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(REVIEW ARTICLE)



Immunomodulatory and phytomedicinal properties of watermelon juice and pulp (*Citrullus lanatus* Linn): A review

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Abstract

Watermelon (*Citrullus lanatus* Linn) is a popular staple summer fruit in the world which is consumed frequently as a dessert, fruit salad and used in garnishing drinks. It is a natural source of antioxidants. Watermelon is an unusual fruit source of the carotenoid lycopene and a rich source of phenolic antioxidants. It contains cucurbitacin E, a triterpene anti-inflammatory phytonutrient and unusual amounts of amino acids like L-arginine and citrulline. Watermelon is an excellent source of immune-supportive vitamin C and vitamin A. In addition, watermelon is a good source of potassium and magnesium. The nutritional profile of water melon is a full array of nutrients, including carbohydrates, sugar, soluble and insoluble fiber, vitamins, minerals e.g. magnesium and potassium, fatty acids and amino acids. The chemical components of watermelon enhance its capacity to scavenge the low-density lipoprotein (LDL) and high-density lipoprotein (HDL) in a cell membrane. A plethora of evidence shows that it can be effective for weight loss. Several epidemiological studies showed it has phytochemicals that can reduce risk of Cardio Vascular Disease (CVD). Watermelon pomace is reported to be a concentrated source of lycopene as compared to the juice.

Keywords: Watermelon; Cucurbitacin; Phytonutrient; Citrulline; Immunity; Vitamins

1. Introduction

Watermelon (*Citrullus lanatus*) is a member of the Cucurbitaceae family native to tropical areas of Africa near Kalahari Desert [1]. Botanists refer to it as a “pepo” which is a fruit having a thick rind and fleshy center [2]. It is largely consumed as refreshing summer fruit, much appreciated because of its refreshing capability, attractive colour, delicate taste and high water content to quench the summer thirst. Watermelon fruits yield about 55.3 % juice, 31.5 % rind and 10.4 % pomace [3]. Carotenoids such as lycopene and β -carotene are responsible for the red and orange colors of the watermelon respectively. The sweetness of watermelon is mainly due to a combination of sucrose, glucose, and fructose. Sucrose and glucose account for 20–40 % and fructose for 30–50 % of total sugars in a ripe watermelon [4].

The chemical component of watermelon enhances its capacity to scavenge the low-density lipoprotein (LDL) and high-density lipoprotein (HDL) in a cell membrane [5]. It has been reported that it can be used to effectively manage weight loss. Several epidemiological reports have shown its loss due to its potency in the management of Cardio Vascular Disease (CVD). As a result, consumption of watermelon has been associated with various health benefits such as lowering the risk of developing heart diseases, age-related degenerative pathologies, and some kinds of cancer [6]. In addition, watermelon is also a rich source of citrulline, which is a nonessential amino acid [7].

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2. Watermelon Nutrition and Health Benefits

Consumption of raw watermelon fruit on hot summer days is a common practice which has been observed across the world. However, to increase utilization and availability throughout the year, watermelon is processed into variety of commercial products [8,9]. The lycopene-rich nature and health benefits of the watermelon juice make it an excellent choice for preparing additional functional foods in order to increase utilization. It has been used in the production of a variety of products like juice, smoothies, jams, sweets, and sauces [10,11].

Watermelon is a good source of minerals and vitamins since it contains 11 minerals and 19 vitamins [12]. It has vitamins such as thiamine (0.021 mg), riboflavin (0.178 mg), niacin (0.221 mg), and folate (0.045 mg). In addition, it has minerals such as potassium (112 mg), magnesium (10.3 mg), calcium (10 mg), phosphorus (11 mg), and iron (0.038 mg) per one gram of watermelon. All these minerals play important roles in cell regulation, maintenance of cell structure and cell differentiation process by acting as co-factors for many enzymes in the cell [13]. The absence of vitamins (e.g ascorbate) may lead to death of the cell. Owing to its reported nutrients, watermelon is regarded as a medicinal plant [14].

Consumption of watermelon is desirable because of its many positive biological effects, which are mostly connected to being fat-free, cholesterol-free, low in sodium, rich in minerals and phytochemicals [15]. As a result, consumption of watermelon provides long-term health benefits such as reduced risk of heart disease, improved blood pressure in hypertension patients, decrease LDL oxidation and exerts a cardio protective effect [16]. Compared to well-known fruits like tomatoes, strawberries, and guavas, watermelon has higher antioxidant capacity (84.05+3.16 -51.10 $\mu\text{mol TE}/100\text{ g}$) [6].

Carbohydrates, vitamin and fiber are the major components that make up watermelon. All these components are present in their most beneficial forms. Watermelon has recently received attention for its fewer quantities of fats; it is therefore considered a constituent of a healthy diet low in cholesterol and sodium. Due to its reported nutrients, watermelon is regarded as a medicinal plant [10]. The watermelon fruit has low energy (127 KJ) value and therefore recommended for weight management [17]. Watermelon consumption can be useful in maintaining acid–base balance in the body that has a major role in normal physiology, maintaining appetite and normal digestion [18].

In addition, Adedeji and Oluwalana [19] reported that minerals such as calcium and potassium play an important role in cell regulation, maintenance of the cell structure and cell differentiation process. The U.S. Department of Health and Human Services and U.S. Department of Agriculture The World Health Organization [20], recommended that the optimal diet for everyone is through the consumption of a low-fat, fiber-rich carbohydrates. Watermelon juice and pulp contain considerable amounts of carbohydrates and fiber, which plays a significant role in blood cholesterol and helps in the prevention of large bowel diseases while carbohydrates are the source of energy for the cells.

3. Immunity and Immune System

Immunity is the state of being able to resist a particular infection or toxin. The term “immunity” is defined as body’s natural defense system against a vast group of diseases and illnesses. The factors which trigger immunity include previous infection, immunization and various external stimuli [21]. Based on the function, immune system has been categorized in two broad sections, innate immune system and adaptive immune system. The innate response is usually triggered when microbes are identified by “Pattern Recognition Receptor” (PRR), which recognizes components that are conserved among broad groups of microorganisms while the adaptive immune system is antigen-specific and requires the recognition of specific antigens [22].

Immunomodulators refer to those substances capable of inducing, amplifying and inhibiting any component or phase of the immune system. Immunostimulators and immunosuppressants are two types of immunomodulators known [23]. The function and efficiency of the immune system are influenced by various exogenous and endogenous factors resulting in either immunosuppression or immunostimulation to control auto-immune disorders when excessive tissue damage occurs. Several agents possessing an activity to normalize or modulate pathophysiological processes are called immunomodulators [24].

The immunomodulatory characteristics of plant-based therapeutics have gathered attention of researchers. Innovative technologies and the excessive research on immunomodulatory natural products, plants, their extracts and their active moieties with immunomodulatory potential, may provide us with valuable entities to develop as novel immunomodulatory agents to supplement the present chemotherapies [25]. An example of immunomodulatory drugs is thalidomide and lenalidomide which are used in the treatment of auto immune disease like multiple sclerosis.

3.1. Immunological Properties of Plants

Plants have been identified as the most important source for the curability of various diseases in the form of medicines [26]. Plants are the main source of drugs used from the ancient times as herbal remedies for health care, prevention and cure of various diseases and ailments. Plants secondary metabolites such as terpenes, phenolics and nitrogen containing compounds have been implicated for most plants therapeutic activities [27]. The prevention and treatment of diseases using plant-based medicines have been reported in human history. In all cultures and through all ages different parts (such as bark, root and leaves) of a huge number of plants have been used as drugs against all kinds of ailments. For example, Vinblastine, vincristine and their semi-synthetic derivatives isolated from the Madagascar periwinkle (*Catharanthus roseus*) have been used as chemotherapy medication to treat a number of types of cancer, which include acute lymphocytic leukemia, acute myeloid leukemia and small cell lung cancer [28]. Capsaicin from chili peppers (*Capsicum* species), is a neuropeptide releasing agent selective for primary sensory peripheral neurons. Used typically, capsaicin aids in controlling peripheral nerve pain [29].

Paclitaxel from Pacific yew (*Taxus brevifolia*) is a chemotherapy medication used to treat a number of cancers, lung cancer, kaposi sarcoma, cervical cancer and galantamine from the Caucasian snowdrop (*Galanthus caucasicus*) are examples of medicines based on plant compounds [30]. The plant-based compounds that served as lead structures and/or were chemically altered are dicoumarol (0.1 %) which is found in spoiled sweet clover (*Melilotus officinalis*), artemisinin (0.02 %) derived from wormwood (*Artemisia annua*), camptothecin (2.46 %) derived from Camptothec (*Camptotheca acuminata*), morphine (0.5 %) derived from opium poppy (*Papaver somniferum*) and salicylic acid (0.03 %) derived from willow tree (*Salix alba*) [31]. Recently the clinical potential of six plant-derived anti-inflammatory compounds: curcumin, colchicine, resveratrol, capsaicin, epigallocatechin-3-gallate (EGCG), and quercetin have been highlighted by Fürst and Zündorf [32].

3.2. Immunological Properties of Watermelon

Watermelon (*Citrullus lanatus*) is a popular staple summer fruit in the world which is consumed frequently as a dessert, fruit salad and in garnishing drinks. It is a natural source of antioxidants [33]. Watermelon (*Citrullus lanatus*) is an unusual fruit source of the carotenoid lycopene and a rich source of phenolic antioxidants and contains cucurbitacin E; a triterpene anti-inflammatory phytonutrient. Watermelon contains unusual amounts of the amino acids and citrulline [34]. Watermelon is also an excellent source of immune-supportive vitamin C and vitamin A (9.0 mg), potassium (11.2 mg) and magnesium (10.2 mg).

The nutritional profile of watermelon is full array of nutrients, including carbohydrates (127 g), sugar (6.2 g), soluble and insoluble fiber (0.4 g), and sodium (1 mg) among others [19]. The consumption of watermelon fruit juices could have both positive and negative effects on consumers. As a result, consumption of watermelon provides long-term health benefits such as reduced risk of heart disease, improved blood pressure in hypertension patients and decrease low-density lipoprotein (LDL) oxidation [10].

However, watermelon is an excellent source of water and an equally great source of dietary fibre. Hence, consuming contaminated juice of the fruit may give rise to infection of digestive systems like diarrhoea [17]. The fruit supplies an excellent medium for the growth of both pathogenic and spoilage microorganisms. Watermelon fruit juices processed under hygienic conditions could play important role in enhancing consumer's health through inhibition of breast cancer, congestive heart failure (CHF) and urinary tract infection [35].

Freshly extracted watermelon juices may not always be safe owing to the heavy load of microbes [36]. Major ingredients of juices such as water, sugar and natural fruit pulp may also carry some microbial contaminants which may cause spoilage of the drinks or gastrointestinal disorders to consumers [37]. Development of new products where two or more kinds of fruit juices are blended to obtain a product that combines the nutritional value of both fruits with the benefit of a pleasant taste has been encouraged by the food industry and has been well accepted by consumers [38].

3.3. Anti-oxidant Properties of Watermelon

The therapeutic effects of *C. lanatus* fruit have been reported and attributed to certain phytochemical compounds [39]. For instance, beta carotene and lycopene have been established to play a key role in the treatment of cancer and cardiovascular diseases [40]. The therapeutic effect of watermelon has been ascribed to its ability to scavenge free radicals [41,42]. Lycopene is an acyclic isomer of β -carotene. It has been demonstrated to play a prominent role in the treatment and management of ailments such as cancer and cardiovascular diseases [42], also reported as having analgesic and anti-inflammatory effects [43,44], with anti-ulcerative activity [45,46], antimicrobial activity [47], laxative activity of the fruit and hepatoprotective [43].

In vitro antioxidant studies have been conducted to screen various plant containing phenolic and flavanoids constituents [2,48]. Plant derived antioxidant compounds, flavonoids and phenolics have received considerable attention because of their physiological effect like antioxidant, anti-inflammatory, antitumor activities and low toxicity compared to those of synthetic phenolic antioxidants such as butylated hydroxyanisole, butylated hydroxytoluene and propyl gallate [49,50].

4. Watermelon Phytochemicals and their benefits to Human Health

Fresh fruits and vegetable juices are important parts of modern day diet in many parts of the world as they are rich sources of nutrients such as vitamins, minerals and other naturally occurring phytochemicals which are of health and therapeutic benefits [51]. Fruit and vegetable intake has been found to reduce the incidence of some chronic diseases such as atherosclerosis and cancers [52,53]. The reason for this relationship appear to be multi-faceted and include compounds in plants that are used as electron scavengers (such as lycopene and β -carotene), detoxification agents (such as halothane and isoflurane), or as plant defense response compounds (e.g., terpenoids, phenolics and alkaloids).

Consumption of food rich in phytochemicals (such as phenolics found in citrus fruits and lycopene found in tomato products and watermelon) has long-term benefits to human health [54]. Phytochemicals such as lycopene and β -carotene have been shown to have antioxidant, anti-inflammatory and hypotensive properties; therefore, their inclusion on diet results in positive effects on the human body. They prevent oxidative changes in the plasma lipoprotein structure by preventing the formation of enzymes involved in cholesterol synthesis [54], prevent macular degeneration and the development of cataracts through anti-inflammatory mechanisms [55] and reduce the nitrogen oxide bioavailability by scavenging the oxidation reaction and they synthesize prostacyclin which causes blood vessels to relax and become reduced. Within the enterocytes, uncleaved carotenoids and retinyl esters (derived from retinol) are incorporated into triglyceride-rich lipoproteins called chylomicrons secreted into lymphatic vessels, and then released in the bloodstream [56]. They may also enhance the immune system function and inhibit tumor progression in some cancers [57].

4.1. Lycopene

Lycopene, a red pigment of the carotenoid class found in only a few fruits and vegetables, is a powerful oxygen radical scavenger and highly effective antioxidant [58]. A high dietary intake of tomatoes, rich in lycopene content, is associated with a lower risk of certain cancers, primarily of the prostate [59]. Watermelon and tomatoes are the most familiar sources of lycopene containing on average 48.6 and 30.1 μg lycopene/g fresh weights respectively [60,61]. It is visible as a red pigment that gives fruits such as watermelon, guava, red bell peppers and tomato their desirable colour and contributes to about 21–43 % of the total carotenoids, accumulated in the human tissue [7,48,54]. Therefore, it is incorporated into the body through diet. The estimated recommended lycopene intake in developed countries is 5–7 mg/day and it is assumed that approximately 10–30 % lycopene is absorbed in the human body [62]. After consumption, lycopene enters the stomach for digestion; it changes into a lipid phase, which is dispersed under the influence of bile salts and pancreatic lipases [63, 70].

Lycopene is a strong antioxidant; therefore, it is an effective free radical scavenger and oxygen quencher among all carotenoids [64]. Lycopene-scavenging rate is higher than β -carotene and tocopherol [1,65]. Watermelon contains the highest bioavailable lycopene which is about 60 % more than that found in tomato making it the lycopene leader among fresh produce [66].

Lycopene is a type of carotenoid that serves as antioxidant. Lycopene imparts red colour in watermelon though its contents varies in watermelon however, the amounts are generally greater than that of tomato. Lycopene lowers the risk of some types of cancer. It helps to reduce cancer risk by lowering insulin-like growth factor. It also helps to lower cholesterol and blood pressure [67]. Lycopene has been classified as useful in the human diet for prevention of cardiovascular diseases as well as certain types of cancer and may protect the skin from ultraviolet light damages [68]. The red-fleshed watermelon varieties contain high lycopene (3.38–11.34 mg/100g) and varying amount of β -carotene (3.38–11.34 mg/100g). The quantity of lycopene varies depending upon the variety and growing conditions [69]. Lycopene has potential to prevent various ailments like dyslipidemia, diabetes, neurodegenerative diseases, osteoporosis among others [6,66].

Thermal processing induces isomerization of lycopene bioavailability [70]. Lycopene has become a compound of interest to both food and health researchers due to its reported benefits on human health. Lycopene has a higher ratio of 1:12 to carotene in watermelon and this yields remarkable antioxidant capacity. It bears significant potential for consideration in both the treatment and the prevention of some chronic diseases such as heart disease. According to this specific characteristic, foods high in lycopene are referred to as functional foods [71].

Recently, the demand for natural form of lycopene has increased, mainly because it is effective at curbing the destructive free radicals including nitrogen dioxide, sulfide, singlet oxygen and inhibiting DNA and cellular membrane damage [72]. Because of its antioxidant functions, it reduces lipids by preventing the formation of enzymes involved in cholesterol synthesis [71]. The consumption of fruits that are rich in lycopene such as watermelon is therefore considered pivotal due to the role it plays in prevention of chronic diseases; it is nontoxic without known side effects.

4.2. B-Carotene

Beta (β -) carotene is a lipophilic macronutrient and an insoluble vitamin which includes a group of unsaturated nutritional organic compounds including retinoic, retinal and retinol [73]. It is made of 40 carbon atoms and contains 11 conjugated and 2 unconjugated double bonds [63]. Beta (β -)carotene has a very low solubility in a number of solvents such as water and ethanol due to its highly conjugated long chain [74]. Visible as the orange color in fruits and vegetables, it serves as a precursor for vitamin A in a human body [75]. Beta-carotene cannot be synthesized by the body; therefore, it is primarily derived from plant-based foods such as watermelon, carrots, sweet potatoes, spinach, and mangoes [76].

Watermelon contains substantial quantities of β -carotene (461 μg) found in a cup of diced watermelon [75]. It has the ability to exhibit both antioxidant activity and pro-oxidant properties [77]. Because of these properties, β -carotene has desirable power in inactivating certain Reactive Oxygen Species (ROS) and it exerts neuroprotective effect against LDL and HDL [4]. The antioxidant potential of β -carotene has been widely investigated and some positive results have been reported [78]. Among other important effects on human health, β -carotene intensifies platelet aggregation increasing the growth factor expression, which leads to the reconstruction of blood vessel walls [63]. Among other functions, it has been shown to be important for the maintenance of the immune system; it supports cell growth and differentiation playing a role in the formation and maintenance of the heart, kidney and other organs [79].

Beta (β -) carotene- enriched diet neutralizes the damaging molecules which results in defying age naturally [48, 80]. It helps the body to absorb light in the eyes for good vision and further functions as growth factor for epithelial cells and modulates gene function mainly due to the enzyme di-oxygenase, which is present in the human small intestine mucosa and it converts β -carotene into retinol [63]. Beta (β -) carotene is also known for its potential anticancer attributes [81]. This is because it may interact with other phytochemicals in fruits and vegetables and have a greater effect on the body than do supplements. It plays an important role in reducing the risk type 2-diabetes and lowering metabolic syndrome in middle-aged adults [82]. Children, pregnant and lactating women are reported to be the most vulnerable groups to vitamin A deficiency [83]. Due to the health benefits of this phytochemical, the demand for it as an additive in functional food applications as well as a supplement is growing.

4.3. Vitamins

The amount of Vitamin A in watermelon ranged between 569 and 864.88 IU. This vitamin has been reported to enhance optimal functioning of the eyes. The deficiency in vitamin A has been reported to produce highest effects in children, pregnant and lactating women [84]. Watermelon is rich in vitamin B (13.53 mg/100g) and responsible for the production of energy in the body. Taking into consideration these health-promoting parameters, watermelon extracts such as Vitamin C, Amino acids and lycopenes are powerful antioxidants which can be incorporated into cosmetics, food, and pharmaceutical products [85, 86].

The presence of vitamin C (ascorbic acid) has been reported to be higher in the rind of watermelon compared to its pulp. Ascorbic acid is water-soluble and have being reported to take an active roles in many biological processes. Apart from its antioxidant property, ascorbic acid has high scavenging ability for free radicals generated in the cells during catabolic activities and oxidative stress. The antioxidant properties of the fruit makes it to serve medicinal purpose apart from its nutritional quality [87,88]. Vitamin C also reduces serum alanine amino-transferase and the risk of inadequacy or adverse health effects. It protects the body against diseases like scurvy and simple cold [84].

Vitamin C is used as a general description for all organic compounds exhibiting biological activity of ascorbic acid [89]. It has two main components which are ascorbate and dehydroascorbic acid [90]. Vitamin C is a water-soluble essential nutrient that is frequently added to a variety of food products for nutrient enhancement and supplementation important for biosynthesis of collagen and certain hormones [91].

Watermelon has been identified a good source of vitamin C [10], with the fresh juice containing about 3.72 mg/100 mL [66]. As with other parameters, the vitamin C content varies due to difference in the watermelon cultivars and

environmental factors. For example, a cup of watermelon juice contains 20 % of the daily value for vitamin C. Ten (10 mg) milligram dosage daily of vitamin C will prevent nutritive deficiency and scurvy. However, 90–500 mg daily is recommended for optimal benefits [84].

Vitamin C may improve the quality of life for cancer patients in several potential mechanisms. Patients with cancer usually suffer from vitamin C deficiency and are exposed to very high oxidative stress [92]. Therefore, oral intake of this vitamin through natural sources may relieve fatigue and various other symptoms caused by a state of chronic vitamin C deficiency in these patients [22].

The other mechanism is that vitamin C has anticancer properties, therefore, consumption of foods that contain this vitamin C may suppress cancer cell in patients by generating pro-oxidant activity, depending on blood concentrations [3, 93]. It has long been reported beneficial in the prevention and treatment of a variety of ailments, scurvy, simple cold as well as being stress resistant [94]. A proper intake of vitamin C-enriched diet over a lifetime will help to maintain our current health and prevent future ailments [1,95]. As with other phytochemicals, consumption of natural vitamin C is recommended as opposed to synthetic ones in the form of supplements.

4.4. Cucurbitacins

Watermelon (*Citrullus* spp.) is one of the most popular sweet fruits and accounts for 7 % of the area worldwide devoted to fruit and vegetable production. Watermelon possesses a wide range of medicinal potentials. Due to the bioactive compounds, cucurbitacins found in watermelon fruits can play an important role in the improvement of disorders like indigestion, dysentery, gastroenteritis, cold, toothaches and diabetes as well as in wound healing, as reported in Pakistan, India, China, other parts of Asia and Africa [96].

Cucurbitacins are a group of tetracyclic triterpenes with a cucurbitane skeleton that were initially identified in the *Cucurbitaceae* family [97]. There are more than 10 classes of cucurbitacins and their derivatives [98]. The cucurbitacins are abundant in *Cucurbitaceae* family members and have been found useful as inhibitors of cancer cells, inhibit actin polymerization, capillary permeability and also serve as anti-inflammatory [99]. Cucurbitacins are generally bitter in taste and at low concentrations in watermelon species its sweet taste also exhibits very low bitter flavors. Cucurbitacin diversity or the presence of their derivatives in different *Citrullus* species has been responsible for their phytomedicinal applications.

4.5. Citrulline

Citrulline is a non-protein amino acid that is reported to be abundant in watermelon [89]. Citrulline is considered a potent osmolyte and radical scavenger against drought/salt stress [72]. Citrulline is found in a watermelon, varying in amounts from 0.7 to 3.6 mg/g fresh fruit. A recent study done on 56 cultivars found the mean value of citrulline as 3.1 mg/g that shows no correlation with cultivar type. Research is still ongoing to determine which part of the watermelon contains more citrulline than the other [99,100]. L-citrulline has been reported to conjugate with as many other NO-boosting supplements nitric oxides in a better way than L-arginine. Reduction in/or lack of nitric acid production could lead to the development of essential hypertension, heart failure reduction of skeletal muscle metabolism that may progress to development of insulin resistance and type 2 diabetes and other age-related muscle wasting [101]. L-citrulline may have a positive impact on endothelial vasodilatory function because it is efficiently converted to L-arginine and consequently transformed to nitric oxide [102].

The amino acid, citrulline has been studied by medical researchers for their usefulness in sickle cell anaemia, immune function, wound healing and cardiovascular health [103]. Citrulline, a non-essential amino acid, is a precursor of arginine, a semi-essential amino acid needed by infants and seriously ill or injured adults [104]. Watermelon is a unique source of amino acids [105]. Citrulline is produced naturally in the body by an enzymatic reaction of nitrogen-carbon contained l-glutamine and mainly absorbed in the intestine [106].

Plasma nitric oxide is rapidly metabolized to nitrite and nitrate, which have as been considered as precursors for nitric oxide synthesis in the cell [107]. L-citrulline and watermelon supplements on vascular and metabolic physiology and their potential therapeutic impact on cardiometabolic health have been reported. L-citrulline also has direct and indirect effects on skeletal muscle and adipose tissue metabolism, which are key mediators for the development of cardiometabolic disorders. The health-related applications of L-citrulline supplementation are largely predicated on the capacity for L-citrulline to increase L-arginine availability for nitric oxide production [43]. As an efficient hydroxyl radical scavenger and strong antioxidant, a diet rich in citrulline is associated with several health benefits [7]. Citrulline was found to be efficient in sections such as skeletal, pharmacology, immunology and neurology. It is important for

young adults with trauma, burn injury, massive small bowel resection, and renal failure [93]. It has also been found to be important in the prevention of anaemia [95].

5. Total Polyphonic Content

Polyphenols, commonly known as polyphenolic compounds, are defined as structural class organic chemicals characterized by the presence of large multiples of phenol structural units including phenolic acids, flavonoids, stilbenes, and lignans [108,109]. Scientific evidence has suggested that due to their antioxidant properties, daily consumption of foods and beverages rich in polyphenols induces positive effects on human health, which results in having specific biological activities affecting gene expression, cell signaling and adhesion [110]. They are the most dominant antioxidants in a diet derived from fruits and vegetables. They have the ability to stop the formation of ROS (Reactive Oxygen Species) in a human body.

However, the health effects of polyphenols depend on both their respective intakes and their bioavailability [110]. Thus, consumption of watermelon juice can serve as a medicinal alternative [6]. Polyphenols have evoked considerable interest among nutritionists, food manufacturers, and consumers because of their safety and potential therapeutic value due to the natural compounds such as lycopene and β -carotene which are also present in watermelon [48].

6. Future Perspectives

Even though watermelon (*Citrullus lanatus*) was found to be the highest source of lycopene and citrulline among all fruits, research has found that at least 85 % of our dietary lycopene is supplied by tomato and tomato based products; therefore, there is a need to produce more watermelon-based products. Since watermelon shows compatibility with other fruits, it can be used together with those fruits to manufacture products that are more commercial. Research has indicated that the lycopene content of watermelon is not totally depleted by processing methods [111]. Therefore, lycopene can be extracted from the watermelon to be used in pharmaceuticals and food manufacturing industries as an ingredient. Monitoring quality attributes of watermelons during processing is still an ongoing research in order to produce high-quality products [112]. Moving forward into the future, it is important to determine the internal qualities of watermelon as affected by maturity and processing in order to provide intensive understanding to food processors..

7. Conclusion

The production of juice from watermelon (*Citrullus lanatus*) is important in that it will reduce wastage of the fruits by farmers and provide vitamins, minerals and the anti-oxidant compound (lycopene) to their respective consumers. It also reduces loss to economy of the country. This study has proved that watermelon juice contains some beneficial nutrients and therefore, its production should be encouraged.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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