Antioxidant vitamins and their effect on immune system

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Abstract. Antioxidant vitamins are organic molecules that have vital roles in the human body. They are essential nutrients and mainly found in the food and are required in small quantities for the maintenance of the human body. Antioxidant vitamins play a major role in reducing and controlling oxidative stress and infectious diseases. This review aims to broaden the knowledge of the antioxidant vitamins (C, E, and A) and their effect on the immune system. These vitamins protect the immune system and enhance resistance against infectious microbes such as bacteria, viruses, and parasites. It is highly recommended to include antioxidants in the daily diet, as their lack can weaken the immune system and ultimately its ability in defending the body against diseases. Although vitamins are required in specific doses to maintain functional immune system, they mostly used as supplements. Vitamin C supplementation, for example, has been shown to reduce the duration and severity of upper respiratory infections, including colds. Moreover, it has been suggested that there is a close relationship between the deficiency of vitamins and infectious diseases such as tuberculosis, AIDS and CoV-2 SARS, as well as infectious diseases spread through the respiratory and digestive systems.

Keywords: Antioxidant Vitamins; Immune System; Vitamin C; Vitamin E; Vitamin A.

1. INTRODUCTION
Antioxidants are substances that may protect cells from the damage caused by unstable molecules known as free radicals. Antioxidants are crucial for life and are required in the diet for good health. They are found in vegetables, fruits, eggs, legumes and nuts. Antioxidants are produced either endogenously or received from exogenous sources. They include enzymes such as superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and minerals such as Se, Mn, Cu, and Zn, or non-enzymatic or nutrient-derived antioxidants such as vitamins A, C and E [1]. Other antioxidants include phytonutrients that present in a wide range of foods [2]. Some foods have high levels of antioxidant vitamins other than enzymes such as vitamin C (ascorbic acid) which can be found in fresh or frozen fruits and vegetables, vitamin E (tocopherols, tocotrienols) is resourced from vegetable oils, nuts and seeds, and carotenoids (carotenes as pro-vitamin A) present in fruits, vegetables and eggs [3]. It is worth mentioning that vitamins like E and C are more effective in terms of their antioxidant activities compared to vitamin A. Some antioxidant vitamins have been suggested to reduce oxidative damage in humans, thus reducing the risk of developing some chronic diseases [4].

An antioxidant can be defined as the molecule that is capable of slowing or preventing the oxidation of other molecules. While oxidation can be defined as the chemical reaction that transfers electrons from a substance to an oxidizing agent. Oxidation reactions can produce free radicals, which starts chain reactions that may damage cells. Antioxidants are often reducing agents that terminate these chain reactions by removing free radical intermediates and inhibit other oxidation reactions by being oxidized themselves [5].
On the other hand, oxidative stress is defined as an oxidative damage caused by an imbalanced ratio of free radicals and antioxidants in the human body. In a healthy body, prooxidants and antioxidants maintain a ratio and any shift in this ratio toward prooxidants leads to oxidative stress. This oxidative stress may be either mild or severe depending on the shift degree, and remains the cause of many diseases such as cardiovascular, neurological, kidney, diabetes, hypertension, skin, respiratory, liver, heart, Alzheimer, malignant tumors, inflammatory problems, Parkinson's, aging, and various types of viral infections. As more reports flow, much information is revealed about oxidative stress in relation to many other diseases [1]. Low levels of antioxidants, or inhibition of the antioxidant enzymes, causes oxidative stress and may damage or kill cells [5]. There is still much debate over whether foods or supplements rich in antioxidants have anti-disease activity. In fact, some argue the hypothesis that antioxidant vitamins can prevent chronic diseases [6], [7].

It should be noted that common medications and nutritional supplements with antioxidant properties may interfere with the efficiency of some anticancer drugs and radiotherapy [8]. However, vitamins C and E as antioxidants have revolutionized the field and have led to the realization of the importance of antioxidants in the biochemistry of living organisms. Vitamin E has found to inhibit the lipid peroxidation process that leads to the identification of antioxidants as reducing agents to prevent oxidation reactions, often by scavenging reactive oxygen species before they can damage cells [9]. Vitamin E treatment after stress has been found to be more effective than vitamins A and C in boosting glutathione and catalase levels and reducing lipid peroxidation. Thus vitamin E can be given as a dietary supplement to scavenging the free radicals generated in brain tissue to reduce oxidative stress [10].

2. VITAMINS

Vitamins are naturally occurring or chemically synthesized molecules that are required in trace amounts for the maintenance of the human body. They are essential nutrients that cannot be synthesized by the human body, so they can be used as food supplements. They perform various and vital functions in the body to maintain a healthy metabolism in the body. For example, vitamin D has hormone-like functions as regulators of mineral metabolism, and vitamin A acts as a regulator of cell and tissue growth, while vitamins E, C and A function as antioxidants. In addition, the B complex group vitamins, which function as enzyme cofactors precursors [11]. According to their solubility characteristics, vitamins are divided into two groups: fat-soluble vitamins and water-soluble vitamins [12], [13]. Fat-soluble vitamins (which include A, D, E and K) dissolve in fat before they are absorbed in the bloodstream to carry out their functions. The excesses of these vitamins are stored in the liver and fatty tissues; therefore, they are not needed in the daily diet. Otherwise, taking supplements that contain high doses of these types of vitamins may lead to toxicity and potential health problems [14]. Water-soluble vitamins (which include B-complex group vitamins and C vitamin) dissolve in water and are not stored in the body, and therefore they can be added to the daily diet. Unlike the fat-soluble vitamins, it was found that the excessive intake of water-soluble vitamins does not cause any problems to the body health, where the excess amounts are eliminated quickly with urine [15].

2.1. VITAMIN C

Vitamin C (Ascorbic acid) is a water-soluble vitamin. The molecular formula of vitamin C is C6H8O6 with molar mass: 176.12 g/mole, and the IUPAC name is 2-oxo-L-threo-hexono-1,4-lactone-2,3-enediol (Figure 1). Ascorbic acid is a weak sugar acid structurally related to glucose, it is formed from a six-carbon compound derived from glucose [16].
In biological systems, ascorbic acid can be found only at low pH, but in neutral solutions above pH 5 is predominantly found in the ionized form (ascorbate). Although, vitamin C is an essential vitamin for the human body, it cannot be synthesized endogenously, therefore, the human body intakes it through the consumption of fruit and vegetables that are rich with this vitamin, including grapefruit, lemons, limes, blackcurrants, oranges, kiwi, broccoli, green and red peppers, tomatoes, cabbage, sprouts, and sweet potatoes. It can also be found in fresh milk, fish and offal such as liver and kidney [17], [18].

Vitamin C is a cofactor for some enzymatic reactions, including several collagen synthesis reactions. It is essential for collagen formation and helps to maintain the integrity of skin and connective tissue, bone, blood vessel walls and dentine. It has an essential role in wound healing and facilitates recovery from burns. It also facilitates the absorption of iron [19]. Vitamin C may also act as an antioxidant agent against oxidative stress and plays a crucial role in neutralizing free radicals throughout the body [20].

Recently, many studies suggest that vitamin C may reduce the risk of certain cancers, heart disease, and cataracts [21], [22]. The antioxidant activity of ascorbic acid (a reducing agent) by donating electrons to various enzymatic and non-enzymatic reactions, making it very effective in biological systems [23]. The effect of vitamin C on the common cold has been extensively studied. However, the controversy over using high doses of vitamin C to prevent or cure the common cold has not been resolved. Many studies have suggested that taking high doses of vitamin C might shorten the course of the cold by 1 to 1.5 days in some patients, however, its activity against other diseases has not been confirmed yet [24]–[26]. Since the human body systems cannot produce or store vitamin C, an adequate daily intake of this nutrient is essential for a healthy body. The recommended daily intake of vitamin C is 90 milligrams/day for adult males and 75 milligrams/day for adult females [23].

Despite being a water-soluble vitamin that the body excretes in the urine when in excess, vitamin C overdoses have been shown to cause some side effects. These include kidney stones, problems with the digestive system, gout, diarrhea, and rebound scurvy [17–19]. Chronic and severe vitamin C deficiency may result in the disease known as scurvy, which leads to the formation of brown spots on the skin (especially on the thighs and legs), and loss of collagen strength throughout the body. The loss of collagen also leads to loose teeth, bleeding and swollen gums, and bleeding from all mucous membranes [26], [29], [30].

2.2. VITAMIN E

Vitamin E, also called Tocopherols (the active form of vitamin E), is a fat-soluble vitamin with molecular formula C19H50O2 and molar mass: 430.717 g/mol. The IUPAC name of vitamin E is 2,5,7,8-Tetramethyl-2-[4,8,12-trimethyltridecyl]-3,4-dihydro-2H-chromen-6-ol, Figure 2.

![Figure 2. General chemical structure of tocotrienols](image.png)

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\alpha\text{-Tocotrienol: } R1 = Me, R2 = Me, R3 = Me \\
\beta\text{-Tocotrienol: } R1 = Me, R2 = H, R3= Me \\
\gamma\text{-Tocotrienol: } R1 = H, R2 = Me, R3= Me
\]
δ-Tocotrienol: R1 = H, R2 = H, R3 = Me

Vitamin E has four isomeric forms: (α, β, γ and δ) – tocopherol, which is a derivative of chromane as well as structured by methyl group substitutions in the benzene ring of chromane. Vitamin E, as an antioxidant, is responsible for protecting the polyunsaturated fatty acids in membranes against lipid peroxidation, free radicals, and singlet oxygen, so that it is thought to be the most important antioxidant found within lipid membranes in the body [31]. Simply, α-tocopherol is capable of trapping peroxyl radical, which is produced by peroxidation of membrane. It is notable that α-tocopherol protects the polyunsaturated fatty acid from peroxidation even at a concentration as low as 0.005 mole%. Consequently, one molecule of α-tocopherol is protecting 20,000 molecules of polyunsaturated fatty acid [18]. Vitamin E seems to be the most important micro-nutrient involved in the protection of low-density lipoprotein (LDL) from oxidation [32]. It has been demonstrated that RBC membrane, mitochondrial membrane and endoplasmic reticulum, contain relatively high levels of this vitamin and that its level varies from one individual to another [33]. The average α-tocopherol content of LDL is 6.5 molecules per LDL particle. It is found that tocopherols are resided in the outer layer of LDL molecule (protecting the monolayer of phospholipid), and that the carotenoids are accumulated in the inner core (protecting the cholesterol esters) [34].

Vitamin E is mainly synthesized by plants and, therefore, is found in plant products such as nuts (almonds, sunflower seeds, vegetable oils, whole grains, olives and beans) and leafy vegetables (asparagus and spinach). Significant amounts of this vitamin can also be obtained from other types of food such as brown rice, corn, eggs, seaweed, milk, and meat. Health organizations recommend adults to consume vitamin E in the range of 7 to 15 mg per day. Vitamin E deficiency occurs only rarely in humans and overt deficiency symptoms in normal individuals with diets low in vitamin E have never been reported. Vitamin E deficiency occurs only as a result of genetic abnormalities in α-tocopherol transfer protein, as a result of various fat malabsorption syndromes, or as a result of protein-energy malnutrition [18]. Deficiency can result from insufficient dietary intake of the vitamin. This deficiency can cause nerve problems [23], and mild hemolytic anemia in newborn infants. High doses of vitamin E increase the incidence congestive heart failure [35]. There are several other dietary factors affect the need for vitamin E such as selenium (Se) and polyunsaturated fatty acids. It is found that selenium relieves the need for vitamin E and therefore, adequate intake of vitamin E becomes even more important in individuals taking low Se-diets [19].

In addition to the antioxidant function, vitamin E has multiple biological functions that include its effect on gene expression [36], and its function as a regulator of enzyme activity, such as protein kinase C (PKC), which plays a role in smooth muscle growth [37].

2.3. VITAMIN A

Vitamin A, also called retinol (the active form of vitamin A), is a fat-soluble vitamin with a molecular formula C20H30O and molar mass: 286.45 g/mol. The IUPAC name is 3,7-dimethyl-9-(2,6,6-trimethylcyclohex-1-yl) nona-2,4,6,8-tetraen-1-ol, Figure 3.
Vitamin A can be obtained either from animal products such as meat, fish, poultry and dairy foods, or as a pro-vitamin A from plant-based foods such as fruits and vegetables. The most common type of pro-vitamin A is beta-carotene. Vitamin A is also available in dietary supplements, usually in the form of retinyl acetate, retinyl palmitate and beta-carotene [38].

Vitamin A has multiple functions for the human body: it is important for growth and development of bone growth, tooth development, vision (especially in the dark by helping the eyes to adjust to light changes), reproduction, cell division, gene expression, and for the maintenance of the immune system [39]. Essentially, the skin, eyes, and mucous membranes of the mouth, nose, throat and lungs depend on vitamin A to remain moist. Vitamin A is also an important antioxidant compound that may play a role in the prevention of certain cancers [12]. The Dietary Reference Intake (DRI) recommended daily amount (RDA) for vitamin A is 900 micrograms/day for adult males and 700 micrograms/day for adult females (42). Vitamin A is supplied primarily by certain foods of animal origin like dairy products, fish and liver. Some foods of plant origin contain beta-carotene, an antioxidant that the body converts to vitamin A. Beta-carotene, comes from fruits and vegetables. Carrots, pumpkin, winter squash, dark green leafy vegetables and apricots are rich sources of beta-carotene [40].

Vitamin A deficiency usually results from inadequate intakes of vitamin A from animal products (as preformed vitamin A) and fruit and vegetables (as pro-vitamin A). Night blindness and rough skin may indicate a lack of vitamin A. In fact, night blindness is one of the first signs of vitamin A deficiency. Vitamin A deficiency contributes to blindness by making the cornea very dry and damaging the retina. Other signs of possible vitamin A deficiency include decreased resistance to infections, faulty tooth development, and slower bone growth [41]. The tolerable upper intake level for vitamin A for adult is 3,000 micrograms/day [42].

An overdose of vitamin A may cause vitamin A toxicity to the body (hypervitaminosis A), because vitamin A is rapidly absorbed and slowly removed from the body [29]. Toxicity of vitamin A is classified into two categories: acute and chronic toxicities. Acute vitamin A toxicity is relatively rare, and symptoms include nausea, headache, fatigue, loss of appetite, dizziness, dry skin and desquamation. Signs of chronic toxicity include dry itchy skin, desquamation, anorexia, weight loss, headache, cerebral edema, enlarged liver, enlarged spleen, anemia, and bone and joint pain. Generally, signs of toxicity are associated with long-term consumption of vitamin A in excess of 10 times the RDA (8,000-10,000 micrograms/day) [43], [44].

3. IMMUNE SYSTEM

The immune system is a complex network of cells and proteins that protect the body against disease and pathogens, such as bacteria, viruses, and protozoan parasites. In fact, there are two main sub-systems of the immune system: the innate immune system and the adaptive immune system. Certain environmental factors can decrease immune system function, including exposure to UV light, cigarette smoking, and viral infections such as human immunodeficiency virus. The aging process is associated with the loss of cell-mediated immune responses and the concomitant increase in infection and cancer incidence [45].
Pathogens, recognized as invaders of the body, and are destroyed by immune cells during body defense process. The immune system responds similarly to the cells of the body that have undergone changes that can lead to cancer. Thus, conditions that reduce immune function increase the risk of infection and the development of some types of cancer. On the contrary, factors that can enhance immunity may reduce these risks [46].

3.1. ANTIOXIDANTS AND IMMUNE SYSTEM

Autoimmune diseases mainly occur when the immune system produces antibodies against some normal cells. Patients with autoimmune diseases usually have a deficiency of dietary antioxidants [47]. An antioxidant has the ability to stabilize highly reactive and potentially harmful molecules called free radicals. The generation of free radicals has been associated with damage to membranes, enzymes as well as the cell's nuclear material. The antioxidant's ability to reduce the highly reactive free radicals serves to protect the structural integrity of cells and tissues of the immune system as well as other systems in the body [12]. In all living systems, cells require adequate levels of antioxidant defenses in order to avoid the harmful effect of excessive production of reactive oxygen species (ROS). Since ROS is produced in vivo and to prevent immune cell damage, antioxidant defense systems work either to prevent ROS generation or to intercept any product being produced [48].

Antioxidant nutrients commonly included directly in the diet such as vitamin E, vitamin C, β-carotene or require micronutrients as integral components like selenium, copper, iron and zinc. Those antioxidants improve different immune functions exhibiting an important protective role in infections caused by bacteria, viruses or parasites. During the inflammatory processes, the activation of phagocytes and/or the action of bacterial products with specific receptors are capable of promoting the assembly of the multicomponent flavoprotein NADPH oxidase, which catalyzes the production of high amounts of the superoxide anion radical O$_2^-$ [49].

Neutrophils and macrophages are recognized to produce superoxide free radicals and H$_2$O$_2$, which are essential for defense against phagocytized or invading microbes. In this state, antioxidants are necessary to regulate the reactions that release free radicals. As a result, dietary antioxidants have been related to modulating the host susceptibility or resistance to infectious pathogens [50]. ROS is a major contributor to many degenerative disorders in immune function and has been observed in elderly individuals after supplements with antioxidant nutrients as observed in younger individuals so it is important to maintain ROS balance to the level of antioxidants [51].

The immune system is especially sensitive to oxidative stress, because immune cells rely heavily on cellular contact, especially across membrane-bound receptors, to work effectively. Cell membranes are rich in polyunsaturated fatty acids which, if peroxidized, can lead to loss of membrane integrity and membrane fluidity change [52]. Exposure to ROS can lead to a decrease in the expression of the cell membrane receptor, ROS production by phagocytic immune cells can damage the cells themselves if they are not adequately protected by antioxidants [53].

3.2. VITAMIN C AND IMMUNE SYSTEM

Vitamin C is one of the biggest immune system enhancer ever. Vitamin C contributes to immune defense by supporting the different cellular functions of both the innate immune system and adaptive immune system. Vitamin C is necessary to stimulate the immune system by increasing the strength and protection of the organism due to its immunostimulant, anti-inflammatory, antiviral, antibacterial roles
[54], and can suppress free radicals and singlet oxygen. It enhances the oxidant scavenging activity of the skin, thus protecting against environmental oxidative stress [45]. It has antimicrobial activities besides its role in promoting the proliferation of lymphocytes, and is rapidly consumed during infections, suggesting a prominent role in the regulation of the immune system [55]. In fact, it has been found that vitamin C deficiency leads to weakened immunity and increases susceptibility to infection [48].

Vitamin C has been used to treat some clinical phagocytic cell dysfunctions. In Chediak-Higashi syndrome, which is characterized in part by defective neutrophil functions, vitamin C supplementation has been shown to increase neutrophil chemotaxis, improve bactericidal activity and reduce the length of clinical illness, also appears to be beneficial in the treatment of chronic granulomatous disease and appears to be able to both prevent and treat respiratory and systemic infection [56]. Ascorbate provides important antioxidant protection to plasma lipids and lipid membranes [57], and can also neutralize phagocyte-derived oxidants released extracellularly, thereby preventing oxidant-mediated tissue damage, particularly at sites of inflammatory activity [56].

Other mechanisms that have been suggested for the immunostimulatory effects of vitamin C include: adjusting the levels of intracellular cyclic nucleotides, modulation the synthesis of prostaglandins, enhancing cytokine production, and hostility to the immunosuppressive interaction between histamine and leukocytes [56]. In addition, ascorbate can also regenerate the form of antioxidants reduced of vitamin E [57].

Coronavirus disease 2019 (COVID-19) is an infectious disease with severe acute respiratory syndrome [58]. In December 2019, COVID-19 was first recognized in Wuhan, China, and it has since spread to the world, resulting in the continuation of the coronavirus pandemic to 2020 [59]. At this time, there is no specific vaccine or antiviral treatment for COVID-19. COVID 19 has been found to attack the immune system of the human body, especially when the immune system response is low, weak, or damaged. In fact, people with vitamin C deficiency may be more likely to develop CoV-2 SARS, or have severe COVID-19 because they have weak immunity. It has been reported that a high dose intravenous vitamin C can be a safe and beneficial option for early-stage COVID-19 treatment, along with anti-inflammatory treatments [60].

3.3. VITAMIN E AND IMMUNE SYSTEM

Vitamin E is a powerful antioxidant and has the ability to affect immune functions. Vitamin E is a physiologic stabilizer of lysosomal membranes, and its deficiency can trigger the process of autoimmune diseases or accelerate its progress. It is assumed that vitamin E can reduce oxidative stress, which is an important factor in the pathogenesis of autoimmune diseases [47]. Vitamin E is the major lipid-soluble antioxidant present in all cellular membranes, protects against lipid peroxidation and prevents the loss of membrane fluidity [45]. Vitamin E is involved in maintaining immune cell function, where it has been reported that a higher vitamin E diet reduces prostaglandin production of macrophages and boosts cellular immune functions [61].

It is found that vitamin E deficiency can cause peripheral neuropathy, myopathies, retinopathy and impairment of immune responses [23]. The anti-inflammatory and protective effect of vitamin E against free radicals, as well as its important effect on the levels of cytokines, make this vitamin may play a powerful role in the prevention and treatment of rheumatoid arthritis, as well as joint inflammation and damage [62]. It was found that greater vitamin E intake is needed to maintain immune function in the elderly, and to improve the low cellular immune functions that occur with ageing [63], [64].

Since vitamin E is the most effective chain-breaking lipid-soluble antioxidant present in cell membranes, it is considered to play a major role in maintaining cell membrane integrity by limiting lipid
peroxidation by ROS. Vitamin E deficiency states are associated with decreased B-cell antibody production and T-cell proliferation to mitogenic stimulation, and an increased rate of infection. While supplementation with higher than recommended dietary levels of vitamin E enhances humoral and cell-mediated immunity [5].

It is also possible that vitamin E and other antioxidant nutrients can influence a variety of inflammatory processes by inhibiting the activity of the transcription factor nuclear factor-kB. This protein transcription factor is required for maximal transcription of many cytokines, including interleukin-1B, and it is thought that the generation of ROS is a vital link in mediating nuclear factor-kB activation by a variety of stimuli. Reduced levels of vitamin E have been reported in human immunodeficiency virus-infected individuals [65]. Most importantly, it has been reported that a high dose vitamin E supplement may be a beneficial treatment, with medical treatment, for human AIDS [66].

3.4. VITAMIN A AND IMMUNE SYSTEM

Vitamin A (carotenoids) has an anti-inflammatory function and plays a crucial role in boosting immune function, where it has been shown to have a therapeutic effect in treating various infectious diseases. It was found that nutrients rich in vitamin A reduce cancer incidence, while its deficiency has been linked to an increased risk of infection [67]. Vitamin A is important for the development and functioning of T and B lymphocytes. Consequently, a decrease in the status of vitamin A understandably reduces cell-mediated immune responses and reduces specific antibody responses after immunization [68]. It has been reported that vitamin A can also prevent normal apoptosis of bone marrow cells, leading to an increase in the number of marrow cells in the bone marrow, spleen and peripheral blood, indicating that vitamin A is involved in regulating bone marrow homeostasis [69].

Vitamin A supplements also act as an adjuvant that boosts immune responses when given at immunization. It was found that vitamin A is important for the recovery from measles in children. Thus, supplements with high doses of vitamin A, administered during the first few days of hospitalization, significantly reduce mortality and morbidity in young children. The improvement in results was associated with increased measles antibody titer in children who received vitamin A supplementation [70], [71]. In fact, vitamin A supplements for children have been known to reduce the risk of death and morbidity from some forms of diarrhea, measles, HIV infection and malaria [72]. Moreover, recent research has suggested a close relationship between vitamin A deficiency and infectious diseases such as tuberculosis, AIDS and infectious diseases spread through the respiratory and digestive systems in children [73].

Exposure to ultraviolet radiation directly increases the free radical load imposed on the body and reduces immune responses, especially cell-mediated responses, also significantly increases the risk of skin cancer [74]. However, β-Carotene and some other carotenoids can prevent singlet oxygen formation induced by ultraviolet radiation. Indeed, this singlet oxygen can initiate\ generate immunosuppression [75].

4. CONCLUSION

Antioxidant vitamins play a major role in protecting cells from damage caused by unstable molecules known as free radicals, thus reducing exposure to oxidative stress and reducing the chances of disease. This review describes several antioxidant vitamins, enzymes, and minerals that affect the immune system, especially the antioxidant vitamins C, E, and A. These vitamins strengthen the immune system and enhance resistance against infections such as bacteria, viruses, and parasites. The description of antioxidant vitamins impact, begins with vitamin C, which is important for immune defense as it
stimulates the immune system and increases the body's strength and protection. While the antioxidant vitamin E reduces oxidative stress, protects against lipid peroxidation and prevents membrane fluidity loss. On the other hand, vitamin A (carotenoids) has an anti-inflammatory function and plays an important role in boosting immune function.

It is recommended to include antioxidants in our daily diet, since their lack can weaken our immune system and increase the incidence of body infections. It was revealed that individuals with autoimmune diseases usually suffer from a deficiency in their dietary antioxidants. Although vitamins are required in specific doses in order to maintain optimal immune system performance, amongst which vitamin C supplement may be the most common protection against infection, especially infections related to the upper respiratory system, such as CoV-2 SARS.

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