has increased (Ahmad et al., 2020; Biswas et al., 2017; Nkoana et al., 2021). This review summarizes our current knowledge of the phytochemical profile and therapeutic effects of watermelon, including the limited information available regarding the ethno-medicinal benefits. This review indicates that watermelon has a superb nutritional profile, contains numerous phytochemicals, and exhibits beneficial therapeutic effects.

Carotenoids. Watermelon is the world's third most popular fruit consumed during hot weather. The color of the watermelon's flesh is an essential characteristic. White, salmon yellow, orange, crimson red, scarlet red, pale yellow, canary yellow, and green are the eight defined flesh colors for watermelon. Except for the green flesh color, watermelon contains a variety of carotenoids that are responsible for the various flesh hues. Carotenoids are important functional components and micronutrients in watermelon. The carotenoid composition and concentration have both become a major focus during watermelon quality assessments (Zhao et al., 2013). The majority of β-carotene and lycopene were found in red-fleshed watermelons. Lycopene accounted for most of the total carotenoids (84%-97%). Carotenoid composition and content in watermelons of varying flesh colors are linked to cultivars and growing conditions (Tadmor et al., 2005).

Lycopene, β-carotene, phytofluene, phytoene, lutein, and neurosporene are some of the carotenoids that have been identified in watermelon. Lycopene is comprised of 13 double bonds two of which are non-conjugated and 11 which are, and it is characterized by an acyclic open-chain structure. The antioxidant property of lycopene and its bright red color are attributed to its unique conjugated polyene structure (Holzapfel et al., 2013; Shi and Maguer, 2000; Stahl and Sies, 1996). In foods, the most widespread and natural lycopene configuration is the all E-isomer. During the oxidation and thermal processing, the lycopene Z and E isomerizations may exist in foodstuffs. The potent antioxidant is composed of only E-isomers, while the 5Z-lycopene is reportedly the most biologically active form. Lycopene is a suitable target for electrophilic reagents, presuming that there is an electron-rich organization due to its polyene structure. In the case of free radicals for oxygen scavenging, it has extreme reactivity (Holzapfel et al., 2013). As a free radical scavenger, the carotenoid's lycopene is reported to be the most effective and potent antioxidant and singlet oxygen quencher, and the risk of cancers and cardiovascular diseases are subsequently reduced (Holzapfel et al., 2013; Perkins-Veazie et al., 2001; Shi and Maguer, 2000; Stahl and Sies, 1996). The most important function of carotenoids is to neutralize compounds produced throughout photosynthesis (Table 4, 5). The structure of lycopene is shown in Fig. 1.

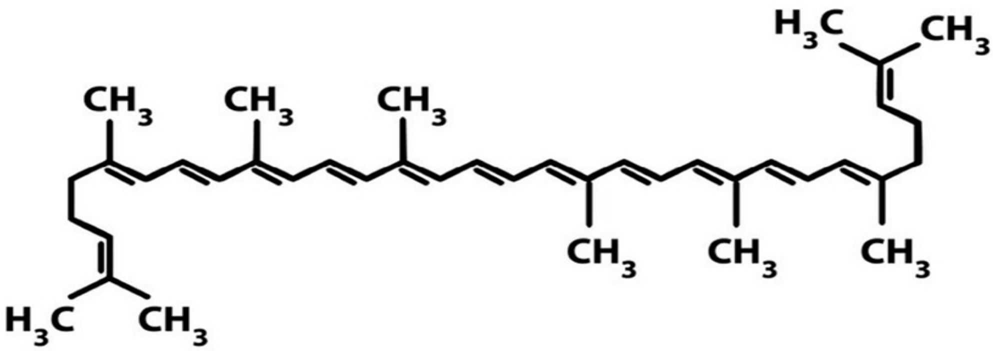

Fig. 1**. Structure of lycopene.8**

Amino acids. The organic constituents comprised of both amino and acid groups are designated as amino acids (AA). All AAs have optical activity and an asymmetric carbon excluding glycine. The arrangement with reference to the glyceraldehydes of AA isomers is nominated as an absolute configuration. All protein AAs allied to the A-carbon atom (hence a-AA) have a carboxyl group and a primary amino group excluding proline (Galli, 2012). AAs have an extraordinarily diverse range of biochemical properties and functions due to the differences in their side chains (Brosnan, 2009; Wu et al., 2007; Yamane et al., 2009). At biological pH, except for (1) cysteine which suffers from rapid oxidation to cysteine and (2) other is progressively to pyroglutamate cyclized at 1%/day at 1 mM is glutamine (25°C). All AAs are normally constant in aqueous solution.

The isoforms can substitute entire AAs, except for glycine. Furthermore, except for D-lysine, D-histidine, D-threonine, D-arginine, and D-cystine in animals, the maximum D-AA via extensive transaminases and oxidases can be converted into AA (Baker and Cameron, 1999; Fang et al., 2009). Dependent on substrates and species, the effectiveness of AA consumption may be 20%-100%, based on isomer (Baker and Cameron, 1999).

In nature, there are more than 300 AAs. However, only 20 of these function as the building blocks of protein. Significant roles in cell metabolism are performed by non-AA (such as β-alanine and taurine) and non-protein AA such as (ascitrulline, homocysteine, and ornithine) (Huh et al., 2014; Manna et al., 2009; Perła-Kaján et al., 2007). In the body for both free AAs and those that are peptide-bound, the chief reservoir is the skeletal muscle since it consists of 40%-45% of an individual's body weight (Davis and Fiorotto, 2009). Watermelon is an admirable source of citrulline (an amino acid), which is utilized to help produce another amino acid called arginine. The effectiveness of citrulline and arginine in cardiovascular health, immune function, wound soothing, and sickle cell anemia has been emphasized in previous studies (Tong and Barbul, 2012). For citrulline, 80% of the ingested aggregate was found to be absorbed quickly into the blood, and it has better bioavailability when compared with arginine (Mandel et al., 2005). The structures of citrulline and arginine are shown in Fig. 2 (Collins et al., 2007; Rimando and Perkins-Veazie, 2005).

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