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# A REVIEW ON: GENERAL INFORMATION OF VITAMIN E AND IT'S PHARMACOLOGICAL USED

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## ABSTRACT

Vitamin E is also known as tocopherol. Vitamin E is group of eight compounds related in molecular structure that includes four tocopherols and four tocotrienols. The tocopherols function as fat-soluble antioxidants which may help protect cell membranes from reactive oxygen species. The conversion from International Units (IU) to milligrams (mg) depends on the specific substance, but generally, for Vitamin D, 1 IU is equivalent to 0.025 micrograms (mcg) or 0.001 mg, and for Vitamin E, 1 IU of the natural form is equivalent to 0.67 mg of alpha-tocopherol. Vitamin E is classified as an essential nutrient for humans. Tocopherols and tocotrienols both occur in α (alpha), β (beta), γ (gamma), and δ (delta) forms, as determined by the number and position of methyl groups on the chromanol ring. Vitamin E is an antioxidant. Antioxidants might protect cells from the effects of free radicals, which are molecules made when the body breaks down food or is in contact with tobacco smoke or radiation. These molecules might lead to heart disease, cancer, and other diseases. vitamin E can be good for hair. It can help with hair growth, shine, and damage. Vitamin E can also improve scalp health. Vitamin E helps you maintain a healthy immune system, healthy vision and skin. Good sources of vitamin E are nuts, seeds and vegetable oils. Having a handful of nuts as a snack is an easy way to add vitamin E to your diet. Vitamin E deficiency is uncommon, since you only need to eat a small amount in your diet to stay healthy. High-dose vitamin E supplements can build up in your body and this can be harmful.

**KEY POINT:** Antioxidant, fat-soluble vitamin, Supplements, Tocopherols.

## INTRODUCTION

**Vitamin E:** Vitamin E is a fat-soluble vitamin with several forms, but alpha-tocopherol is the only one used by the human body. Vitamin E is the Collective term Given to a group of fat-soluble compounds first discovered in 1922 by Evans and Bishop; these compounds have distinct antioxidant activities essential for health. Its main role is to act as an antioxidant, scavenging loose electrons—so-called "free radicals"—that can damage cells. It also enhances immune function and prevents clots from forming in heart arteries.[1] Vitamin E helps you maintain a healthy immune system, healthy vision and skin. Good sources of vitamin E are nuts, seeds and vegetable oils. Having a handful of nuts as a snack is an easy way to add vitamin E to your diet. Vitamin E is an antioxidant, preventing free radical reactions with cell membranes. Though in some cases vitamin E has been shown to have pro-oxidant activity. One mechanism of vitamin E's antioxidant effect is in the termination of lipid peroxidation.[2]

Wheat germ oil has the highest natural concentration of vitamin E, followed by sunflower seeds and almonds. Other foods that are high in vitamin E include:

- ✓ **Nuts and seeds**: Hazelnuts, peanuts, pumpkin seeds, pine nuts, Brazil nuts, pistachios
- ✓ **Vegetable oils**: Sunflower, safflower, corn, and soybean oils
- ✓ **Fruits**: Avocados, mangoes, kiwi fruit, mamey sapote
- ✓ **Vegetables**: Spinach, broccoli, red bell pepper, turnip greens, butternut squash
- ✓ **Seafood**: Salmon, trout, abalone
- ✓ **Fortified foods**: Breakfast cereals, fruit juices, margarines, and spreads
- ❖ 1 tablespoon of wheat germ oil contains 20.3 milligrams of vitamin E
- ❖ 1 ounce of dry roasted sunflower seeds contains 7.4 milligrams of vitamin E
- ❖ 1 ounce of dry roasted almonds contains 6.8 milligrams of vitamin E.

vitamin E is generally considered beneficial for hair health, offering potential benefits like promoting hair growth, reducing breakage, and improving scalp health due to its antioxidant and moisturizing properties. vitamin E is good for skin because it's an antioxidant that protects skin cells and moisturizes the skin. It can help with dry skin, sun damage, and hyperpigmentation.[3]

Vitamin E is an antioxidant. Antioxidants might protect cells from the effects of free radicals, which are molecules made when the body breaks down food or is in contact with tobacco smoke or radiation. These molecules might lead to heart disease, cancer, and other diseases.

Benefits of Vitamin E, Antioxidant-Vitamin E is a fat-soluble vitamin that acts as an antioxidant, protecting cells from damage caused by free radicals. Immune System- It plays a role in maintaining a healthy immune system. Skin and Vision-Vitamin E contributes to healthy skin and vision. Dietary Sources-You can obtain Vitamin E through a variety of foods, including nuts, seeds, vegetable oils, and certain fruits and vegetable.[4]

**Potential Risks of High-Dose Vitamin E Supplements**

Bleeding-High doses of vitamin E supplements can increase the risk of bleeding.

Stroke-There's a potential link between high-dose vitamin E and an increased risk of hemorrhagi stroke.

Prostate Cancer-Some studies suggest that taking high doses of synthetic vitamin E supplements may increase the risk of prostate cancer.

Other Risks- Some research indicates that high doses of vitamin E may be linked to other health risks, such as early death.[5,6]

**Chemistry of Vitamin E:** Vitamin E is a group of eight fat-soluble compounds, including four tocopherols (α, β, γ, and δ) and four tocotrienols (α, β, γ, and δ), characterized by a chromanol ring and a phytyl-like side chain, with α-tocopherol being the most biologically active form. The term ‘tocopherol’ signifies the methyl-substituted derivatives of tocol and is not synonymous with the term ‘vitamin E’. Natural tocochromanols comprise two homologous series: tocopherols with a saturated side chain and tocotrienols with an unsaturated side chain. Tocopherols and tocotrienols have the same basic chemical structure, which is characterised by a long isoprenoid side chain attached at the 2 position of a 6-chromanol ring.

Tocotrienols differ from tocopherols in that they possess a farnesyl rather than a saturated isoprenoid C16 side chain. Natural tocopherols occur in the RRR-configuration while the synthetic form contains eight different stereoisomers and is called all-racalpha- tocopherol. Tocotrienols possess only the chiral stereocenter at C-2 and naturally occurring tocotrienols exclusively possess the 2R,3’E,7’E configuration.5 The receptors and enzymes in the body are highly stereoselective and interact exclusively with one of the enantiomers of a chiral molecule in a process called chiral recognition. As a result, only one enantiomer has the

desired effect on the body, while the others may have either no effect or an adverse effect. Vitamin E isoforms are not interconvertible inside the human body.[7]

**Chemical Structure and Classification of Vitamin E**

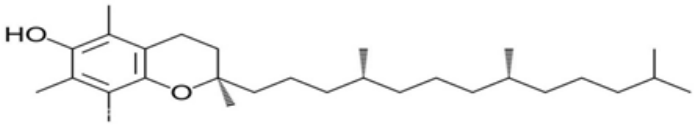
**Tocochromanols:** Vitamin E compounds are collectively known as tocochromanols, which are further divided into tocopherols and tocotrienols.

**Tocopherols:** These have a saturated side chain, while tocotrienols have an unsaturated side chain with three double bonds.

**Chroman Ring:** Both tocopherols and tocotrienols share a common structure: a substituted 6-chromanol ring (a six-membered ring with a hydroxyl group).

**Phytyl-like Side Chain:** A long isoprenoid side chain is attached to the 6-chromanol ring.

**Methylation Pattern:** The methylation pattern of the chromanol ring determines the classification of the tocopherol or tocotrienol as α, β, γ, or δ.




α-Tocopherol
Vitamin E

$C_{29}H_{50}O_2$

**Figure 1: Chemical Structure of Vitamin E.**

***α*-tocopherol:** The most biologically active form, characterized by methylation at positions 5, 7, and 8 of the chromanol ring.

**Other forms:** β-tocopherol is methylated at positions 5 and 8, γ-tocopherol at positions 7 and 8, and δ tocopherol only at position 8.

**Tocotrienols:** Similar to tocopherols but with three double bonds in their side chain.[8]

**Chemical Features**

**Antioxidant Activity:** Vitamin E acts as a fat-soluble antioxidant, protecting cell membranes and other lipids from damage caused by free radicals.

**Hydrogen Donation:** Vitamin E donates a hydrogen atom from its phenolic group to stabilize free radicals, thereby halting the chain reaction of lipid peroxidation.

**Solubility:** Vitamin E is soluble in organic solvents, vegetable oils, and alcohols, but not in water.

**Stability:** Vitamin E is sensitive to light, oxygen, and transition metal ions, which can cause oxidation and degradation.[9,10]

**Sources and Recommended Intakes of Vitamin E**

Vitamin E is found in various foods and oils. Nuts, seeds and vegetable oils contain high amounts of alpha-tocopherol, and significant amounts are also available in green leafy vegetables and fortified cereals. Some of the richest sources of vitamin E, along with their tocopherol content and percent daily values, are shown in Tables 1.

**Table-1: dietary sources of vitamin E (alphatocopherol).**

| Food and recommended intake | Alphatocopherol content in mg per serving | Percent daily value |
|---|---|---|
| Wheat germ oil, 1 tablespoon | 20.3 | 100 |
| Sunflower seeds, dry roasted, | 7.4 | 37 |
| Almonds, dry roasted, 1 ounce | 6.8 | 34 |
| Sunflower oil, 1 tablespoon | 5.6 | 28 |
| Safflower oil, 1 tablespoon | 4.6 | 25 |
| Hazelnuts, dry roasted, 1 ounce | 4.3 | 22 |
| Peanut butter, 2 tablespoons | 2.9 | 15 |
| Peanuts, dry roasted, 1 ounce | 2.2 | 11 |
| Corn oil, 1 tablespoon | 1.9 | 10 |
| Spinach, boiled, ½ cup | 1.9 | 10 |
| Broccoli, chopped, boiled, ½ cup | 1.2 | 6 |
| Soybean oil, 1 tablespoon | 1.1 | 6 |
| Kiwifruit, 1 medium | 1.1 | 6 |
| Mango, sliced, ½ cup | 0.7 | 4 |
| Tomato, raw, 1 medium | 0.7 | 4 |
| Spinach, raw, 1 cup | 0.6 | 3 |

No specific recommendations regarding the intake of vitamin E have been made officially, and the optimal supplementation dosage of mixed tocopherols is still undetermined. When obtained from food sources alone, vitamin E has no documented evidence of toxicity. However, evidence of pro-oxidant damage has been found to be associated with supplements, but usually only at very high doses (for example at >1,000 mg/day).9 The recommended dietary allowances (RDAs) for vitamin E (alpha-tocopherol).[11]

**Regulation of platelet aggregation and protein kinase c activation**

An increase in the concentration of alpha-tocopherol in the endothelial cells has been found to inhibit platelet aggregation and to release prostacyclin from the endothelium. This effect was thought to occur because of the downregulation of the intracellular cell adhesion molecule (ICAM-1) and the vascular cell adhesion molecule (VCAM-1), thereby decreasing the adhesion of blood cell components to the endothelium. Also, due to their upregulation by vitamin E in the arachidonic acid cascade, the increase in the expression of cytosolic phospholipase A2, and cyclooxygenase-1, increases the release of prostacyclin, which is a potent vasodilator and inhibitor of platelet aggregation in humans. A few other studies suggest that tocopherols appear to inhibit platelet aggregation through the inhibition of protein kinase C (PKC) and the increased action of nitric oxide synthase.[12]

The natural RRR-configuration form of alphatocopherol has been shown to be twice as potent as the other all-racemic (synthetic) alpha-tocopherols in inhibiting PKC activity. This occurs because of the attenuating effect of alpha-tocopherol on the generation of membrane-derived diacylglycerol (a lipid which facilitates PKC translocation and thus increases its activity); additionally, alpha-tocopherol increases the activity of protein phosphatase type 2A, which inhibits PKC autophosphorylation and, consequently, its activity. Mixed tocopherols are more effective than alpha-tocopherol in inhibiting platelet aggregation. Adenosine diphosphate-induced platelet aggregation decreased significantly in healthy people who were given gamma-tocopherol-enriched vitamin E (100 mg of gamma-tocopherol, 40 mg of delta-tocopherol and 20 mg of alpha-tocopherol per day), but not in those receiving pure alpha-tocopherol alone (100 mg per day) or in the controls.[13]

**Biological Role of Vitamin E**

Alpha-tocopherol is a phenolic antioxidant. The scavenging mechanism involves the donation of hydrogen from the hydroxyl group (-OH) of the phenolic ring to free radicals (ROS). In this way, the free radicals become unreactive and unable to do any more damage.

After this reaction, also the phenolic compound itself becomes relatively unreactive with a higher stability. Its stability is guaranteed by the now unpaired electron which is on the oxygen atom and which is delocalized in the structure of the aromatic ring. _-tocopherol is located within the phospholipid membrane of the cell, and it occurs with the radical chain embedded in the hydrophobic core of the double layer. Its concentration, compared to the lipids present in the membrane, is very low, but in spite of this, it plays an important role in preserving the integrity of the membrane by preventing lipid peroxidation which causes damage of cellular membranes, lipoproteins, and other molecules that contain lipids, in conditions of oxidative stress donation of hydrogen from the hydroxyl group (-OH) of the phenolic ring to free radicals (ROS). In this way, the free radicals become unreactive and unable to do any more damage.

After this reaction, also the phenolic compound itself becomes relatively unreactive with a higher stability. Its stability is guaranteed by the now unpaired electron which is on the oxygen atom and which is delocalized in the structure of the aromatic ring. α-tocopherol is located within the phospholipid membrane of the cell, and it occurs with the radical.[14]

**Pharmacological used of Vitamin E**

Vitamin E has been found to be very effective in the prevention and reversal of various disease complications due to its function as an antioxidant,its role in anti-inflammatory processes, its inhibition of platelet aggregation and its immune-enhancing activity.[15]

**Cardiovascular diseases**

Cardiovascular complications basically arise because of the oxidation of low-density lipoproteins present in the body and the consequent inflammation. Gammatocopherol is found to improve cardiovascular functions by increasing the activity of nitric oxide synthase, which produces vessel-relaxing nitric oxide. It does this by trapping the reactive nitrogen species (peroxynitriten) molecules and thus enhancing the endothelial function. Researchers have found that the supplementation of 100 mg per day of gammatocopherol in humans leads to a reduction in several risk factors for arterial clotting, such as platelet aggregation and cholesterol.In another study, mixed tocopherols were found to have a stronger inhibitory effect on lipid peroxidation and the inhibition of human platelet aggregation than individual tocopherols alone, suggesting a synergistic plateletinhibitory effect. Apart from tocopherols, tocotrienols were also found to inhibit cholesterol biosynthesis by suppressing 3-hydroxy-3-methylglutaryl-CoA (HMGCoA) reductase, resulting in less cholesterol being manufactured

by the liver cells. Contradictory to this, most of the recent large interventional clinical trials have not shown cardiovascular benefits from vitamin E supplementation and report that the use of vitamin E was associated with a significantly increased risk of a haemorrhagic stroke in the participants. Thus, it was suggested that understanding the potential uses of vitamin E in preventing coronary heart disease might require longer studies with younger participants.[16]

**Cancer**

Vitamin E also possesses anti-cancer properties. This is possibly because of the various functions of vitamin E which include: the stimulation of the wild-type p53 tumor suppressor gene; the downregulation of mutant p53 proteins; the activation of heat shock proteins, and an anti angiogenic effect mediated by the blockage of transforming growth factor alpha.31 Alpha-, gammaand delta-tocopherols have emerged as vitamin E molecules with functions clearly distinct from each other in anti-cancer activity as well. Alpha-tocopherol was found to inhibit the production of PKC and collagenase, which facilitate cancer cell growth. In this context gamma-tocopherol was found to be more effective than alpha-tocopherol in its growth inhibitory effect on human prostate cancer cell lines, whereas delta-tocopherol has shown growth inhibitory activity against mouse mammary cancer cell lines.

Gamma-tocopherol inhibits the growth of cancer cells in cultures through a number of mechanisms. It traps free radicals, including the reactive nitrogen species molecules that cause mutations in the deoxyribonucleic acid strands and malignant transformations in the cells. It also downregulates the control molecules known as cyclins, stopping the cancerous cell cycle in the middle and thus preventing their proliferation. Gamma-tocopherol has also been found to be superior to alpha-tocopherol in: inducing apoptosis; triggering a number of cell-death-inducing pathways; stimulating peroxisome proliferator activated receptor gamma activity, especially in colon cancer cells, and in reducing the formation of new blood vessels in tumours, thus depriving them of the nutrients they need to thrive. In this context, tocotrienols were also found to have antiproliferative and apoptotic activities on normal and cancerous cells in humans, which could be due to the induction of apoptosis by a mitochondria-mediated pathway, or due to the suppression of cyclin D which would therefore arrest the cell cycle. They also inhibit vascularisation and suppress 3-hydroxy-3-methyl coenzyme A (HMG-CoA) reductase activity, thus preventing malignant proliferation.[17]

**Cataracts**

Cataracts are one of the commonest causes of significant vision loss in older people. They basically occur due to the accumulation of proteins damaged by free radicals. Several observational studies have revealed a potential relationship between vitamin E supplements and the risk of cataract formation. Leske *et al*. found that lens clarity was superior in participants who took vitamin E supplements and those with higher blood levels of the vitamin. In another study, a long-term supplementation of vitamin E was associated with the slower progression of age-related lens opacification. However, in the randomised Age-Related Eye Disease Study (AREDS), vitamin E had no apparent effect on cataract development/progression over an average of 6.3 years. Overall, the available evidence is insufficient to conclude that vitamin E supplements, taken alone or in combination with other antioxidants, can reduce the risk of cataract formation.[18]

**Alzheimer's disease**

Alzheimer's disease (AD) occurs as a result of protein oxidation and lipid peroxidation via a free radical mechanism, where the beta amyloid protein induces cytotoxicity through a mechanism involving oxidative stress and hydrogen peroxide, leading to neuronal cell death and, finally, AD. Vitamin E can block the production of hydrogen peroxide and the resulting cytotoxicity. It reduces beta amyloid-induced cell death in rat hippocampal cell cultures and PC12 cells47 and attenuates the excitatory amino acid-induced toxicity in neuroblastoma cells. The Alzheimer's Disease Cooperative Study in 1997 showed that vitamin E may slow disease progression in patients with moderately severe AD. High doses of vitamin E delayed the loss of the patient's ability to carry out daily activities and their consequent placement in residential care for several months. In another study, it was found that subjects with AD had reduced concentrations of plasma antioxidant micronutrients, suggesting that inadequate antioxidant activity is a factor in this disease. High plasma levels of vitamin E are associated with a reduced risk of AD in older patients and this neuroprotective effect is related to the combination of different forms of vitamin E rather than to alphatocopherol alone. A study published in 2009 examined the effects of taking 2,000 IU of vitamin E with and without an AD drug on 847 people. It concluded that vitamin E plus a cholinesterase inhibitor may be more beneficial than taking either agent alone. At the biomarker level. demonstrated that plasma levels of tocopherols and tocotrienols together with automated magnetic resonance imaging (MRI) measures can help to differentiate patients with AD and mild cognitive impairment (MCI) from the control subjects, and prospectively predict the MCI conversion

into AD. This therefore suggests the potential role of nutritional biomarkers detected in plasma-tocopherols and tocotrienols as indirect indicators of AD pathology. However, researchers have recommended that patients should not take vitamin E to treat AD without the supervision of a physician, as in high doses it can interact negatively with other medications, including those prescribed to lower cholesterol.[19]

**Human Immunodeficiency Virus And Acquired Immunodeficiency Syndrome**

Vitamin E is an important anti-inflammatory agent that is often found to be deficient in human immunodeficiency virus (HIV)-positive individuals; however, it is not known whether vitamin E supplementation is beneficial either at every or any stage of HIV infection. At a dose of 400 IU, vitamin E was shown to restore delayed skin hypersensitivity reactions and interleukin-2 production, and at high doses it was shown to stimulate T helper cell (CD4 T-cell) proliferation. In 1997, Tang *et al*. studied the association between serum vitamin A and E levels with HIV-1 disease progression. In this study, it was found that men with serum vitamin E levels above 23.5 μm/L had a significantly reduced risk of disease progression. A strong correlation was noted in this cohort between the intake of supplements containing vitamin E at the point of entry into the study and high blood levels of vitamin E.

A study on murine acquired immunodeficiency syndrome (AIDS) using a 15-fold increase in dietary vitamin E showed the normalisation of immune parameters that are altered in HIV/AIDS. Apart from this, an increase in dietary vitamin E has also been shown to protect against the side-effects of azidothymidine, such as bone marrow toxicity. Related studies on bone marrow cultures from stage IV AIDS patients using d-alpha-tocopherol supplementation revealed similar results. Nevertheless, it has also been reported that higher vitamin E levels pre-infection were found to be associated with increased mortality. Thus, further research is needed to elucidate the role vitamin E plays in the pathogenesis of HIV-1.[20]

**Immunity**

It has now been proven that vitamin E stimulates the body's defences, enhances humoral and cell immune responses and increases phagocytic functions. It has a pronounced effect in infectious diseases where immune phagocytosis is involved, but is less effective in the case of cell-mediated immune defences. Its supplementation significantly enhances both cellmediated and humoral immune functions in humans, especially in the elderly. A daily intake of 200 mg of vitamin E improved the antibody response to various vaccines in healthy subjects who showed no adverse side-effects to vitamin E supplementation. Vitamin E also

enhanced resistance to viral diseases in elderly subjects, where higher plasma vitamin E levels correlated with a reduced number of infections over a three-year period. A recent study showed that a daily supplementation of vitamin E can enhance the immune response to a specific antigen.

Besides the above mentioned diseases, vitamin E has also been found to play a beneficial role in other diseases, such as photodermatitis, menstrual pain/ dysmenorrhoea, pre-eclampsia and tardive dyskinesia, when taken along with vitamin C.[21]

## CONCLUSION

Vitamin E is an fat-soluble nutrient with powerful antioxidant properties substance. It help a vital role in protecting cells from oxidative damage, provide the supports of immune function also involved in skin and eye health. Vitamin E is found in various foods and also available of dietary supplements, including nuts, seeds, vegetable oils, and leafy greens. While deficiencies are rare in developed countries, they can occur in individuals with certain health conditions, leading to potential issues like weakened immunity or vision problems. While vitamin E has numerous health benefits, excessive intake especially through supplements can cause adverse effects like bleeding disorders due to its anticoagulant properties. Therefore, it's essential to consult a healthcare provider before taking high-dose vitamin E supplements, especially for individuals on blood-thinning medications. Pharmacological Uses of Vitamin E Antioxidant Effects, Cardiovascular Health, Skin Health, Neurological Support, Eye Health, Immune Function, Management of Fat-Soluble Vitamin Deficiencies. The Conclusion of the Vitamin E maintaining an adequate intake of vitamin E is crucial for overall health. However, excessive supplementation can lead to adverse effects, so it's important to aim for a balanced approach through diet and, when necessary, supplements under the guidance of a healthcare provider.

## REFERENCE

1. Rizvi S, Raza ST, Ahmed F, Ahmad A, Abbas S, Mahdi F. The role of vitamin e in human health and some diseases. Sultan Qaboos Univ Med J., 2014; 14(2): 157-65. Epub 2014 Apr 7. PMID: 24790736; PMCID: PMC3997530.
2. Traber MG. Vitamin E. In: Shils ME, Shike M, Ross AC, Caballero B, Cousins R, eds. Modern Nutrition in Health and Disease. 10th ed. Baltimore, MD: Lippincott Williams & Wilkins, 2006; 4: 396-411.

3. Bartolini D, Marinelli R, Stabile AM, Frammartino T, Guerrini A, Garetto S, Lucci J, Migni A, Zatini L, Marcantonini G, Rende M, Galli F. Wheat germ oil vitamin E cytoprotective effect and its nutrigenomics signature in human hepatocyte lipotoxicity. Heliyon, 2022; 8(9): 10748. doi: 10.1016/j.heliyon.2022.e10748. PMID: 36193535; PMCID: PMC9525900.
4. Pham-Huy LA, He H, Pham-Huy C. Free radicals, antioxidants in disease and health. Int J Biomed Sci., 2008; 4(2): 89-96. PMID: 23675073; PMCID: PMC3614697.
5. Szewczyk K, Górnicka M. Dietary Vitamin E Isoforms Intake: Development of a New Tool to Assess Tocopherols and Tocotrienols Intake in Adults. Nutrients, 2023 Aug 28; 15(17): 3759. doi: 10.3390/nu15173759. PMID: 37686791; PMCID: PMC10490030.
6. Khallouki F., Owen R.W., Akdad M., El Bouhali B., Silvente-Poirot S., Poirot M. Molecular Nutrition. Elsevier; Amsterdam, The Netherlands: 2020. Vitamin E: An overview, pp. 51–66.
7. Schneider C. Chemistry and biology of vitamin E. Mol Nutr Food Res., 2005 Jan; 49(1): 7-30. doi: 10.1002/mnfr.200400049. PMID: 15580660.
8. Mohd Zaffarin AS, Ng SF, Ng MH, Hassan H, Alias E. Pharmacology and Pharmacokinetics of Vitamin E: Nanoformulations to Enhance Bioavailability. Int J Nanomedicine, 2020 Dec 8; 15: 9961-9974. doi: 10.2147/IJN.S276355. PMID: 33324057; PMCID: PMC7733471.
9. Maeda H, Song W, Sage TL, DellaPenna D. Tocopherols play a crucial role in low-temperature adaptation and Phloem loading in Arabidopsis. Plant Cell, 2006 Oct; 18(10): 2710-32. doi: 10.1105/tpc.105.039404. Epub 2006 Sep 29. PMID: 17012603; PMCID: PMC1626601.
10. Li Z, Keasling JD, Niyogi KK. Overlapping photoprotective function of vitamin E and carotenoids in Chlamydomonas. Plant Physiol., 2012 Jan; 158(1): 313-23. doi: 10.1104/pp.111.181230. Epub 2011 Nov 11. PMID: 22080601; PMCID: PMC3252108.
11. Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. Washington (DC): National Academies Press (US); 2000. 6, Vitamin E. Available from: https://www.ncbi.nlm.nih.gov/books/NBK225461/.
12. Awad JA, Morrow JD, Hill KE, Roberts LJ II, Burk RF. 1994. Detection and localization of lipid peroxidation in selenium- and vitamin E-deficient rats using $F_2$ ¨isoprostanes. J Nutr., 124: 810–816.

13. Konopatskaya O, Matthews SA, Harper MT, Gilio K, Cosemans JM, Williams CM, Navarro MN, Carter DA, Heemskerk JW, Leitges M, Cantrell D, Poole AW. Protein kinase C mediates platelet secretion and thrombus formation through protein kinase D2. Blood, 2011 Jul 14; 118(2): 416-24. doi: 10.1182/blood-2010-10-312199. Epub 2011 Apr 28. PMID: 21527521; PMCID: PMC4773892.
14. Mohd Zaffarin AS, Ng SF, Ng MH, Hassan H, Alias E. Pharmacology and Pharmacokinetics of Vitamin E: Nanoformulations to Enhance Bioavailability. Int J Nanomedicine, 2020 Dec 8; 15: 9961-9974. doi: 10.2147/IJN.S276355. PMID: 33324057; PMCID: PMC7733471.
15. Paolisso G, D'Amore A, Giugliano D, Ceriello A, Varricchio M, D'Onofrio F. Pharmacologic doses of vitamin E improve insulin action in healthy subjects and non-insulin-dependent diabetic patients. Am J Clin Nutr., 1993 May; 57(5): 650-6. doi: 10.1093/ajcn/57.5.650. PMID: 8480681.
16. Vardi M, Levy NS, Levy AP. Vitamin E in the prevention of cardiovascular disease: the importance of proper patient selection. J Lipid Res., 2013 Sep; 54(9): 2307-14. doi: 10.1194/jlr.R026641. Epub 2013 Mar 15. PMID: 23505320; PMCID: PMC3735930.
17. Wang H, Khor TO, Shu L, Su ZY, Fuentes F, Lee JH, Kong AN. Plants vs. cancer: a review on natural phytochemicals in preventing and treating cancers and their druggability. Anticancer Agents Med Chem., 2012 Dec; 12(10): 1281-305. doi: 10.2174/187152012803833026. PMID: 22583408; PMCID: PMC4017674.
18. Braakhuis AJ, Donaldson CI, Lim JC, Donaldson PJ. Nutritional Strategies to Prevent Lens Cataract: Current Status and Future Strategies. Nutrients, 2019 May 27; 11(5): 1186. doi: 10.3390/nu11051186. PMID: 31137834; PMCID: PMC6566364.
19. Butterfield DA, Lauderback CM. Lipid peroxidation and protein oxidation in Alzheimer's disease brain: potential causes and consequences involving amyloid beta-peptide-associated free radical oxidative stress. Free Radic Biol Med., 2002 Jun 1; 32(11): 1050-60. doi: 10.1016/s0891-5849(02)00794-3. PMID: 12031889.
20. Itinoseki Kaio DJ, Rondó PH, Luzia LA, Souza JM, Firmino AV, Santos SS. Vitamin E concentrations in adults with HIV/AIDS on highly active antiretroviral therapy. Nutrients, 2014 Sep 15; 6(9): 3641-52. doi: 10.3390/nu6093641. PMID: 25225815; PMCID: PMC4179180.
21. Lewis ED, Meydani SN, Wu D. Regulatory role of vitamin E in the immune system and inflammation. IUBMB Life, 2019 Apr; 71(4): 487-494. doi: 10.1002/iub.1976. Epub 2018 Nov 30. PMID: 30501009; PMCID: PMC7011499.