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Foods Containing Vitamin C and Their Health Benefits

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Abstract: Vitamin C (VC) is a water-soluble vitamin essential for human health. Since humans lack the ability to synthesize VC endogenously, it must be obtained through dietary intake. Absorption primarily occurs in the small intestine. When administered at pharmacological doses, VC has been shown to alleviate oxidative stress and inflammation, thereby contributing to the restoration of endothelial and organ function. In cases of deficiency, a potentially fatal disease called scurvy can develop, which is characterized by impaired collagen synthesis. This condition is effectively treated only through VC supplementation. This study focuses on the antioxidant properties of VC and its roles in immune function, as well as its effects on common colds, sepsis, and organ damage. Additionally, the health benefits of VC-rich vegetables and fruits particularly rose hips, citrus fruits, parsley, and tomatoes are highlighted.

1. Introductıon

Vitamin C (VC), also known as L-ascorbic acid or ascorbate, is a water-soluble vitamin (Travica et al., 2017). It is synthesized from glucose in many living organisms. In mammals, this biosynthesis occurs in the liver, while in reptiles, it takes place in the kidneys. However, in humans, the gene responsible for encoding the enzyme L-gulono-γ-lactone oxidase, which is involved in the final step of VC biosynthesis, has lost its functionality (Kaplan and Gönül, 2010). Consequently, humans are unable to synthesize VC and must obtain it through dietary intake. VC is absorbed in the gastrointestinal tract through a saturable transport mechanism. At a dosage of 1 gram, the absorption rate is approximately 75%; however, bioavailability decreases inversely at higher doses. After absorption, VC is widely distributed throughout the body, including within intracellular compartments. The typical plasma concentration is around 1 mg/dL, with significantly higher concentrations found in platelets and leukocytes compared to plasma. When administered at daily doses of 75 mg or more, VC saturates body tissues (Akıcı et al., 2012). Excess VC is filtered through the glomeruli of the kidneys, and any amount that exceeds the reabsorption threshold is excreted in the urine. VC is eliminated slowly, with a half-life of approximately 16 days. This slow elimination accounts for the delayed onset of scurvy symptoms in cases of deficiency. A portion of VC is converted to oxalic acid in the liver, contributing to urinary oxalate levels. Additionally, VC is partially metabolized through sulfation (Akıcı et al., 2012).

VC as an Antioxidant; VC is recognized as the most important antioxidant in extracellular fluids, where it plays a critical role in protecting tissues from oxidative damage. In addition to its extracellular activity, VC also exhibits intracellular antioxidant functions. Its antioxidant effect is primarily achieved through its ability to bind strongly to reactive oxygen species (ROS)—such as hydrogen peroxide, singlet oxygen, hydroxyl radicals, and superoxide anions—effectively neutralizing these harmful free radicals. By doing so, VC contributes to maintaining cellular integrity and preventing oxidative stress-related cellular dysfunction (Aktaş and Armağan, 2019; Aktaş al., 2020; Aktas and Bayram, 2020; Aktas and Ozgocmen, 2020; Aktaş and Sevimli, 2020; Aktas and Gur, 2021).

2. Vitamin C and Immune Function

The immune system is composed of specialized organs, tissues, cells, proteins, and signaling molecules that collectively function to protect the host from pathogens such as bacteria, viruses, parasites, and fungi. Given the limited storage capacity of VC in the human body, regular and sufficient dietary intake is essential to prevent hypovitaminosis (Carr and Maggini, 2017; Aktaş and Satılmış, 2025).

A daily intake of 100–200 mg of VC is considered sufficient to saturate plasma concentrations and has been associated with a reduced risk of chronic diseases. During disease states, VC contributes to immune defense through several mechanisms:

- Enhancing chemotaxis and supporting lymphocyte proliferation
- Promoting bactericidal activity of leukocytes
- Exhibiting bacteriostatic effects by inhibiting bacterial replication
- Reducing lipopolysaccharide-induced lung injury in sepsis
- Preventing apoptosis of endothelial progenitor cells, thereby maintaining vascular health and immune surveillance

In conditions of VC deficiency, natural killer cell-mediated cytotoxicity is delayed, primarily due to suppressed cytotoxic T cell activity, which impairs effective bacterial clearance. These findings highlight the critical role of VC in both innate and adaptive immunity, and its importance in supporting host defense, especially during infection and inflammation (Teng et al., 2018).

3. The Health Importance and Sources of Vitamin C

In experimental models of trauma, ischemia-reperfusion injury, and sepsis, VC administered at pharmacological doses has been shown to restore endothelial and organ function by alleviating oxidative stress and inflammation (Spoelstra-de Man et al., 2018). In cases of deficiency, scurvy, a potentially fatal condition characterized by impaired collagen synthesis and connective tissue damage, develops. Notably, scurvy can be fully reversed with VC supplementation alone (Padayatty and Levine, 2016). VC is naturally found in a variety of plant-based foods, including: Tomatoes, citrus fruits (oranges and lemons), green leafy vegetables, various fruits, mMilk (in smaller amounts). However, it is important to note that pasteurization significantly reduces the VC content in milk due to its heat sensitivity. For example, orange and lemon juices contain approximately 0.5 mg of VC per milliliter (Kaya et al., 2013). This study highlights the importance of VC for human health, its therapeutic effects in various diseases, and identifies key fruits and vegetables that serve as rich dietary sources of this essential nutrient.

4. Vitamin C and Diseases

During periods of infection and physiological stress, the concentration of VC in the body rapidly declines due to increased metabolic demand. Supplementation under these conditions has been shown to enhance immune system function and increase resistance to infections (Ran et al., 2018).

In the context of bacterial infections, VC contributes to the immune response by:

- Enhancing chemotactic activity of immune cells
- Supporting lymphocyte proliferation, which strengthens adaptive immunity
- Assisting leukocytes (especially neutrophils) in the phagocytosis and destruction of bacteria

Furthermore, VC exhibits bacteriostatic activity by inhibiting bacterial replication, which limits the spread and severity of infection. These effects collectively underscore the critical role of VC in host defense, particularly during infectious disease processes (Teng et al., 2018).

4.1. Vitamin C in common cold, covid-19, and wound healing

The common cold is primarily characterized by symptoms such as nasal congestion, fever, sore throat, cough, and fatigue. Clinical studies have shown that the incidence and duration of colds can be reduced with VC supplementation. Specifically, the administration of 1 g/day of VC to school-aged children significantly decreased the frequency and duration of cold episodes (Hemilä, 2017). In the context of COVID-19, which can lead to acute respiratory distress syndrome (ARDS), the disease mechanism involves free radical formation, cellular damage, and ultimately multi-organ failure and death (Carr, 2020). In such cases, high-dose intravenous VC has been found to exert protective effects, particularly in sepsis-induced ARDS. It does so by:

- Strengthening the alveolar epithelial barrier
- Supporting protein channels that regulate alveolar fluid clearance, thereby improving pulmonary function (Kakodkar et al., 2020)

For general health maintenance and chronic disease prevention, a daily dietary intake of 100–200 mg of VC is recommended. Since VC is water-soluble and has limited storage capacity in the body, regular and adequate consumption is essential to avoid hypovitaminosis (Carr and Maggini, 2017). VC also plays a vital role in wound healing by stimulating collagen synthesis, an essential process in tissue repair. To accelerate healing in such cases, daily doses of 500 mg to 1.0 g of VC are recommended (Naidu, 2003).

4.2. Obesity and the role of vitamin C

Obesity is defined as an excess accumulation of adipose tissue in the body. In adults, the normal fat mass is approximately 15–18% in men and 20–25% in women. When this percentage exceeds 25% in men and 35% in women, the condition is classified as obesity (Gülcan and Özkan, 2006). Obesity typically results from excessive energy intake combined with insufficient energy expenditure, leading to an increase in white adipose tissue. The expansion of white adipocytes is often accompanied by elevated oxidative stress, which plays a key role in the development of metabolic syndrome complications (Garcia-Diaz et al., 2014). This condition is a major risk factor for chronic diseases, including type 2 diabetes**,** cancer, and cardiovascular diseases (CVDs) (Ellulu, 2017). VC, through its antioxidant properties, can modulate several pathophysiological mechanisms associated with obesity. Its beneficial effects include:

- Scavenging of ROS generated during free fatty acid oxidation
- Regulating nitric oxide synthesis
- Inhibiting excessive ROS production
- Enhancing the activity of antioxidant enzymes

These mechanisms contribute to the protective effects of VC against oxidative damage, inflammation, and metabolic disturbances commonly observed in obesity. Therefore, maintaining sufficient VC levels may play a supportive role in obesity management and the prevention of its associated comorbidities (Ellulu, 2017).

4.3. Cardiovascular diseases and the role of vitamin C

CVDs encompass a range of conditions, including coronary heart disease, cerebrovascular disease, and rheumatic heart disease. It is estimated that four out of every five CVD-related deaths are caused by heart attacks and strokes. The primary underlying mechanism of CVD is atherosclerosis**,** a condition characterized by the narrowing and hardening of arteries due to the accumulation of atheromatous plaques. These plaques can eventually lead to partial or complete arterial blockage caused by blood clots**,** which restrict blood and oxygen flow to tissues. This ischemia may result in tissue damage or organ failure.

- Major risk factors for atherosclerosis include: Aging-related arterial stiffness
- Smoking
- Hyperglycemia and hyperlipidemia
- Obesity
- Hypertension

In the development of atherosclerosis, macrophages absorb low-density lipoprotein (LDL) cholesterol and convert it into foam cells, which contribute to vascular blockage. VC helps prevent CVD by inhibiting LDL oxidation, thereby slowing down the formation of foam cells (Al-Khudairy et al., 2017). Furthermore, in the early stages of atherosclerosis, monocytes adhere to the endothelial wall, leading to thickening and reduced elasticity of the vascular lining. VC intake has been shown to decrease monocyte adhesion, thereby helping preserve vascular integrity (Al-Khudairy et al., 2017).

VC also contributes to cardiovascular health through additional mechanisms:

- Stimulating type IV collagen production in the vascular basement membrane
- Promoting endothelial cell proliferation
- Preserving nitric oxide (NO) bioavailability in endothelial cells
- Preventing endothelial apoptosis
- Scavenging ROS, thus reducing oxidative stress

Collectively, these effects highlight VC 's protective role in cardiovascular health and its potential as a supportive nutrient in the prevention and management of CVD (Al-Khudairy et al., 2017).

4.4. Cancer and the role of vitamin C

Cancer is a complex disease characterized by uncontrolled cell proliferation, and it arises from the interaction of both genetic predispositions and environmental influences (Uçak and Kızıltan, 2021). In many individuals with advanced-stage cancer**,** VC deficiency is frequently observed. This deficiency may be attributed to multiple factors, including:

- Inadequate dietary intake of VC-rich foods
- Reduced gastrointestinal absorption or bioavailability
- Increased metabolic consumption of VC due to disease burden

- Elevated oxidative stress levels in cancer-affected tissues (Chen et al., 2015)

VC exhibits several well-documented anti-cancer mechanisms, such as:

- Protecting against DNA and molecular damage
- Modulating gene expression
- Inducing apoptosis in malignant cells via regulation of cellular signaling pathways
- Inhibiting abnormal cell proliferation and metastasis (Schlueter et al., 2011)

In addition to its direct effects on tumor biology, VC may improve the quality of life in cancer patients. Clinical studies have reported that VC supplementation can alleviate common symptoms associated with both cancer and chemotherapy, including: Fatigue, insomnia, loss of appetite, nausea, pain (Carr et al., 2014). These findings underscore VC's potential as a complementary agent in cancer management—both in slowing disease progression and in symptom relief, thereby improving patient well-being and treatment outcomes**.**

4.5. Diabetes mellitus

Diabetes mellitus is a metabolic disorder characterized by impaired insulin secretion from the β-cells of the pancreatic islets of Langerhans and hyperglycemia resulting from decreased sensitivity to insulin. The underlying mechanisms include defects in insulin action in peripheral tissues, insufficient insulin secretion, or a reduced cellular response to insulin (Aktaş and Gür, 2021b). Over time, chronic hyperglycemia can lead to severe complications, including damage to blood vessels, the heart, kidneys, eyes, and nervous system (Franke et al., 2013). VC supplementation has been shown to mitigate glucose-induced oxidative stress (glucotoxicity) and may help preserve pancreatic β-cell function (Dakhale et al., 2011). Moreover, a diet rich in VC-containing fruits and vegetables is considered beneficial for diabetes prevention and overall metabolic health (Christie-David and Gunton, 2017).

4.6. Eye diseases

VC plays a vital role in maintaining the structural integrity of blood vessels and connective tissues within the eye. Due to the high metabolic activity in ocular tissues, the eye is particularly vulnerable to oxidative stress. VC acts as a powerful antioxidant by neutralizing free radicals and preventing oxidative damage (McCusker et al., 2016). As a result, adequate VC intake has been associated with a reduced risk of developing advanced cataracts, age-related macular degeneration, and glaucoma (Raman et al., 2017).

4.7. Neurodegenerative diseases and psychiatric disorders

VC plays a crucial role in the body's response to stress and is found in high concentrations in the adrenal cortex. Its levels fluctuate according to adrenal activity, with stimulation by adrenocorticotropic hormone and increased steroidogenesis leading to a reduction in VC content (Akıcı et al., 2012). During periods of stress and infection, VC contributes to hormonal regulation, supporting the body's stress response. Oxidative stress is a significant contributing factor to the development of cognitive impairments such as memory loss, impaired reasoning, and decreased problem-solving ability, particularly in older adults. The brain is highly susceptible to oxidative stress due to its high oxygen consumption and abundance of oxidation-prone polyunsaturated fatty acids. As a potent antioxidant, VC is considered an essential neuroprotective molecule (Tardy et al., 2020).

VC influences several components of the nervous system, including neurotransmitter receptors, glial cells, myelin synthesis, and the processes of neuronal maturation and differentiation (Ballaz et al., 2019). The brain's neuroendocrine tissues contain the highest concentrations of VC in the body. In neurological disorders—often marked by excessive free radical production—VC has shown therapeutic potential by modulating oxidative damage and preserving neuronal function (Kocot et al., 2017).

Moreover, VC has been found to reduce the accumulation of amyloid-beta, enhance the differentiation of neural stem cells into dopaminergic neurons, and protect neurons against glutamate-induced excitotoxicity, thereby slowing the progression of neurodegenerative conditions such as Parkinson's disease and dementia (Uğur et al., 2020). In multiple sclerosis, characterized by damage to the myelin sheath of neurons, VC supports collagen synthesis, a process linked to myelination, and may thus contribute to slowing disease progression (Eldridge et al., 1987). VC deficiency is also associated with psychological disturbances, including depression, melancholy, and mood disorders. These effects may be related to impaired dopamine synthesis, oxidative stress, disrupted neurotransmitter activity, and altered cortisol regulation (De Oliveira et al., 2015).

4.8. Bone diseases

VC is essential for the development and maintenance of tissues of mesenchymal origin, including bone, connective tissue, dentin, and cartilage. It plays a crucial role in collagen synthesis, particularly type I collagen, which is the primary structural component of the extracellular matrix in bone. VC also contributes to the structural integrity of capillaries by facilitating the interconnection of endothelial cells and the formation of the pericapillary matrix. Moreover, VC stimulates both collagen production and the differentiation of osteoblasts—the cells responsible for bone formation. Through its antioxidant properties, VC helps to neutralize free radicals, thereby reducing oxidative stress that contributes to bone resorption and the progression of osteoporosis (Malmir et al., 2018). In addition to its structural and antioxidant roles, VC is necessary for the activity of two dioxygenase enzymes involved in carnitine biosynthesis, which is critical for energy production through mitochondrial β-oxidation. Inadequate VC intake can impair carnitine metabolism, potentially leading to fatigue and musculoskeletal pain due to compromised energy delivery to muscle tissue attached to bones (Johnston, 2012).

4.9. Skin diseases

When applied topically, VC plays a protective and therapeutic role in skin health by neutralizing ROS generated from environmental factors such as ultraviolet (UV) radiation, cigarette smoke, and air pollution. This antioxidant activity aids in the repair of oxidative damage and supports skin regeneration. VC is also effective in the treatment of hyperpigmentation disorders, including melasma and sunspots. This effect is attributed to its ability to inhibit the enzyme tyrosinase, a key regulator in the melanogenesis pathway, thereby reducing melanin synthesis (Caritá et al., 2020). In addition to its anti-pigmentation properties, VC contributes to skin resilience by stimulating collagen synthesis, which improves skin elasticity and reduces the appearance of photoaging (Pullar et al., 2017). VC deficiency can lead to delayed wound healing, which is associated with impaired collagen production. It also results in epidermal thickening and subcutaneous hemorrhage due to weakened connective tissue structure (Ellinger et al., 2009). Prolonged exposure of the skin to UV radiation leads to inflammation, pigmentation changes, structural degradation, and, in severe cases, the development of skin cancer. VC provides a protective barrier against such damage, making it an essential nutrient for maintaining skin integrity and preventing photoinduced dermal disorders (Blume-Peytavi et al., 2016).

4.10. Reproductive system diseases

The testes are particularly sensitive to fluctuations in VC levels. Adequate VC intake has been shown to significantly enhance male reproductive health by improving sperm quality.

Specifically, increased VC levels contribute to greater sperm viability, enhanced motility, and a higher total count of mature sperm. In contrast, VC deficiency is associated with increased sperm abnormalities and agglutination (stickiness), which can impair fertility. These findings highlight the importance of VC as an antioxidant that protects spermatozoa from oxidative stress and supports overall reproductive function (Millar, 1992).

4.11. Scurvy

Scurvy is a clinical condition resulting from a prolonged deficiency of VC in the diet. The primary pathological mechanism is impaired collagen synthesis and accelerated degradation of tissues of mesenchymal origin. This leads to increased capillary fragility, resulting in ecchymosis, petechiae, intra-tissue hemorrhages, and delayed wound healing. Clinically, scurvy manifests with symptoms such as gingival inflammation and bleeding, loosening and loss of teeth, perifollicular hyperkeratosis of the skin, impaired bone calcification, epiphyseal swelling, periosteal hemorrhages, and an increased susceptibility to bone fractures. In children, VC deficiency may also cause growth retardation, increased bone resorption, and bleeding into muscles and joints. Additionally, macrocytic anemia may occur due to impaired iron absorption and metabolism. If left untreated, scurvy can progress to severe complications including convulsions, coma, and death. Lobular pneumonia is the most frequently encountered complication, and the primary cause of death is often secondary bronchopneumonia. The minimum daily requirement of VC to prevent the onset of scurvy is approximately 10 mg (Carr and Maggini, 2017).

4.12. Anemia

Anemia is a common manifestation of VC deficiency. In conditions such as scurvy, increased excretion of oxidized folate derivatives contributes to folate deficiency, while capillary fragility leads to recurrent microhemorrhages and hemolysis, further exacerbating the anemic state. VC plays a key role in hematopoiesis through its involvement in the reduction of dietary folic acid to its active form, tetrahydrofolic acid. Additionally, it enhances the absorption of non-heme iron by reducing ferric iron (Fe^{3+}) to the more bioavailable ferrous form (Fe^{2+}) in the acidic environment of the stomach. Through these mechanisms, VC facilitates the uptake of both folic acid and non-heme iron into the bloodstream, thereby helping to prevent and correct anemia associated with its deficiency (Tardy et al., 2020; Uğur et al., 2020).

Table 1. Recommended vitamin C to be taken daily.

Men women stages	**Required daily intake (mg)**
0/6 months	40 mg
Children 7/12 months	50 mg
Children 1/3 years old	15 mg
Children 4/8 years old	25 mg
Children 9/13 years old	45 mg
14/18 years old women	65 mg
14 - 18 years old men	75 mg
Women 19 years and over	75 mg
Men 19 years and over	90 mg
Pregnant women	80/85 mg
Pacifiers	115/120 mg

(Onganer et al., 2020)

5. Foods Containing Vitamin C

5.1. Dietary sources and stability of vitamin C

VC is most abundant in a variety of fruits and vegetables, particularly citrus fruits such as orange, grapefruit, and lemon. It is also richly present in green leafy vegetables including lettuce, spinach, and parsley**,** as well as in tomatoes, rose hips, green peppers, cabbage, broccoli, strawberries, grapes, melons, blackberries, bananas, watermelons**,** and new (young) potatoes**.** For example, freshly squeezed orange juice contains approximately 0.5 mg of VC per milliliter. However, packaged orange nectars are typically diluted and contain significantly lower concentrations of VC.

The stability of VC is influenced by several environmental and processing factors:

- Acidic environments enhance the stability and preservation of VC.
- Exposure to heat, oxygen, and light**,** as well as chopping or long storage of fresh plant-based foods**,** leads to significant degradation of VC content.
- Interestingly, canned vegetables, when properly processed and stored, retain a substantial portion of their original VC content (Akıcı et al., 2012).

Examples of VC -rich fruits include: Black currant, orange, kiwi, papaya, strawberry, lemon, pineapple, grapefruit, mango, pea.

VC -rich vegetables include: Tomato, green and red bell pepper, cauliflower, broccoli, brussels sprouts, parsley (Anonymous, 2021a). These foods are essential components of a VC-rich diet and contribute significantly to maintaining antioxidant defenses and overall health.

Table 2. Average amount of vitamin C in foods (Onganer et al., 2020).

Foods	Amount of VC in foods (mg)
1 (piece) medium-sized kiwi	70 mg
1 large slice of melon	59 mg
1/2 cup cooked brussels sprouts	48 mg
1 medium sized orange	90 mg
1 glass of orange juice	97 mg
1 glass of tomato juice	33 mg
1/2 serving red pepper, raw	95 mg
1 serving of cooked broccoli	74 mg
1/2 serving of strawberries	49 mg
1/2 serving of green pepper	60 mg
1/2 serving of red cabbage	40 mg

5.2. Rosehip (Rosa spp.) and its nutritional properties

Rosehip is the fruit of plants belonging to the *Rosa* genus, within the Rosaceae family. It has long been utilized for both nutritional and medicinal purposes due to its rich content of bioactive compounds**.** Rosehip exhibits potent antioxidant and antimicrobial properties. These biological activities are primarily attributed to its high levels of: Polyphenols, vitamin C, Vitamin E, Vitamin B complex.

In addition to its antioxidant capacity, rosehip also demonstrates anti-inflammatory, anti-diabetic, and anticancer effects (Mármol et al., 2017). Its fruit is a notable source of lycopene and a significant concentration of VC, which contributes to its therapeutic potential. Rosehip products, such as marmalade or nectar, are particularly valuable from a nutritional standpoint. They are capable of meeting the entire daily VC requirement, while also supplying a substantial portion of the daily needs for various minerals and other vitamins. Therefore, rosehip can be considered a functional food with broad applications in health promotion and disease prevention (Öz et al., 2018; Aktaş et al., 2024).

5.3. Citrus fruits: nutritional composition and health benefits

Citrus fruits, members of the Rutaceae family, are cultivated extensively in tropical and subtropical regions. Among them, the sweet orange (*Citrus sinensis*) represents approximately 70% of total global citrus production and consumption. Other widely cultivated and consumed citrus varieties include: Tangerine (*Citrus reticulata*), grapefruit (*Citrus vitis*), lime (*Citrus aurantifolia*), lemon (*Citruslimonum*) (Sharma et al., 2017). Citrus fruits are particularly noted for their high VC content, which constitutes about 51% of their total vitamin composition. In addition to VC, citrus fruits are rich in carotenoids, such as: β-cryptoxanthin (68% of total carotenoids), zeaxanthin (43%). Citrus fruits and their juices are excellent sources of bioactive compounds, including: Flavonoids, carotenoids, limonoids, coumarin-related compounds, folates, essential oils, pectins.

Among citrus juices, VC is the key contributor to their antioxidant capacity. Antioxidant contribution rates of VC in various citrus juices are as follows: Grapefruit juice: 8.60%, orange juice: 8.16%, lemon juice: 6.15%.

These findings emphasize the nutritional and therapeutic value of citrus fruits, not only as a major source of VC but also as carriers of a wide range of bioactive compounds with antioxidant, anti-inflammatory, and immune-supporting properties (Martí et al., 2009).

5.4. Parsley (*Petroselinum crispum*)

Parsley is a vascular green plant species belonging to the Apiaceae family. Its fruit contains a flavonoid glycoside known as apiin, as well as a volatile essential oil. The root of parsley also contains essential oil, apiin, and mucilage, contributing to its traditional medicinal uses (Anonymous, 2021b). Due to its rich antioxidant content, parsley exhibits tumor-preventive properties. Additionally, it has been used to relieve symptoms of: Indigestion, gallstones, constipation, kidney Stones, edema.

However, because parsley has the potential to stimulate uterine contractions and increase bleeding, its consumption should be limited during pregnancy due to the risk of miscarriage (Anonymous, 2021b).

5.5. Tomato (*Solanum lycopersicum*)

Tomato is a member of the Solanaceae (nightshade) family and is widely recognized for its nutritional density and health-promoting properties (Anonymous, 2021c). Tomatoes are rich in VC, lycopene, beta-carotene, and various polyphenolic compounds that contribute to their antioxidant and anti-inflammatory effects. Reported health benefits include:

- Strengthening the immune system
- Reducing asthma symptoms
- Acting as a hematopoietic (blood builder) agent
- Lowering LDL ("bad") cholesterol
- Protecting against cardiovascular diseases
- Preventing certain cancers
- Reducing the risk of cataract development
- Improving oral health by preventing tooth decay and tartar accumulation
- Providing a cooling and thirst-quenching effect

Given their broad spectrum of bioactive components, tomatoes serve as a functional food in the prevention and management of various chronic diseases (Anonymous, 2021d).

6. Discussion

Numerous studies have demonstrated the protective and therapeutic effects of VC in a range of diseases, particularly infections and metabolic disorders. In a notable study conducted at a boarding school, VC supplementation was associated with a 45–91% reduction in the incidence of the common cold and an 80–100% reduction in pneumonia cases (Hemilä, 2004). During respiratory tract infections, plasma leukocyte levels and urinary VC concentrations decrease, suggesting increased metabolic utilization. This decline is believed to stimulate the activity of VC-dependent phagocytes, thereby neutralizing oxidative damage caused by infection (Hemilä, 2003).

In another clinical study involving 50 patients with moderate to severe COVID-19, the administration of 10 to 20 g/day intravenous VC over 8–10 hours resulted in significant clinical improvement, suggesting its potential as a supportive therapy in viral pneumonia and ARDS) (Cheng, 2020). Beyond its immune-modulating properties, VC has been studied for its role in obesity and metabolic regulation. In an experimental study on obese rats, VC administration led to increased levels of:

- Glutathione in brown adipose tissue
- Superoxide dismutase activity in liver cells
- Catalase enzyme activity in blood cells

These results suggest that VC may protect against obesity by enhancing antioxidant enzyme activity, thereby reducing oxidative stress associated with adipose tissue expansion (Drehmer et al., 2019). Furthermore, in guinea pigs, VC supplementation resulted in body weight reduction, while in rats, direct injection of VC into adipose tissue significantly decreased the number of adipocytes. Supporting these findings, a long-term observational study reported that diets rich in VC prevented weight gain and abdominal fat accumulation in obese individuals over a three-year follow-up period (Garcia-Diaz, 2014). Taken together, these findings highlight the multifaceted benefits of VC in both infectious and metabolic diseases, reinforcing its value as a therapeutic and preventive agent in clinical nutrition and public health.

The cardiovascular benefits of VC have been well-documented in both clinical and observational studies. For instance, Sadeghpour et al. (2015) administered a 2 g bolus of VC to 290 patients following cardiac surgery and observed a significant reduction in the length of hospital stay, highlighting VC's role in postoperative recovery. Similarly, another study found that individuals who consumed 400 mg/day of VC experienced a 25% lower incidence of coronary heart disease compared to non-supplement users. These findings suggest that cardioprotective effects of VC become more pronounced with intakes exceeding 400 mg/day (Schlueter and Johnston, 2011). Further evidence supports that even moderate daily intake of 100 mg of VC can lead to a reduction in cardiovascular mortality (Naidu, 2003). These results underscore the preventive potential of VC in managing cardiovascular disease risk.

VC has also been linked to gastrointestinal and cancer prevention mechanisms. Correa (1992) reported that VC concentrations in gastric juice were significantly higher than in plasma, and that VC inhibited the formation of mutagenic N-nitroso compounds, which are known contributors to gastric carcinogenesis. Epidemiological studies have further associated high dietary VC intake with a reduced risk of cancers in various organs, including the: Oral cavity, esophagus, colon, lung (Paoletti, 1998).

Moreover, Naidu (2003) reported that a daily intake of 100 mg of VC significantly lowered cancer-related mortality, affirming the potential of VC as an adjunctive nutrient in cancer prevention and patient survival. Collectively, these findings provide robust support for the therapeutic and preventive value of VC across multiple disease domains, particularly in cardiovascular health and oncological outcomes.

Emerging evidence from both animal and clinical studies supports the role of VC in glucose metabolism and diabetes management. In an experimental model, oral VC supplementation improved insulin sensitivity in hyperglycemic ob/ob mice, although no change in body weight was observed (Garcia-Diaz, 2014). Complementary findings in humans suggest that high-dose VC supplementation—beginning with 1 g/day for 4 weeks, followed by a week off, and then 3 g/day for another 4 weeks—contributed to improved glycemic control in diabetic patients (Park and Lee, 2003).

Further epidemiological evidence by Zhou et al. (2016) indicated that individuals with VC intake exceeding 140 mg/day had a reduced risk (<5%) of developing diabetes, likely due to the amelioration of insulin resistance. These findings support the view that VC supplementation may play an adjunctive role in the prevention and management of type 2 diabetes. VC also exhibits significant benefits in ocular health, particularly in preventing age-related eye diseases. According to Robertson et al. (1989), a daily intake exceeding 300 mg of VC reduced the risk of cataract formation by 70%. Supporting this, Jacques et al. (1991) reported that individuals consuming more than 490 mg of VC per day had a 75% lower risk of developing cataracts compared to those consuming less than 125 mg/day.

In the context of age-related macular degeneration (AMD), Aoki et al. (2016) found a significant association between higher VC intake and reduced AMD risk, suggesting a protective effect of VC on retinal health and visual function. Together, these findings reinforce the broad therapeutic potential of VC, not only in metabolic diseases such as diabetes, but also in the prevention of degenerative ocular conditions, underlining its value in long-term dietary strategies and preventive medicine. Beyond its known antioxidant and metabolic effects, VC also plays a crucial role in neurological protection and bone health. In an experimental study conducted on rats exposed to neurotoxic substances, VC administration significantly improved memory impairments and reversed neuropathological and neurodegenerative changes. These neuroprotective effects are attributed to VC's capacity to neutralize superoxide radicals, thereby mitigating oxidative neuronal damage (Olajide et al., 2017). VC has also been implicated in bone metabolism and osteoporosis prevention. Epidemiological data indicate that VC deficiency is associated with reduced bone formation, leading to an increased risk of osteoporosis and bone fractures (Aghajanian et al., 2015). In a long-term prospective cohort study with a 17-year follow-up, Sahni et al. (2009) found that individuals with higher dietary intake of VC experienced significantly fewer hip fractures and non-vertebral osteoporotic fractures compared to those with lower intake.

These findings highlight the multifunctional role of VC, not only in supporting immune, metabolic, and cardiovascular health, but also in protecting neural function and maintaining skeletal integrity, particularly in aging populations. VC also exhibits dermatological and protective cellular effects through its potent antioxidant properties. For instance, Darr et al. (1992) demonstrated that VC reduces oxidative damage induced by UV radiation, highlighting its photoprotective capacity. In skin-related metabolic disorders such as Porphyria Cutanea Tarda, VC has been shown to reduce hepatic accumulation of urinary porphyrins, support keratinocyte differentiation, and maintain skin barrier integrity. These effects extend to inflammatory skin diseases, including atopic dermatitis, where VC contributes to skin protection and regeneration (Wang et al., 2018).

Sarı Kılıçaslan et al. (2009) evaluated the effects of VC on diabetic dermal complications, including dermal thickening, elastic fiber aggregation, and fibroblast degeneration. VC treatment was found to significantly ameliorate these pathological changes, with outcomes approaching those observed in healthy control groups. VC's protective role also extends to the reproductive system. In a study conducted by Artıran et al. (2017), VC was found to alleviate testicular damage induced by gentamicin administration in rats. Gentamicin caused extensive degeneration in spermatogenic cells, thickening of the basal lamina, tubular atrophy, interstitial expansion, and vascular congestion. VC treatment significantly mitigated these histopathological effects, supporting its use as a protective agent against drug-induced reproductive toxicity. These findings collectively emphasize the broad cytoprotective roles of VC, ranging from skin health and detoxification to reproductive tissue preservation, and strengthen its position as a versatile therapeutic micronutrient in various systemic conditions.

Citrus fruit consumption remains one of the most effective preventive strategies against scurvy, a disease resulting from prolonged VC deficiency (Granger and Eck, 2018). Oral supplementation with 100–300 mg/day of VC has been shown to replenish serum VC levels and restore tissue stores. Clinical manifestations such as gingival lesions begin to resolve within 2 to 4 days of initiating VC therapy, with complete healing typically achieved within 2 to 3 weeks (Popovich et al., 2009). In the context of physical exertion and athletic performance, Koçyiğit et al. (2011) found that iron (Fe^{2+}) losses through sweat increased with exercise intensity. This loss was significantly minimized when VC intake exceeded the standard daily requirement, supporting its role in iron absorption and conservation, particularly in physically active populations.

7. Conclusion

VC plays a fundamental role in the structural and physiological functions of the human body. Through its diverse mechanisms—most notably its antioxidant, anti-inflammatory, immune-modulating, and tissue-protective effects— VC contributes to the prevention and treatment of various acute and chronic conditions. The requirement for VC may increase under certain conditions, including: Environmental pollution, smoking, pregnancy and lactation, infections, chronic diseases.

Given these factors, healthcare professionals are increasingly advocating for targeted VC supplementation as a preventive and therapeutic strategy. When administered appropriately, VC supports immune competence, helps combat oxidative stress, and contributes to the maintenance of systemic health. Future research and public health policies should further address optimal dosing strategies, bioavailability, and clinical outcomes associated with VC to ensure its effective use in preventive medicine and therapeutic interventions.

Declaration of Author Contributions

All authors declare that they have contributed equally to this manuscript, have reviewed the final version, and have approved it for publication.

Declaration of Conflicts of Interest

The authors declare that there is no conflict of interest regarding this study.

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