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Review Article

Recent insights on bioactive nutrients to prevent cardiovascular disease

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Abstract

Cardiovascular diseases are principally responsible for the maximum number of mortalities, with 17.5 million deaths worldwide. This review summarizes the current evidence and concisely presents the relationship between bioactive nutrients and their positive impact on preventing cardiovascular diseases. Meals rich in dietary fiber have proven to significantly reduce serum cholesterol levels by 15-19% and reduce blood pressure and hypertension. Coenzyme Q_{10} is a cardioprotective ingredient that improves endothelial function and positively affects the lipid profile. An average intake of 2 g per day of phytosterol can lower the low-density lipoprotein by 8-10%. Omega-3 fatty acids significantly reduce by 15% the likelihood that a person will die from cardiovascular disease. Recent studies have shown that a lack of vitamin C increases the risk of cardiovascular disease-related fatalities. Vitamin C slightly enhances lipid profiles and endothelial function. Several oxidation reactions that can result in cardiovascular diseases can be stopped by vitamin E, which can scavenge free lipid radicals. Carotenoids reduce oxidative damage and the emergence of diseases linked to oxidation by neutralizing the toxicity of free radicals.

Keywords

cardiovascular diseases, Coenzyme Q_{10}, phytosterol, omega-3 fatty acid, Vitamin C, antioxidant, Vitamin E

Abbreviations

CoQ_{10} – Coenzyme Q_{10}; PUFA – Polyunsaturated fatty acids; RDA – Recommended Daily Allowance; EPA – eicosapentaenoic acid; DHA – docosahexaenoic acid

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Introduction

The heart, arteries, and veins constitute the cardiovascular system. Cardiovascular diseases are broadly classified as diseases affecting the heart, arteries, and veins, with dyslipidemia, atherosclerosis, hypertension, and ischemic heart disease being the most prevalent (Olvera Lopez et al. 2023; Chest Heart and Stroke Scotland 2022; Szczepańska et al. 2022). Cardiovascular diseases are principally responsible for the maximum number of deaths in many nations, with 17.5 million deaths worldwide (Brandhorst and Longo 2019; Ludovici et al. 2017). Two main factors influence cardiovascular diseases: modifiable and non-modifiable. Inherent factors, like gender, age, ethnicity, and family history about a particular disease, such factors cannot be modified and hence are known as non-modifiable factors. Factors like body weight, dietary regimen, exercise, exposure to stress, smoking, and use of alcohol are factors that can be modified and are known as modifiable factors. Diseases like hypertension, hyperlipidemia, ischemic heart disease, and diabetes can be considered to have a partially modifiable effect on cardiovascular diseases. The development of cardiovascular diseases is unquestionably attributed to an inappropriate dietary regimen. Most common errors include not having a fixed time of consumption of meals, consumption of highly processed foods, consuming a diet with low dietary fiber content, lack of inclusion of unsaturated fatty acids, and a high proportion of saturated fatty acid-rich meats in the diet.

Dietary risk factors are characterized by inadequate intake patterns, like overconsumption of a food product directly associated with increased cardiovascular diseases or underconsumption of food products proven to lower the disease's risk. Evaluation of the quality of the diet is of great importance as it conforms to the current idea that the totality of the diet has a more significant impact on health than the individual components (Szczepańska et al. 2022). Bioactive nutrients are necessary for the human body as they exhibit antioxidant, anti-allergic, anti-inflammatory, antibacterial, anticarcinogenic, and antimutagenic activities (Câmara et al. 2020).

Dietary Fiber

Dietary fiber mainly consists of various plant compounds and is not completely digested by the human gut. Dietary fiber is broadly classified into four major types: soluble dietary fiber and insoluble dietary fiber, resistant starches, and prebiotics. Insoluble dietary fibers, such as cellulose, lignin, and hemicelluloses, such as arabinoxylan and glucomannan, are not digested by the human gut due to a lack of enzymes (Evans 2020). The human gut digests soluble dietary fibers, such as pectins, β-glucans, mucilages, and hydrocolloids such as gums. Sources of fiber are mainly plant-based foods, particularly cereals, potatoes, beans, pulses, fruits, and vegetables (Evans 2020). Consumption of high quantities of dietary fiber is inversely proportional to the onset of cardiovascular diseases; high dietary fiber intake has also been linked to a significant drop in blood pressure and various cardiometabolic factors (Reynolds et al. 2022). Many health benefits are linked to the intake of dietary fibers; a good dietary fiber-enriched meal reduces the risk for the onset of coronary heart disease, stroke, high blood pressure, diabetes, obesity, and digestive system disorders. Regular consumption of dietary fiber improved serum lipid concentrations, lowered blood pressure, aided weight loss, and improved immune function (Anderson et al. 2009). According to the WHO, a healthy diet must contain more than 25g of dietary fiber, and in most European countries, dietary fiber intake should vary from 25g to 30 g daily. Therefore, to meet the recommended daily allowance (RDA) of dietary fiber, it is vital to include more fruits, vegetables, cereals, and legumes daily (Evans 2020).

Foods containing soluble dietary fiber are carrots, onions, artichokes, broccoli, bananas, cherries, apples, pears, oats, and barley. Whole grains, bran, nuts, and seeds are rich in insoluble dietary fiber.

Mechanism of Action of Dietary Fiber

Soluble dietary fiber is more readily digested by the gut microbes by the action of endogenous enzymes like α-amylase, amyloglucosidase, and protease (McCleary 1999). In contrast, it is relatively complex to digest insoluble dietary fiber.

Soluble dietary fibers have some prebiotic functions on digestion and are a source of short-chain fatty acids (Soliman 2019). Short-chain fatty acids are proven to have multiple positive effects on the energy metabolism of mammals (den Besten et al. 2013). Short-chain fatty acids are readily imbibed from the small intestine, which is further utilized by oxidation for energy production. Propionic acid, among other short-chain fatty acids on absorption, has decreased cholesterol synthesis in the liver, resulting in reduced cholesterol concentration in the blood and increased sodium and water absorption in the mucosal cells of the colon (Soliman 2019).

The acidic environment of the colon reduces the absorption of free bile acids and simultaneously increases the elimination of bile. Additionally, secondary bile acids, which are more toxic than free bile acids, are less frequently formed when short-chain fatty acids are present (Soliman 2019).

Hypercholesterolemia is a disorder where low-density lipoprotein is present in large quantities inside the body, which makes the deposition of fat in the blood vessels lead to a higher chance of stroke or heart attack (Cleveland Clinic 2022a). It was found by Kasahara et al. (2017) that gut microbiota could regulate the homeostasis of cholesterol via the bile acid mechanism in people having hyper-cholesterolemia (Ohira et al. 2017).

Dietary fiber has many significant hypo-cholesterolemic effects and is proven to reduce the risk of coronary artery disease. Foods rich in dietary fiber might decrease serum cholesterol levels by 15% to 19% and decrease the risk for coronary heart disease by more than 30% (Anderson 1987).

Coenzyme Q_{10}

Cardioprotective food ingredients are sources of food that, when consumed, can improve the health of people ailing from cardiovascular disease and prevent the onset in healthy people. One such cardioprotective food ingredient is Coenzyme Q_{10} (CoQ_{10}) (Szczepańska et al. 2022).

The chemical molecule known as CoQ_{10} was initially recognized by Crane et al. (1957). CoQ_{10}'s main job is moving electrons from complex I and II to complex III as part of the mitochondrial electron transport chain (Festenstein et al. 1955; Crane et al. 1957). The outcome of CoQ_{10}'s primary function is crucial for energy

metabolism. The mitochondria's inner membrane's improved and more effective electron transport leads to a significantly higher and more abundant production of ATP. CoQ_{10} undergoes oxidation to form various oxidation products, ubiquinone, semi-ubiquinone, and ubiquinol (Gutierrez-Mariscal et al. 2021). Since CoQ_{10} is made by the body rather than being a vitamin, it must be obtained through diet (Raizner 2019).

By moving electrons to and from the protein complexes in the respiratory chain, ubiquinone actively contributes to energy production in the mitochondria. Ubiquinol reduces stress by taking oxygen (Szczepańska et al. 2022). Cardiomyocytes are cells responsible for the heart's contractions, aiming to efficiently execute the contraction-relaxation cycle (Keepers et al. 2020). Cardiomyocytes have a higher demand for ATP and CoQ_{10} due to the large number of mitochondria. Hence, CoQ_{10} is essential for all cells, mainly cardiomyocytes. The benefits of CoQ_{10} are that it improves endothelial function and positively affects the lipid profile. CoQ_{10} also increases the activity of vascular smooth muscle, prevents vasoconstriction, and lowers blood pressure, all of which directly affect the endothelium (Digiesi et al. 1994). By re-coupling endothelial nitric oxide synthase, CoQ_{10} is thought to have a protective role in the management of hypertension by indirectly lowering inflammation, oxidative stress, and nitrative stress (Belardinelli et al. 2008).

Individuals with modest dyslipidemia and endothelial dysfunction improved their cardiovascular health after receiving CoQ_{10} therapy (Sabbatinelli et al. 2020). A similar reduction in endothelial dysfunction was seen when CoQ_{10} treatment was combined with anti-atherogenic drugs such as statins (Chew and Watts 2004).

Apart from the endogenous origin of CoQ_{10}, we can provide the coenzyme in the form of various exogenous sources, such as fatty fish, spinach, nuts, and soybeans being the chief sources of CoQ_{10} (Szczepańska et al. 2022).

Plant Sterols

Phytosterols are of plant origin, whereas zoosterols are of animal origin, with cholesterol being the most prevalent zoosterol. Phytosterols and cholesterol are structurally and functionally similar (Alissa and Ferns 2012). Phytosterols are a collective name for plant sterols and stanols (Ras et al. 2015).

Phytosterols are triterpenes, which are fat-soluble compounds that contribute to the structure and stability of plant cell membranes (Poli et al. 2021). Plant sterols are mainly known for their ability to lower cholesterol, most notably low-density lipoprotein cholesterol (Ras et al. 2015). An average intake of 2g per day of phytosterol can lower low-density lipoprotein cholesterol by 8-10% (Ras et al. 2015). Since phytosterols and cholesterol have a similar structure and absorption pathway, they compete with cholesterol for digestion by blocking their uptake and facilitating excretion from the body. This lowers cholesterol levels (Cleveland Clinic 2022b; Mohebi-Nejad and Bikdeli 2014). The most found plant sterols in the diet are campesterol (65%) and beta-sitosterol (30%). Beta-sitosterol and campestanol are the most common plant stanols (Cabral and Klein 2017; Makhmudova et l. 2021).

Table 1. Phytosterols in food sources
*Adapted from Cabral and Klein (2017) Copyright 2017, Brazilian Society of Cardiology

Food Sources	Quantity
Corn oil	90.9 mg.10 mL^{-1}
Sunflower oil	41.1 mg.10 mL^{-1}
Soybean oil	32 mg.10 mL^{-1}
Olive oil	30 mg.10 mL^{-1}
Almonds	18.3 mg.10 g^{-1}
Wheat Germ	34.4 mg.10 g^{-1}
Passion Fruit	4.4 mg.10 g^{-1}
Orange	2.4 mg.10 g^{-1}
Cauliflower	4 mg.100 g^{-1}

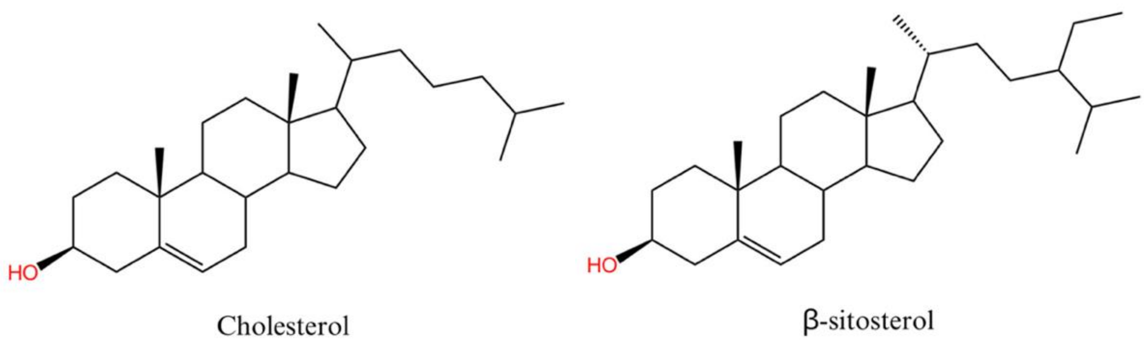

Figure 1. Structure of cholesterol and β-sitosterol
*Adapted from Yuan et al. (2019) Copyright 2019, Springer Nature.

Omega-3 Fatty Acids

Omega-3 fatty acids are a polyunsaturated fatty acids (PUFA) family (Innes and Calder 2020). The structure of PUFAs is marked by the presence of a long carbon chain with an end with a methyl [-CH3] group and a carboxyl [-COOH] group (Mohebi-Nejad and Bikdeli 2014). The omega-3 and omega-6 fatty acid groups comprise the two main subgroups of PUFAs. Omega-n refers to the number of carbon atoms away from the methyl group by the first double bond (Ras et al. 2015).

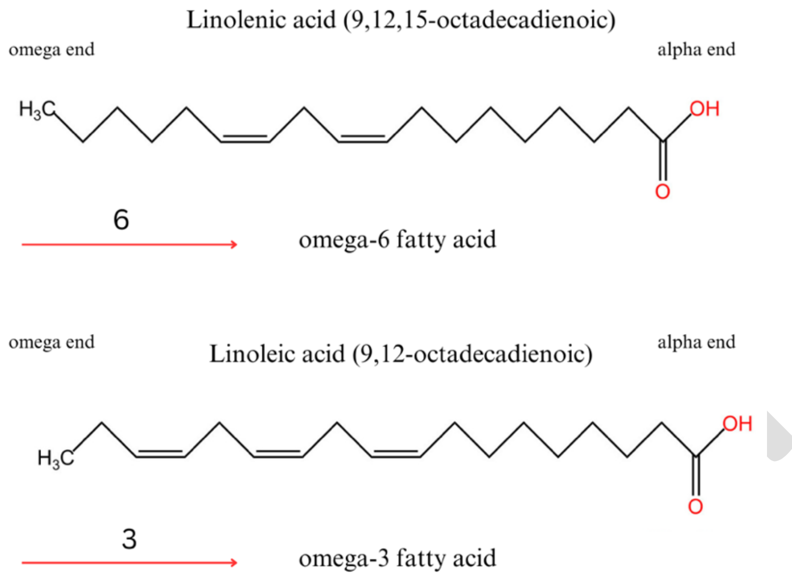

Figure 2. Structure of omega-3 and omega-6 fatty acids
*Adapted from Generalic (2022) Copyright 2022, University of Split, Faculty of Chemistry and Technology

N-3 PUFAs can lessen inflammation and may help reduce the risk of developing chronic illnesses like arthritis, cancer, and heart disease. Additionally, they control the growth and operation of the nervous system, blood pressure, haematic clotting, and glucose tolerance (Wall et al. 2010). Omega-3 fatty acids majorly consist of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). It is believed that ingesting alpha-linolenic acid synthesizes small amounts of eicosapentaenoic acid and docosahexaenoic acid. In contrast, docosapentaenoic acid is believed to be formed through the metabolic pathways over dietary intake (National Institutes of Health 2023).

Docosahexaenoic acid and eicosapentaenoic acid should be consumed in 1g per day to protect the heart. To reduce excessive triglyceride levels, higher dosages of omega-3 fatty acids (2-4 g per day) are required (Jain et al. 2015). In a study involving 11.324 patients with coronary heart disease, those who took fish oil and alpha-linolenic acid pills daily saw a 15% reduction in heart attack-related deaths, stroke incidence, a 20% reduction in overall mortality, and a 45% reduction in sudden cardiac death. A further 4% reduction in triglyceride levels was also observed (Marchioli 1999; Chaddha and Eagle 2015). It can be interpreted that omega-3 fatty acid consumption may lower the risk of death from heart disease in people. Consuming omega-3 fatty acids has been found to slightly lower diastolic blood pressure and reduce body fat, both of which lead to improved heart health (Chaddha and Eagle 2015; Kris-Etherton et al. 2002).

Omega-3 fatty acids have been shown to significantly lessen the risk of sudden cardiac death and overall mortality in people with existing coronary heart disease. Omega-3 fatty acids are additionally utilized to treat hyperlipidemia and hypertension (Jain et al. 2015). Eicosapentaenoic acid and docosahexaenoic acid have been shown in clinical studies to reduce cardiovascular risk factors such as high blood pressure and cholesterol. Fish oil has been shown to lower triglyceride levels, lessen the risk of cardiovascular death, and lower the incidence of irregular cardiac rhythms. It can stop the heart conditions that lead to unexpected death (Lemaitre et al. 2003; Yokoyama et al. 2007; Albert et al. 2002; Gammone et al. 2018).

Table 2. EPA and DHA content of cooked seafood.
*Adapted from National Institutes of Health (2023) Copyright 2023, U.S. Department of Health & Human Services

Seafood	EPA, mg.85 g^{-1}	DHA, mg.85 g^{-1}
Oysters	0.30	0.23
Atlantic herring	0.77	0.94
Atlantic mackerel	0.43	0.59
Rainbow trout	0.40	0.44
Shrimp	0.12	0.12
Sea bass	0.18	0.47
Sardines	0.45	0.74

Table 3. Recommended daily allowance of alpha-linolenic acid.
*Adapted from National Institutes of Health (2023) Copyright 2023, U.S. Department of Health & Human Services

Age	Recommended Intake, g per day
0-12 months	0.5
1-3 years	0.7
4-8 years	0.9
Boys 9-13 years	1.2
Girls 9-13 years	1.0
Boys 14-18 years	1.6
Girls 14-18 years	1.1
Men	1.6
Women	1.1
Pregnant women	1.4

Vitamins

Vitamins are organic substances classified as micronutrients because they are microscopic amounts required by the human body for proper functioning and metabolism.

Vitamins are broadly classified into two categories, namely, fat-soluble and water-soluble vitamins.

Vitamins A, D, E, and K are fat-soluble vitamins that quickly dissolve in fat and build up in the body. The body cannot store water-soluble vitamins because they dissolve in water before storing them. Instead, they are excreted in urine when they are primarily not needed. The vitamin B complex and vitamin C are among the water-soluble vitamins (Harvard T.N. Chan School of Public Health 2023).

Vitamin C. Due to its potential impact on heart health, strong dietary antioxidant vitamin C has attracted much attention (Moser and Chun 2016).

L-ascorbic acid, also known as vitamin C, is an essential nutrient for people; it has various positive effects, including regulation of the immune system, antioxidant activity, and synthesis of neurotransmitters. Patients suffering from cardiovascular diseases are expected to overcome them by consuming vitamin C owing to its antioxidant properties (Hamishehkar et al. 2016). Due to its role as an essential cofactor for numerous enzymes, vitamin C is crucial. Because of its strong ability to donate electrons and the ease with which it can be converted back to its reduced form, ascorbic acid, a reduced vitamin C, functions as an efficient antioxidant (Jacob and Sotoudeh 2002). While maintaining glutathione in its reduced form and protecting it from depletion may require optimal levels of plasma vitamin C (Shang et al. 2003; Waly et al. 2015), the increase of oxidized glutathione in the heart and the resulting decrease in the reduced glutathione to oxidized glutathione ratio may cause ventricular arrhythmias through mechanisms such as mitochondrial depolarization in cardiomyocytes (Brown et al. 2006). Overall, research indicates that vitamin C regulates redox by increasing other cellular radical scavenger levels and directly interacting with ROS to produce its antioxidative action. (Morelli et al. 2020).

Infectious processes may benefit significantly from vitamin C's anti-oxidant properties and its restricting effects on endothelial permeability (Montel-Hagen et al. 2008; Wang et al. 2007; Bauer et al. 2020; Carr and Rowe 2020). Additionally, studies have shown that vitamin C can synergistically improve the benefits of other drugs. For instance, vitamin C has been shown to improve endothelial function and lower oxidative stress in Type 1 diabetic patients when combined with glucagon-like peptide (Gillani et al. 2017) and to improve endothelial function further and reduce cardiovascular complications associated with diabetes when combined with metformin (Ceriello et al. 2013).

Hence, it may be able to take advantage of the relationship between Vitamin C and other nutrients and micronutrients that have similar therapeutic effects (Bae and Kim 2020).

According to recent research, vitamin C deficiency is directly linked to a higher risk of death from cardiovascular diseases. It may even slightly improve lipid profiles and endothelial function in specific sets of people, particularly those with low plasma vitamin C levels (Moser and Chun 2016).

Vitamin C-rich food sources include citrus fruits, tomatoes, red and green peppers, kiwi, strawberries, Brussel sprouts, and cantaloupe (National Institutes of Health 2021).

Vitamin E. A naturally occurring fat-soluble vitamin, vitamin E, is obtained exclusively from the diet and has been proposed as a treatment for both primary and secondary protection against cardiovascular diseases (Rizvi et al. 2014; Vardi et al. 2013). Vitamin E consists of eight lipophilic molecules, of which four are tocopherols and four are tocotrienols, with α-tocopherol being the most biologically active (Vardi et al. 2013).

Vitamin E is a vital component in the cell antioxidant system and has numerous essential functions in the human body owing to its antioxidant activity. Vitamin E's capacity to scavenge free lipid radicals and put an end to chain oxidations has been attributed to it as an antioxidant (Vardi et al. 2013). Oxidation is known to cause several diseases, including cancer, cardiovascular diseases, cataracts, and arthritis, and vitamin E is effective against these diseases (Rizvi et al. 2014). By reacting with the lipid peroxyl radical and stopping the production of new radicals, vitamin E stops radical chain reactions. α-tocopherol reacts with other radicals by converting them into non-radical forms after supplying hydrogen atoms with α-tocopherol being converted to tocopheroxyl radicals. These tocopheroxyl radicals react with themselves or other radicals, breaking the lipid peroxidation chain reaction (Shah et al. 2021). After the oxidation of Vitamin E, it is recycled back to its initial unoxidized form by soluble antioxidants like vitamin C. This process prevents the aggregation of vitamin E radicals, which is considered critical for the antioxidant activity of vitamin E (Vardi et al. 2013).

Atherosclerosis, an accumulation of cholesterol in the blood vessels (National Heart, Lung and Blood Institute 2023) and primarily caused by platelet aggregation, can also be prevented by the antioxidant properties of vitamin E (Rizvi et al. 2014). Inflammation is brought on by the oxidation of low-density lipoprotein cholesterol, which leads to cardiovascular diseases (McAnally et al. 2007). Nitric oxide relaxes the blood vessels produced by nitric oxide synthase. Gamma-tocopherol increases nitric oxide synthase activity and improves cardiovascular functions (McAnally et al. 2007; Sesso et al. 2007).

Endothelial function is enhanced as vitamin E traps the reactive oxygen species. Researchers have discovered that adding 100 mg of gamma-tocopherol to a person's diet daily reduces several risk factors for artery coagulation, including cholesterol and platelet aggregation (McAnally et al. 2007; Shklar and Oh 2002). Other studies suggested that the consumption of mixed tocopherols had a strong restraining effect on platelet aggregation and peroxidation of lipids rather than individual tocopherols, which suggests that they have a synergistic effect on platelet inhibition (McAnally et al. 2007; Singh et al. 2007; Ricciarelli et al. 1999).

Table 4. Vitamin E-rich food sources with the concentration of α-tocopherol.
*Adapted from Rychter et al. (2022). Copyright 2022, Elsevier

Dietary source	**α-tocopherol, mg.100 g^{-1}**
Wheat germ oil	133
Almond oil	39.2
Extra virgin olive oil	16
Corn oil	14.3
Peanut oil	11.62
Soybean oil	10.99
Sunflower seeds	25.9
Almonds	23.8
Hazelnuts	15.05

Carotenoids. Carotenoids are essential since humans cannot synthesize them (Fasset and Coombes 2011). Carotenoids are tetraterpenoid, lipid-soluble, highly unsaturated red, orange, or yellow pigments naturally found in fruits, vegetables, algae, fungi, plants, and bacteria (Saini et al. 2022; Bhatt and Patel 2020). They are divided into carotenes and xanthophylls based on their chemical makeup. Xanthophylls comprise lutein, fucoxanthin, canthaxanthin, and zeaxanthin, whereas carotenes include beta-carotene and lycopene (Gammone et al. 2015). The color intensity directly correlates to the number of carotenoids present (Bhatt and Patel 2020). Clinical and epidemiological studies have shown that eating foods high in carotene content lowers the risk of fatal diseases like cancer, type 2 diabetes, and card fatal diseases like cancer, type 2 diabetes, and cardiovascular diseases. The color intensity directly correlates to the number of carotenoids present (Bhatt and Patel 2020). Clinical and epidemiological studies have shown that eating foods high in carotene content lowers the risk of fatal diseases like cancer, type 2 diabetes, and cardiovascular diseases. Free radical toxicity is known to be neutralized by carotenoids, reducing oxidative damage and the onset of oxidation-related diseases (Saini et al. 2022). Carotenoids and their derivatives are pivotal in plants and animals at the cellular and molecular levels. The most notable are the antioxidant and provitamin effects of foods rich in carotenoids (Saini et al. 2015). Various laboratory experiments have concluded that carotenoids minimize oxidative stress and inflammation, promoting the cell's normal functioning. Numerous studies have revealed that

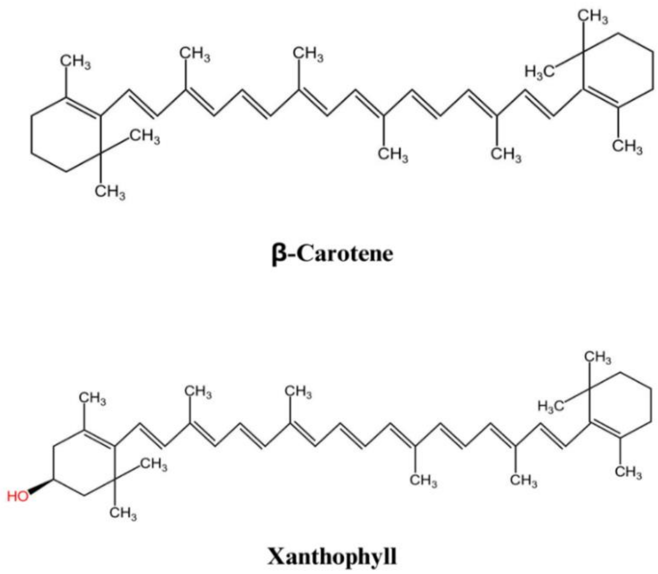

Figure 3. Structure of carotenes and xanthophylls.
*Adapted from Shankaranarayanan et al. (2018). Copyright 2018, Emerald

increasing the consumption of foods high in carotenoids facilitates the repression of cardiovascular diseases in humans.

A meta-analysis consisting of 25 studies, majorly from the United States and Finland, consisting of a pool of 211.704 participants with the highest serum concentration (0.41 $\mu mol.L^{-1}$) or with the highest daily consumption of lycopene (9.81 mg per day) had significantly lower incidences of strokes and cardiovascular diseases. Moreover, it was also proven that people with the largest serum lycopene concentration experienced the least mortality risk (Gammone et al. 2015; Cheng et al. 2019). Numerous epidemiological studies have found positive links between consuming large amounts of carotenoids and reducing cardiovascular disease risk (Gammone et al. 2015; Cheng et al. 2019; Asbaghi et al. 2022). Lycopene supplementation significantly reduced systolic blood pressure to a greater extent in participants with a baseline systolic blood pressure of more than or equal to 130 mmHg when they consumed more than or similar to 15 mg per day for at least 8 weeks, according to a meta-analysis of randomized controlled trials that included 10 studies (Gammone et al. 2015; Asbaghi et al. 2022). This study also stated a significant decrease in diastolic blood pressure among people with more than 80 mmHg (Gammone et al. 2015; Asbaghi et al. 2022). In conclusion, the comprehensive meta-analysis indicates that higher daily intake or higher serum concentration of lycopene is linked to considerable reductions in the risk of cardiovascular diseases (14%), mortality (37%), and stroke (26%) (Cheng et al. 2019).

In addition to the above, lycopene consumption has shown beneficial effects on cardiovascular health owing to its antihypertensive actions. The beneficial effects of lycopene consumption on blood pressure levels may be explained by its anti-inflammatory and antioxidant properties on endothelial cells (Asbaghi et al. 2022).

The antioxidant activity of carotenoids keeps oxidative stress in check, which is additionally accountable for preventing the expression of pro-inflammatory mediators; these incidences reduce the risk of cardiovascular diseases, type 2 diabetes, cancer, and neurodegenerative diseases, which are supported by several epidemiological studies (Gammone et al. 2015).

Future Insights

Recent pandemics, cases of antibiotic resistance in pathogenic microorganisms, rising consumer awareness of sustainable products, bioremediation initiatives, and the emergence of non-communicable diseases like cancer, obesity, diabetes, and others over the past few decades have all contributed to an increase in demand for healthier, natural, immune-boosting and bio-fortified foods, novel antibiotics and pharmaceuticals, and bio-based raw materials for various processes (Pai et al. 2022). According to estimates, the global nutraceutical market will grow from $241 billion in 2019 to $373 billion in 2025 (Chrzan 2019). Further study into efficient and sustainable ways to screen, extract, characterize, process, and market high-quality bioactive chemicals is required in light of increased demand (Pai et al. 2022).

Conventional techniques for isolating bioactive chemicals from food sources include pulse electric field-assisted extraction, supercritical fluid extraction, enzyme-assisted extraction, pressurized liquid extraction, and ultrasound-assisted extraction. Nanoencapsulation techniques can preserve bioavailability, enhance stability, and permit the controlled release of bioactive components when delivering chemicals into functional food products. Several strategies include encapsulation inside spontaneously assembled structures and using biopolymer sheets in food packaging (Pai et al. 2022).

Fu et al. (2019) advised switching from traditional chromatography methods to multi-targeted ways to screen several bioactive chemicals simultaneously using biosensors and microfluidic chip-based technologies.

Conclusions

Current literature and research studies support the fact that the development of cardiovascular diseases is directly linked to an inappropriate dietary regimen. A recommended daily intake of 25 g per day of dietary fiber has proven to prevent the development of various fatal diseases like coronary heart disease, stroke, and hypertension. Cardioprotective ingredients like CoQ_{10} are vital for cells like cardiomyocytes; they improve endothelial function and conclusively affect the lipid profile. Phytosterols and cholesterol are structurally and functionally similar. Hence, phytosterol blocks cholesterol absorption by the digestive system, followed by an effective excretion of cholesterol from the body. The three different kinds of omega-3 fatty acids, namely, alpha-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid, have been proven by a clinical trial to reduce cardiovascular mortalities significantly.

Current research trends indicate that the deficiency of vitamin C has a direct correlation with an elevated danger of death from cardiovascular diseases. Consumption of vitamin C-rich meals slightly improves the endothelial function and lipid profile in people with low levels of vitamin C.

Vitamin E is a vital component of the cell antioxidant system and nullifies the negative effect of oxidation reactions, which causes cardiovascular diseases and cancer. Oxidation of lipids is the principal reason for plaque formation, which blocks blood vessels. Vitamin E prevents lipid oxidation and effectively prevents the development of cardiovascular diseases.

Carotenoids are proven to minimize oxidative stress and promote the normal working of a cell; they annul the toxicity of free radicals present in cells, which are known to cause oxidative damage.

We can effectively conclude that cardiovascular diseases are directly linked with the dietary regimen and can be kept at bay by consuming cardioprotective foods discussed in this review.

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