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WATERMELON (*Citrullus lanatus* Thunb. L); A VEGETABLE CROP FOR HEALTHY LIVING AND FOOD SECURITY: A REVIEW

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ABSTRACT: Watermelon (*Citrullus lanatus* Thunb L.) is a nutrient-dense vegetable crop that provides numerous benefits for healthy living and food security. Its drought tolerance and adaptability enable it to flourish in various environments, making it an appealing choice for farmers and consumers. Watermelon (*Citrullus lanatus*) 2n = 2x = 22, is a herbaceous plant species and a member of the Cucurbitacea family and subtribe *Benincasinae* and has a small genome of 425Mb. It is an annual plant with a climbing habit and has diameter about 5-6 feet. It is a large, green colour and unique with pinnate lobed leaves among other members of the Cucurbitaceae. Its flowers are usually light-yellow flowers with odour that are not pungent. It is botanically classified into a pepo. Fruits are variable shape and sizes usually oval or cylindrical and round. They are stripped green or plain green colour. The fleshy, juicy, edible part is red in colour with small black or brown in colour seeds. This review examines the nutritional value, cultivation methods, and potential applications of watermelon as a versatile crop. With its high-water content, rich antioxidant profile, and diverse culinary uses, watermelon can significantly enhance food availability and sustainable farming practices. This paper discusses the origin and current state of watermelon production and also brought out the potential of watermelon in meeting the nutritional and economy needs of the people. It lastly pointed out the future research directions.

Keywords: Food security, healthy living, vegetable crop, watermelon.

INTRODUCTION

Watermelon (*Citrullus lanatus* L) is an annual vegetable and fruit specially appreciated in the tropics especially during the warm season. Watermelon is a spreading crop with a unique flowering pattern, featuring the male and female reproductive parts on same or separate plants, according to Boualem *et al.* (2016). ‘’Watermelon” *Citrullus lanatus* is derived from both Greek and Latin roots, “Citrullus” from the Greek” meaning fruit while the “lanatus” is from Latin, meaning wooly in nature (Erhirhie and Ekene, 2013). It belongs to the *Cucurbitaceae* family and represents almost half of the total production from the family in the year 2010 (Egel and Martyn, 2013). Other members of the family include cucumber, squash, muskmelon,

calabash, bitter melon and Cucumis. Watermelon originated from Africa, and this was because A wide range of genetic diversity is observed in wild watermelon populations native to Southern Africa (Naz *et al*., 2014; Kyriacou *et al*., 2018). The origins of watermelon are further supported by evidence of early domestication in Africa and the Middle East dating back to the second millennium BC (Zohary *et al*., 2012). From there, watermelon was introduced to other regions via established trade routes, with cultivation records showing its presence in India and China (Paris *et al*., 2013). It is a crop that provides source of income for small – scale farmers and therefore regarded as an economically important and most consumed vegetable crop (Nimmakayala *et al.,* 2014; Zhang *et al.,* 2016; Levi *et al*., 2017). The production of watermelon is of high importance in improving economic activities, poverty reduction and enhancing the socio-economic status of its producers. In terms of economic value, one kg of watermelon is about 7 times higher than one kg of coffee beans (Bi *et al*., 2003), thus, making its cultivation very profitable. It is cherished for its sweet-flesh (it contains sucrose, glucose, and fructose), it is a source of vitamin A and C, minerals including K, Fe and Ca and it possesses high amounts of citrulline and lycopene (Ren *et al.*, 2012; Reetu and Tomar, 2017). In summer, watermelon serves as a means of refreshment and aids relief from thirst due to its attractive color, sweet taste, and high-moisture content (Romdhane *et al*., 2017). Watermelon provides relatively inexpensive and accessible nutritious fruit for Africa, particularly throughout the summer. It is a traditional food in Africa and could contribute to food security and enhanced good nutrition, aid rural development and capable of ensuring sustainable utilization of land (Ufoegbune *et al.,* 2014).

BOTANY OF WATERMELON

The name *Citrullus lanatus* originates from Latin and Greek. '*Citrullus*' is from the Greek word "*citrus*," and the Latin word "l*anatus*" stands for the minor hairs on the trunks and the plant's foliage. Watermelon is a part of the Plantae kingdom, Cucurbitaceae family, order Cucurbitales, and Citrullus genus (Nadeem *et al*, 2022). Watermelon (2n = 2x = 22), belongs to the subtribe *Benincasinae* and has a small genome of 425Mb (Zhu *et al.,* 2016). Other members of the genus include *C. lanatus* (syn. vulgaris), *C. colocynthis* and *C. rehmii*, which are all relatively cross compatible (Masih *et al*., 2021). The stems of watermelon are often angular, hairy, and slender, with branching tendrils at each node. Few dwarf forms with genes that control plant height and internode length and the genes that affect plant height and stem length (Wehner, 2008). With taproots and numerous lateral roots, the roots are broad but shallow. Unlike other cucurbits, watermelons have smaller, less ostentatious blooms. Four to eight weeks after sowing, flowering starts. Watermelon flowers are solitary, measuring 2-3 cm in diameter, with five light yellow petals. They can be male (staminate), female (pistillate) with an inferior ovary, or hermaphroditic, typically appearing at every 7th or 8th leaf axil (Alka *et al*., 2018). The size and shape of the ovary in female flowers are indicative of the final fruit size and shape.

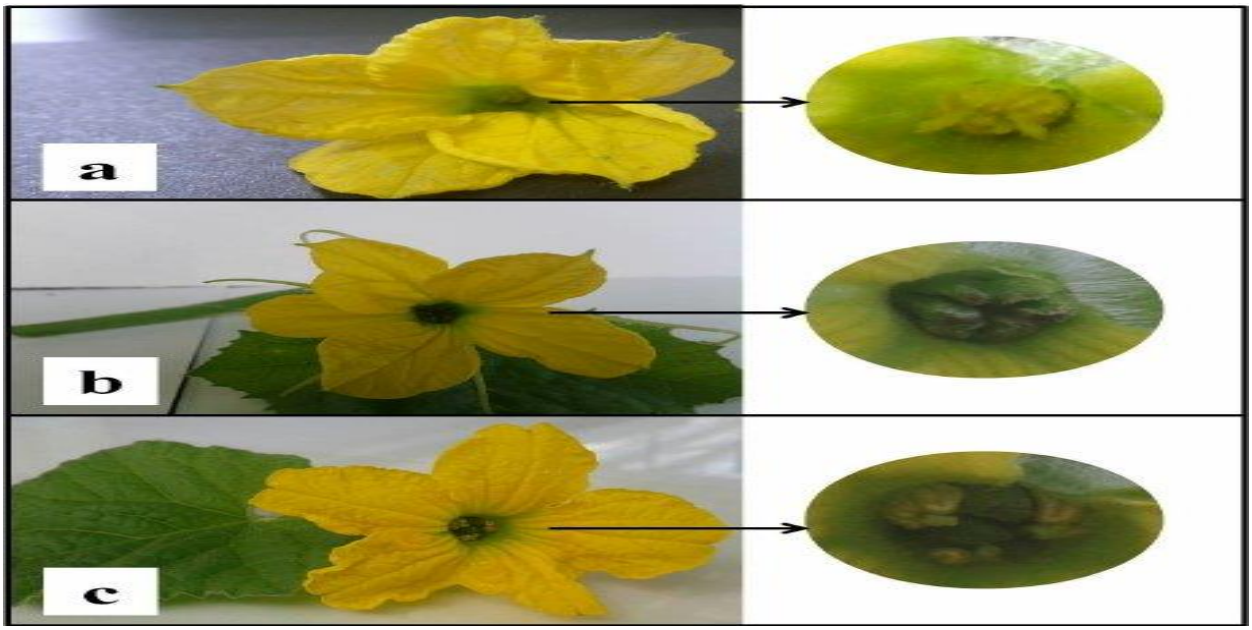

Plate 1. Types of flowers in melon. *Source; (Girek et al., 2013)*
Key: a = staminate flower b; = pistillate flower; c = perfect flower


Plate 2: A whole fruit and cutting of a watermelon fruit

Many modern watermelon cultivars are monoecious (having separate male and female flowers), while others often exhibit andromonoecy (having both male and perfect flowers, with the latter containing both male and female reproductive organs, (Aguado, 2020). A typical watermelon cultivar possesses 7:1 flower ratio (staminate: pistillate), with variations at either 4:1 or 15:1. Ovaries and primordial fruits become glossy as they grow.

Watermelon fruit has a thick rind (exocarp) and fleshy center which is a major characteristic of cucurbitaceae (Mehra *et al.,* 2015). Watermelon flesh has varied pigments with either a solid or striped appearance with colors from white, yellow or red (Bahari *et al.,* 2012; Munisse *et al.,* 2013). The period between anthesis and fruit maturity is between 25 and 40 days though the physical expression of fruit ripening is invisible. There seems to be a direct relationship between the days from sowing, maturity and the fruit size. It has been observed that early cultivars that took about 65 days to mature bore small fruits (about 5kg) while more recent cultivars that took about 100 days to mature bear much bigger fruits(Paris, 2015). Desert grown watermelons fruit weigh over 100 kg. Most commercially available watermelons range between 3 and 13 kg (Maynard, 2001; Wehner, 2008) with globular, oval or oblong shape fruit shape (Paris, 2015; Reetu and Tomar, 2017). Watermelon can be stored for weeks or even months without getting spoilt or losing quality, provided the storage condition is cool and shady (Jensen, 2012).

The watermelon rind possesses two distinct layers "exocarp and endocarp", the external layer (exocarp), is usually thin and glossy with bold strips or patterned in shades of green, ranging from light to dark. Unlike the exocarp, the mesocarp, is the firm, white and moist inner rind. The endocarp is the fruit part that is often consumed and lies beneath the peel. The fruit's flesh is insipid, hard, and white or pale at other stages of growth. When citron watermelons reach fruit maturity their flesh stays hard, colorless, and tasteless (Xu *et al*., 2012). When sweet dessert watermelons are ripe, the flesh becomes delicate and accumulates sugar and carotenoid pigments (Soteriou *et al*., 2014). The endocarp of ripe watermelon fruits can be red, pink, orange, yellow, a combination of these colours, green, or white, depending on the genotype (Gusmini and Wehner, 2004). Watermelon fruit has an average of 200 seeds, which appear to be distributed within the flesh and this poses a discomfort to many consumers. Generally, sweet watermelon seeds are hard, flat, oval, and ranges between 8 - 16 mm in length (Paris, 2015)

In Africa, three major types of watermelon are consumed; dessert type (*C. lanatus* var. *lanatus* L), cooking type (*C. lanatus* (Thunb.) var citroides) and the seed type (*C. colocynthis* L. Schrad.). The distinguishing characteristics of dessert types include sweet taste and a low-calorie of the fruit, so often used in salads and juices (Bahari *et al*., 2012; Gbotto *et al*., 2016). The cooking type, also called cow watermelon, is grown majorly to feed animals, and for human consumption (like cooking thick or mixed in dry maize (*Zea mays* L.) grain. (Nantoumé *et al.,* 2013). The seed type is mainly used for oil, soup, snacks, and flour (Jensen, 2012).

ORIGIN, DISTRIBUTION AND PRODUCTION OF WATERMELON

Watermelon originated in Africa and through established trade routes, got to other parts of the world

(Urrutia *et al*., 2014). It got to the "New World" around 1500s. The world production of 104 million tonnes in 2023, this was an increase of 1.83% from what was recorded in 2022, thus making it among the top five most consumed fresh fruits (FAO, 2022). The world production of watermelon is on area of over 3.7 million ha, thus, it is the second largest vegetable crop in area after tomato. (Martyn, 2014). World production has increased continuously, particularly in the five leading producing countries (Figure 1.). This is partly due to the good income generated from watermelon production that is far better when compared with income from other crops.

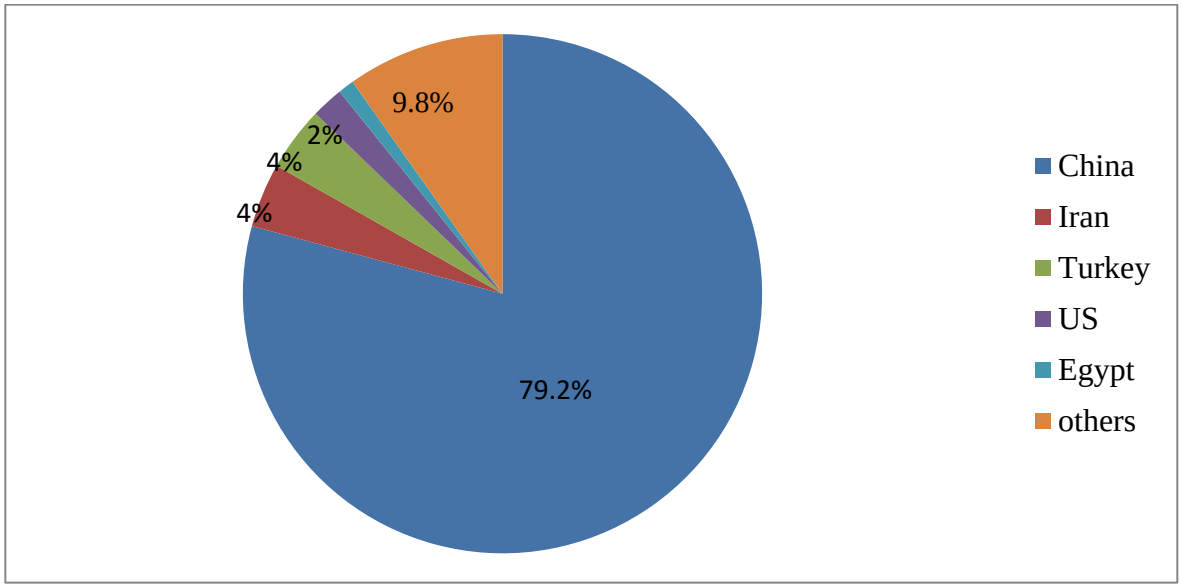

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Figure 1. Percentage of watermelon production in some countries (Source: FAO, 2022)

According to Dube *et al*., 2020, Asia accounts for more than 80% of world's watermelon production with China being the largest producer of watermelon with about 70 million tons which is about 79.2 % of total global production with roughly 4.04 and 3.80 million tonnes, respectively, representing 3.84 and 3.60% of the global total. Turkey (1.97% of the global total) ranked second, followed by Iran product (1.78% of the global total) in terms of production with 2.08 million tonnes () and 1.88 million tonnes (respectively, Brazil and Egypt rank fourth and fifth in terms of production. With 1.77 million tonnes (1.68% of the global total), the United States comes in sixth place in terms of output. Next on the list are Kazakhstan (1.16 million tonnes, or 1.1% of the world total), Uzbekistan (1.35 million tonnes, or 1.28% of the world total), Mexico (1.03 million tonnes, or 0.98% of the world's total production), Algeria (1.50 million tonnes, or 1.42% of the world total), and Russia (1.45 million tonnes, or 1.38% of the world total).

In 2017, watermelon covered up to 5.4% of the cultivated area in Africa. The total production from the continent in that year was 5% of the world production (Dube *et al*., 2020). According to (FAO, 2019), Africa is the third largest producer of watermelon with leading producing countries which includes Egypt, Algeria, Tunisia, Morocco, Mali, Libya, Senegal, South Africa, Sudan and Kenya (Jansen, 2012).

Among the higher plant kingdom's most effective at using the natural ambient elements for development and metabolism are watermelon plants. A single plant takes 85–90 days from seeding to growth, blossom, set fruit, and mature up to 80–100 lbs (36 – 45kg) of ripe melons with 10 –12% total solids. There aren't many cultivated herbaceous plants that can absorb light, water, CO_2, and soil nutrients to produce a tasty edible product in that amount of time.

POTENTIALS OF WATERMELON IN FOOD SECURITY

The world food summit held in 2006 came up with a definition for food security as physical, social, and economic access to sufficient, safe, and nutritious food that meets dietary needs and preferences. - Food security essentials are availability, access, utilization,

and stability of safe and nutritious food for an active and healthy life. Comprehensive food security is a state where all people have consistent access to enough safe and nutritious food, supporting overall well-being and health. Going by this definition, about 2.37 billion people (or 30% of the global population) lacked access to adequate food in 2020 (FAO, 2021) and an estimated 2 billion people are affected by insufficient intakes of micronutrients (WHO, 2016). It thus means that food security goes beyond calorie intake but includes the quality of food taken. Factors responsible for food insecurity include conflict, socio-economic conditions, natural hazards, climate change and pests.

Watermelon fruits are common in areas under high temperatures and at times, where very few other crops can survive, and therefore serve as alternative food source in such an environment (Jensen *et al*, 2011). The fruit is commonly grown in rural, urban and peri-urban areas of Asia and thus very much available to people, irrespective of their financial status (both rich and poor people) (Webber *et al*., 2019). The fruits can be stored for over a year and thereby serve as source of food when there is food scarcity (Jensen, 2012). Its production often relies on organic fertilizers, less on chemical fertilizers and pesticides (Nantoume *et al*, 2012). These facts make production less expensive and more environmentally friendly. A study conducted in Tajumoddin and Charfasson Upazilas regions of Bangladesh, comparing the potential of watermelon and rice on food security showed watermelon was better than rice (Sawn *et al*, 2020). Watermelon farmers generated more income when compared with the income generated from the sale of same quantity of rice, thus raising their purchasing ability for other food items. Similarly, Baba *et al*. (2014), reported that watermelon production generated net farm income of ₦ 30, 946 ha^{-1}, this was much higher than the ₦ 19, 592 ha^{-1} generated from hot pepper. Similarly, Namdari (2011) estimated the cost-benefit ratio of 2.61 and 2.06 for high and low levels of watermelon production technologies, respectively in Iran. Again, watermelon is often use in intercropping farming system and therefore serves as "back-up" in case of loss of other crops such maize, millet and sorghum. Another good use of watermelon is as a component of crop rotation. This is because of its creeping nature that serves as control for weed and means of improving soil fertility status (Tian, *et al*., 2023). The income generated through the production and sale of watermelon and its use as a "back-up" crop on the field could assist in ensuring food security. Again, when compared to other crops in terms of cost of production, watermelon costs less and yield more and therefore, it would be more economical to embark on the production of watermelon.

NUTRITIONAL COMPOSITION AND HEALTH BENEFITS OF WATERMELON

Watermelon (*Citrullus lanatus* L.) is a vegetable fruit that contains nutrients and phytochemicals that are useful for the healthy living of human beings (Choudhary *et al*., 2015; Naz *et al*., 2013; Jensen *et al*., 2011). It contains over 91% water, 7% carbohydrates, about 11 minerals and 19 vitamins (Figure 2).

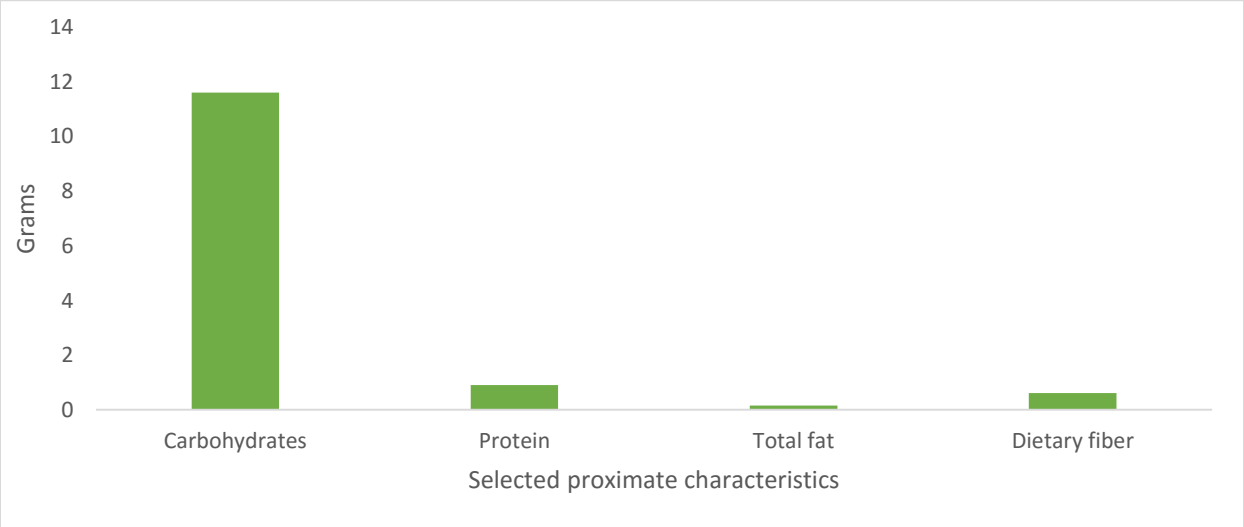

Figure 2: Average nutritional content of watermelon fruit
Source; USA data (2022)

Table 1: Parameter value reference

Parameter	Average Value/100g juice	Reference
Energy	36.2 Kcal	USA data (2022)
Cholesterol	0.01 mg	USA data (2022)
Vitamin A	664.88 IU	USA data (2022)
Vitamin C	10.31 mg	USA data (2022)
Lycopene	9.34 mg	Oberoi and Sogi, (2017)
Sodium	0.001	USA data (2022)
Ash	5.4%	Fila *et al*., (2013)
Moisture	94.2%	Oberoi and Sogi, (2017)

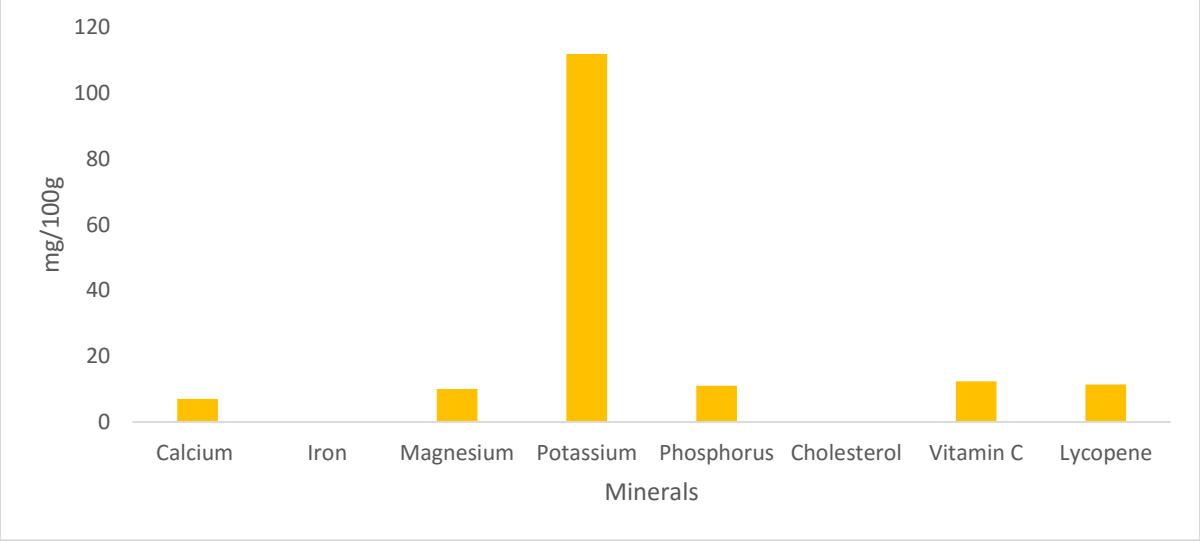

Figure 2: Average content of selected minerals in watermelon fruit
Source: USA data (2022)

Health Benefits of Watermelon

The health benefits derived from watermelon are due to the following elements that it has in appreciable quantity:

a. Lycopenes

An important carotenoid that is present in high level in watermelon is lycopene. This makes watermelon to be considered as a functional food (Soteriou *et al*., 2014). Lycopene ($C_{40}H_{56}$) that contributes about 21- 43% of the total carotenoids in human tissue (Elumalai *et al*., 2013) is a straight chain hydrocarbon with 13 double bonds (Soteriou, 2014; Castro-López *et al*., 2017). Lycopene is responsible for the red coloration in fruits such as watermelon, tomato, guava (Wang *et al*., 2019). The most recent record showed watermelon as leading all other fruits in lycopene production; it possesses about 60% bioavailable lycopene higher than that found in tomato (Srivastava and Srivastava, 2015; Oberoi and Sogi, 2017). This phytochemical is a strong antioxidant that is capable of preventing the damaging effects of free radicals on DNA and proteins through electron transfer, electron addition which results in radical adduct formation and hydrogen atom transfer at level of prevention, interception, and repair of diseases, particularly heart related ones (Kulczynski *et al*., 2017; Oberoi and Sogi, 2017; Reetu and Tomar, 2017; Bianchi *et al*., 2018). The scavenging ability of lycopene is twice as great as that of β-carotene and 10 times higher than that of α-tocopherol (Naz *et al*., 2014; Kulczynski *et al*, 2017).

The production and activities of tumor necrosis factor and stroke are reduced by lycopene (Choudhary *et al*., 2015; Dia *et al*, 2016). Lycopene's efficacy as anticarcinogenic factor is linked with its tumor suppressing activity, decreases in cellular proliferation in various cancer cell lines and ability to regulate gap–junction communication in embryo fibroblast cells (Johary *et al*., 2012; Elumalai *et al*., 2013). The

consumption of lycopene- containing fruits such as watermelon has related to reduction in the incidence of cervical, breast, bladder, and prostate cancers (Kehili *et al*., 2017; Bianchi *et al*., 2018). The consumption of the juice extracts of watermelon has been linked with reduction in hypertension and lower blood pressure in obese adults (Dia *et al*., 2016; Wong *et al*., 2016).

b. **β-carotene**

β-carotene is a phytochemical that is present in watermelon in high quantities; its fresh flesh contains about 4.82mg/g. (Kim *et al*. 2014; Shao *et al*., 2017). It is an insoluble vitamin that includes organic compounds. It is a precursor of vitamin A in the body, and it is represented as orange colour in various fruits and vegetables (Shao *et al*., 2017). The main source of β-carotene in the body is plant-based foods like carrots, sweet potatoes, spinach, watermelon, and mangoes; it cannot be synthesized (Chen *et al*., 2017). β-carotene, like other phytochemicals, has the potential of showing both antioxidant activity and pro-oxidant properties (Lin *et al*., 2018). These qualities give β-carotene the ability to inactivate certain ROS and thus able to confer neuroprotective protection against low- density lipoprotein (LDL and high- density lipoprotein (HDL) (Barkura *et al*., 2017; Rajabi *et al*., 2017). The activities of free radical are prevented by β- carotene transfer which forms carotenoid cation radical and hydrogen atom transfer (Kulczynski, *et al*., 2017).

Watermelon, through the possession of the antioxidant characteristics found in β-carotene aids platelet aggregation and the subsequent fast reconstruction of the walls lining the blood vessel. (Kulczynski *et al*., 2017). β-carotene enhances the immune system and sustains good growth of vital organs such as heart and kidney through cell growth and differentiation (Barkura *et al*., 2017; Shao *et al*. 2017). The consumption of watermelon, a β-carotene rich fruit vegetable, can guard against the damaging effect that could result from ageing (Kim *et al*., 2014). Another health benefit derivable from watermelon is its effect on good vision through the ability of β-carotene to absorb light in the eyes. Furthermore, β-carotene acts as growth factor for epithelial cells and controls gene function, this it does through the enzyme dioxygenase in the human small intestine mucosa where β-carotene is converted to retinol (Kulczynski *et al*., 2017; Nzamwita *et al*., 2017). There are good records of the roles of β-carotene in the prevention of scurvy, inhibition of growth of cancer cells and the reduction of the risk in type 2- diabetes (Pacier and Martirosyan, 2015; Barkura *et al*., 2017; Chen *et al*., 2017; Lum *et al*., 2019). Functional foods such as watermelon that supplies β-carotene is important to the good health of children, pregnant and lactating women that are more susceptible to Vitamin A deficiency and likely blindness (Nzamwita *et al*., 2017).

c. **Citrulline**

Citrulline is a non-protein amino acid that is found most abundantly in watermelon (Kyriacou *et al*., 2018). This precursor for arginine was first extracted from watermelon juice but found also in the flesh and rind (Hong *et al*., 2015). Citrulline is produced in the body through an enzymatic reaction of nitrogen–carbon and absorbed in the intestine (Odewunmi *et al*., 2015). The consumption of watermelon juice after every meal has been reported to lead to increase in plasma arginine and ornithine concentrations, thus confirming the potential of citrulline in watermelon juice in increasing plasma concentration of arginine (Barba *et al*., 2015; Sai'd, 2014).

Diet rich in citrulline offers a lot of health benefits and this is because citrulline is a powerful antioxidant and therefore strong as a hydroxyl radical scavenger (Soteriou *et al*., 2014). The health benefit of citrulline includes the reduction in the elevated total leukocyte and segmented neutrophil counts in sickle cell patients, when given L-Citrulline orally (Rimando and Perkins-Veazie, 2005). Also, citrulline has been associated with improved sexual stamina and erectile functions. Citrulline, as an amino acid also functions against trauma, burn injury, renal failure and the prevention of anemia (Choudhary *et al*., 2014; Ijah *et al*., 2015).

d. **Vitamins**.

Watermelon contains a high quantity of vitamins such as Vitamins A, B6, and C. (Maoto *et al*., 2019; Dube *et al*., 2020). The nutritional composition of watermelon includes 46% calories, 20% vitamin C, and 17% vitamin A (Jumde *et al*., 2015; Biswas *et al*., 2017). The intake of a cup of watermelon will provide about 20% of the daily requirement of vitamin C and this amount is enough to prevent nutritive deficiency and scurvy (Doll and Ricou, 2013; Pacier and Martirosyan, 2015; Maoto *et al*., 2020).

Watermelon provides natural vitamin C which helps the body to develop resistance to the harmful activities of infectious agents. It could lead to a reduction in fatigue and other symptoms experienced by cancer patients who often suffer from vitamin C deficiency (Takahashi *et al*., 2012; Reetu and Tomar, 2017). Other means by which ingestion of vitamin C aids healthy growth include the inhibition of cancer cell growth through cutting off of blood supply to the growing cancer cells and the exhibition of its anticancer properties such as protecting the oxidation of LDL and HDL and

prevention of cell damage by free radicals (Choudhary *et al*., 2014; Kehili *et al*., 2017; Lemos *et al*., 2017;

Romdhane *et al.,* 2017). Vitamin C is also in high quantity in the brain and it has therefore been linked with cognitive functions and involves in the synthesis of carnitine, norepinephrine, and collagen (Pacier and Martirosyan, 2015).
Vitamin C has been helpful in lowering blood pressure in hypertensive patients (Choudhary *et al*., 2015). A study reported by Pacier and Martirosyan (2015) showed that the administration of 2 g and subsequent daily doses of 500 mg of vitamin C for 1 month on hypertensive patients led to a 9.1% drop in their blood pressure. It can thus be concluded that the consumption of vitamin C rich diet could keep one healthy and well.

Watermelon is also confirmed to be a good source of vitamin A and this is because of its high amount of beta-carotene that can be converted to vitamin A. Vitamin A is associated with good skin and hair growth as well as the formation of new collagen and elastin cells (Reetu and Tomar, 2017). Watermelon being a natural source of vitamin A could also protect the lung and oral cavity against cancers. The consumption of watermelon aids energy production and this is due to the presence of vitamins A, B and C in the fruit (Rahman *et al*., 2013).

e. **Minerals**

Watermelon contains about 11 minerals that include potassium, magnesium, calcium, phosphorus, and iron (Adedeji and Oluwalana, 2013). They support healthy living of man by the maintenance of cell structure and regulating differentiation of the cells. The seed of watermelon is reported to have Mg (11.4 mg), Ca (16.8mg), K (7.8 mg), Na (5.7 mg), Zn (1.2 mg) and a few others present in mg/kg. (Lucky *et al*., 2012; Mogotlane *et al*., 2018). Watermelon contains a high amount of K which is a significant component of the cell and body fluids and therefore assists in heart rate and blood pressure moderation, thus preventing stroke and other coronary heart disease. (Sivudu *et al*. 2014). The Manganese found in watermelon acts as a co-factor for the antioxidant enzyme, superoxide dismutase (Reetu and Tomar, 2017).

CONCLUSION

Watermelon is a nutrient – rich vegetable fruit for human consumption. The fact that almost all parts of the fruit (rind, pulp and seeds) are sources of vital nutrients makes the fruit very useful in meeting both the nutritional and health needs of the people. It is loaded with phytochemicals that have been associated with anticardia, gastroprotective, hepatoprotective, antibacterial, antimicrobial, antiulcer, antioxidant, and anti-inflammatory are examples of pharmacological actions and therapeutic qualities. Watermelon has been found to be effective in preventing obesity, because it contains very little sodium. When it comes to the efficient use of natural resources, watermelon farming is somewhat inexpensive. Because of these characteristics, it is a crop that will be more cost-effective to propagate and yield higher yields than most other food crops.

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Conflicts of interest/Competing interests

No conflicting interests

Consent for publication

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