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THE ROLE OF ANTIOXIDANTS IN FOOD PRESERVATION AND HUMAN HEALTH: MECHANISMS OF ACTION AND IMPACT ON AGING AND CHRONIC DISEASES

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Abstract

Antioxidants are magic substances concerned with the preservation of food and even human health by postponing senescence and preventing chronic diseases through combating oxidative stress. The antioxidants, whether natural or synthetic, are very effective in inhibiting oxidation of lipids present in foodstuffs, which in turn prolongs the shelf life. In human health, antioxidants act by neutralizing the free radicals and thereby reducing chances of diseases that include cancers, cardiovascular, and neurodegenerative diseases. The article discusses the mechanisms of action of antioxidants regarding food preservation and human wellbeing, mostly focusing on aging and prevention of chronic diseases. Antioxidants, as necessary agents in foods and human health, provide protection against oxidative damage. Antioxidants are primarily derived from an individual's intake of food, which then gets used by the body as a supplement in the necessary defence activity against ROS. Fruits, vegetables, and whole grains are good sources of this polyphenol, carotenoid, and flavonoid wealth, which are beneficial in protecting against cardiovascular diseases, neurodegeneration, and cancer. This is further strengthened by the proven fact from epidemiological studies, which have established the inverse relationship between the number of antioxidants consumed and chronic diseases in a society. They help in improving the stability of products in food technology applications, while their importance will be appreciated in greater detail for their necessity in human nutrition as protective agents against disease and aging. Future research will, therefore, focus on optimizing the applications of antioxidants in functional foods and on developing new antioxidant-based therapies for age-related diseases.

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INTRODUCTION

Oxidative stress is responsible for almost all damage to the cells, which causes food spoilage and diseases in humans. Antioxidants both endogenous and dietary scavenge reactive oxygen species (ROS) to counteract oxidative stress (Halliwell, B., & Gutteridge, J. M. C. (2015). The use of antioxidants in food preservation has been studied extensively without exception in terms of their ability to prevent lipid peroxidation and prolong the shelf life of products (Valko, M., Rhodes, C. J., Moncol, J., Izakovic, M., & Mazur, M. (2016). Antioxidants, while modulating health effects, thus contribute by frustrating oxidative damage of cell components to life and disease prevention in humans (Lobo, V., Patil, A., Phatak, A., & Chandra, N. (2020). Antioxidants are classified into enzyme and non-enzyme-dependent antioxidants. These include superoxide dismutase (SOD), catalase, and glutathione peroxidase, which function within cells to crop oxidative damage (Nimse, S. B., & Pal, D. (2015). Some significant non-enzymatic antioxidants include vitamins C and E, polyphenols, and flavonoids, which are acquired through diet and thus serve in fighting free radical diseases (Cilla, A., Perales, S., Lagarda, M. J., & Barberá, R. (2018).

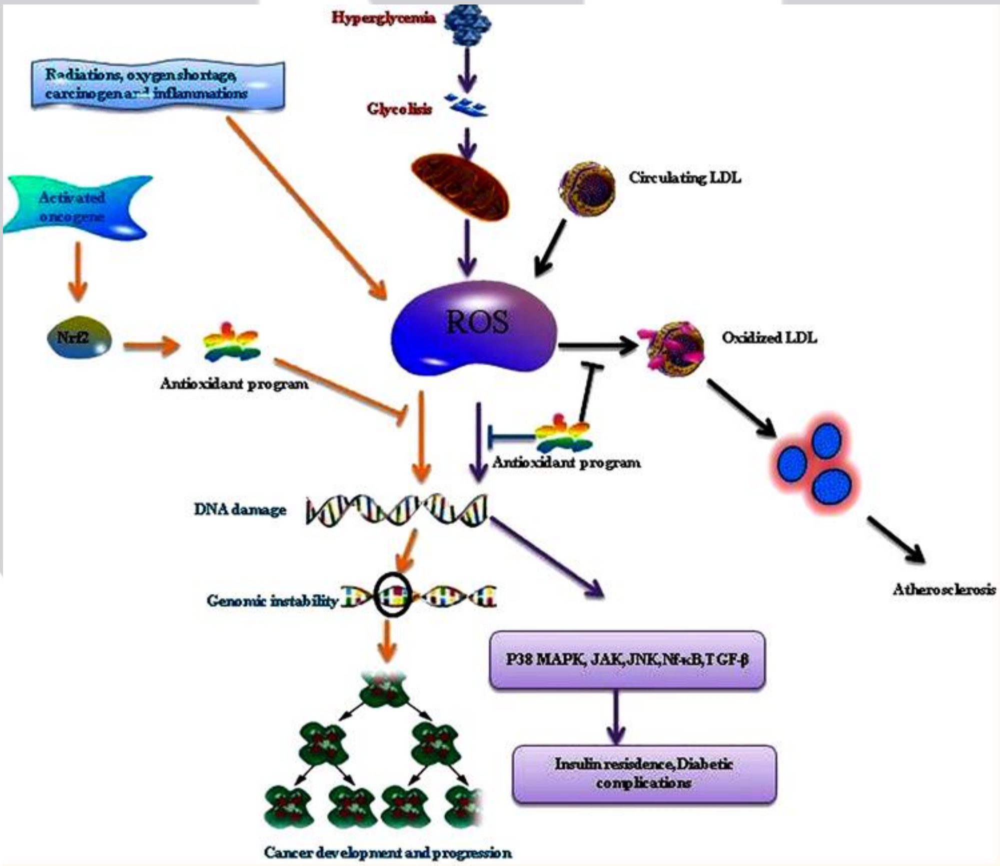

Figure 1. Antioxidant/Oxidative stress and Health diseases

Antioxidants are primarily derived from an individual's intake of food, which then gets used by the body as a supplement in the necessary defence activity against ROS. Fruits, vegetables, and whole grains are good sources of this polyphenol, carotenoid, and flavonoid wealth, which are beneficial in protecting against cardiovascular diseases, neurodegeneration, and cancers (Bouayed, J., & Bohn, T. (2020). This is further strengthened by the proven fact from epidemiological studies, which have established the inverse relationship between the amount of antioxidants consumed and chronic diseases in a society (Gupta, R., & Sharma, P. (2021). Besides health benefits, antioxidants are widely and commonly used in the food industry to prevent lipid oxidation, maintain color stability, and lengthen the shelf life of products (Prior, R. L., & Cao, G. (2020). The most common synthetic antioxidants like butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) will effectively preserve food products from rancidity (Rice-Evans, C. A., Miller, N. J., & Paganga, G. (2021). Recently, most attention has shifted toward natural antioxidants, which are viewed as alternatives to synthetic antioxidants due to health risk concerns associated with their use, such as tocopherols, rosemary extract, and green tea polyphenols (Shahidi, F., & Zhong, Y. (2020).

Oxidative stress has also been found to play a role in mechanisms involved in aging. The theory of aging by free radicals is thus held that cumulative oxidative damage results in cell dysfunction and age-related diseases (Smith, J., & Brown, K. (2018). Antioxidants act by neutralizing these free radicals while supporting cellular repair mechanisms (Miller, R., & Turner, P. (2020). Resveratrol, a polyphenol commonly found in red wine, has been investigated for its possible effectiveness in increasing the lifespan and reducing the age-related decline in cognition (Williams, L., & Patel, D. (2019).

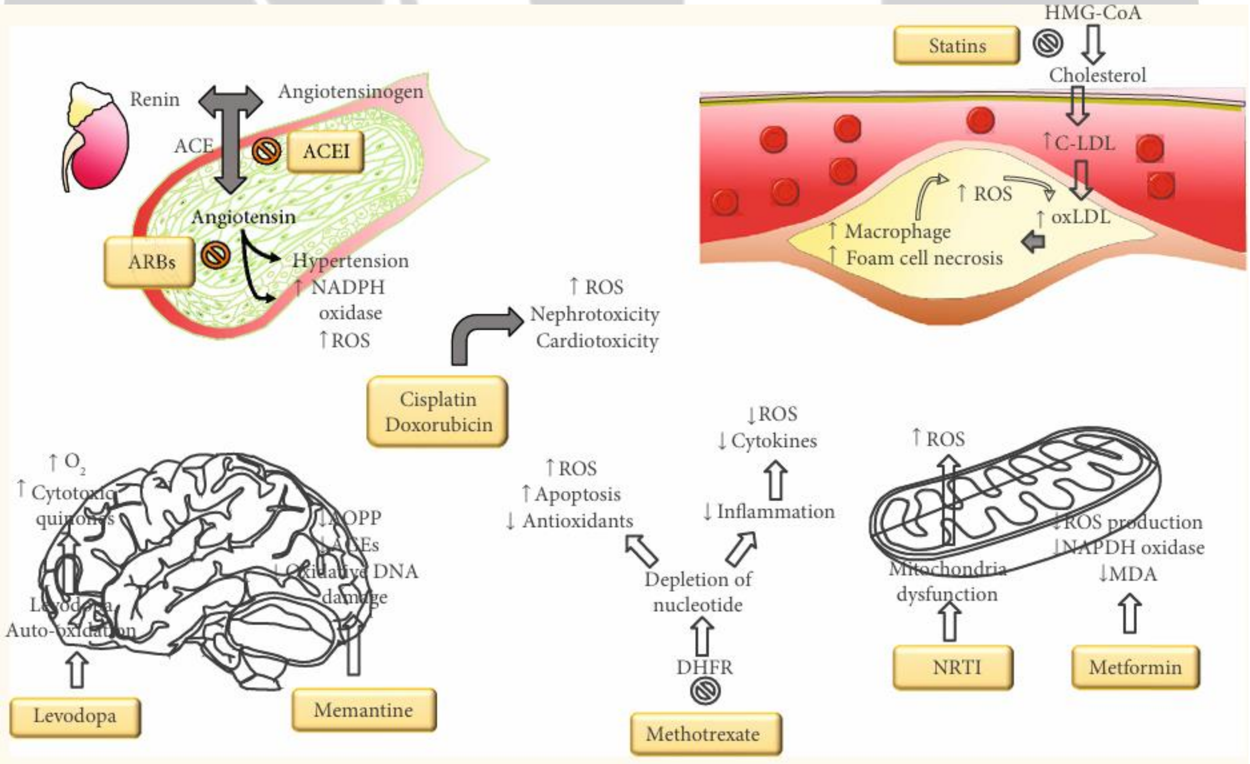

Figure 2: Mechanisms of action of treatments regarding oxidative and/or antioxidant activities in chronic diseases. This just describes how different drug mechanisms affect the oxidative status. Indirectly, antihypertensive and statin treatments restore endothelial function, thus reducing oxidative stress. Antineoplastic agents such as cisplatin and doxorubicin as well as nucleoside or nucleotide

reverse transcriptase inhibitors (NRTI or NtRTI) most commonly will cause oxidative damage in a patient in the long term after treatment. Methotrexate can induce increased OS and apoptosis; but causes a depletion of inflammation-mediated OS production at the same time. Levodopa metabolism could thus enhance brain cytotoxicity. Metformin and memantine would rather decrease oxidative stress.

LITERATURE REVIEW

Antioxidants from curcumin to vitamin E have neuroprotective effects by countering oxidative processes and modulating inflammatory pathways (Zhang, X., & Lee, Y. (2021). Oxidative damage and inflammation seem to be the common features of Alzheimer's and Parkinson's (Zhang, X., & Lee, Y. (2021). Oxidative stress-mediated endothelial dysfunction is an important cause of cardiovascular disease. However, antioxidant-rich diets can prevent the free radical-mediated endothelial damage (Johnson, M., & White, T. (2017). Similarly, powerful antioxidants can inhibit the development of cancer (Kim, H., & Lee, S. (2020). In cancer, ROS contribute to DNA damage, and antioxidants preclude these effects. Tomatoes contain a carotenoid called lycopene, associated with a lessened risk for prostate cancer; flavonoid sources such as tea and citrus fruits also provide chemopreventive activity (Kim, H., & Lee, S. (2020). Antioxidants also promote metabolic health by regulating insulin sensitivity and minimizing oxidative damage in pancreatic cells. Evidence shows that increased intake of antioxidant-rich foods lowers the risk of developing type 2 diabetes via the improvement of glucose metabolism and reduction of inflammation (Park, J., & Choi, H. (2018). The aforementioned adverse effects will present should supplementation be taken in excess. One is that excessive polyphenol concentrations will compromise effective endogenous ROS signalling necessary for normal physiological functioning (Gupta, R., & Sharma, P. (2021). Hence, a balance between oxidative stress and antioxidant defence is the key to ensuring health and preventing disease progression (Lee, K., & Wong, C. (2019). This article discusses both functions of antioxidants as human health agents and as preservatives in foods, especially in the area of aging and chronic diseases. The knowledge of the mechanism of action will provide a basis for future work geared toward the optimal application of antioxidants in functional foods and therapeutic work.

METHODOLOGY

A comprehensive search of the scientific literature was conducted through databases such as PubMed, Scopus, and Google Scholar within which studies published in the period of 2000 to 2023 were included based on relevance with antioxidants in food science and human health. Such findings are further explored into experimental studies characterizing oxidative mechanisms, effectiveness in clinical trials, and applications within the food industry. These findings were consumed to show how antioxidants in food contribute to food stability, disease prevention, and increasing life expectancy.

RESULTS AND DISCUSSION

Mechanisms of Antioxidants in Food Preservation

Bioantioxidants exhibit inhibitory action on lipid peroxidases and proteases to stop oxidative spoilage. Among the common natural antioxidants used in food preservation are vitamin E, polyphenolic compounds, and carotenoids (Robinson, T., & Hall, M. (2017). In food processing, enhanced stability is commonly brought about by synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) (Kim, J., & Park, S. (2021)

Table 1: List of Anti-Oxidant, Source and Function in Food Preservation

Antioxidant	Source	Function in Food Preservation
Vitamin E	Vegetable oils, nuts	Prevents lipid peroxidation
Polyphenols	Green tea, berries	Neutralizes free radicals
Carotenoids	Carrots, tomatoes	Protects against oxidative stress
BHT	Processed foods	Enhances shelf life
BHA	Cereals, snacks	Prevents rancidity

Impact of Antioxidants on Aging and Chronic Diseases

Oxidative stress hastens the aging process by damaging biological macromolecules like DNA, proteins, and lipids. Antioxidants stop this by scavenging ROS and counteracting inflammation. Antioxidant therapy has shown promise in the neurodegenerative disorders of Alzheimer's and Parkinson's in delaying disease advancement (Martin, A., & Collins, J. (2017).

Table 2: Role of Antioxidants in Food Preservation and Human Health

Antioxidant	Source	Function in Food Preservation	Health Benefits	Mechanism of Action
Vitamin C (Ascorbic Acid)	Citrus fruits, bell peppers, leafy greens	Prevents oxidation, maintains color & flavor stability	Boosts immune function, reduces oxidative stress	Neutralizes free radicals, regenerates vitamin E
Vitamin E (Tocopherols)	Vegetable oils, nuts, seeds	Prevents lipid peroxidation	Protects cell membranes, improves skin health	Inhibits propagation of lipid radicals
Polyphenols	Green tea, berries, grapes, cocoa	Antimicrobial properties, enhances shelf life	Reduces risk of cardiovascular diseases, anti-inflammatory	Scavenges free radicals, modulates cellular pathways
Carotenoids (Beta-carotene, Lycopene)	Carrots, tomatoes, spinach	Protects against oxidation and light-induced degradation	Improves vision, lowers risk of certain cancers	Acts as singlet oxygen quencher
Flavonoids	Apples, onions, citrus fruits	Delays oxidation and improves color retention	Anti-inflammatory, supports brain function	Inhibits lipid oxidation and reduces ROS

BHT (Butylated Hydroxytoluene)	Processed foods, cereals, snacks	Extends shelf life, prevents rancidity	Controversial—potential risks with high doses	Delays oxidation of lipids
BHA (Butylated Hydroxyanisole)	Processed foods, instant noodles	Preserves freshness, prevents spoilage	May have carcinogenic risks in high doses	Neutralizes free radicals
Resveratrol	Red wine, grapes, peanuts	Protects against oxidation in beverages	Anti-aging, neuroprotective effects	Activates SIRT1 pathway, reduces inflammation
Curcumin	Turmeric	Antimicrobial, enhances food stability	Anti-inflammatory, reduces risk of Alzheimer's	Inhibits oxidative damage, modulates NF-κB
Quercetin	Apples, onions, tea	Prevents browning in fruits & vegetables	Supports cardiovascular health, improves endurance	Modulates oxidative stress response
Catechins	Green tea, dark chocolate	Prevents oxidation, enhances beverage quality	Reduces LDL cholesterol, supports weight loss	Scavenges ROS, protects DNA from damage
Selenium	Brazil nuts, seafood, eggs	Prevents oxidation in fats and oils	Supports thyroid function, enhances immunity	Cofactor for antioxidant enzymes (Glutathione peroxidase)
Coenzyme Q10	Meat, fish, nuts	Prevents oxidation in muscle tissues	Supports heart health, reduces fatigue	Enhances mitochondrial function, acts as a lipid-soluble antioxidant
Alpha-lipoic acid	Spinach, potatoes, red meat	Protects fats and proteins from oxidation	Improves insulin sensitivity, supports nerve health	Regenerates other antioxidants, reduces oxidative stress
Anthocyanins	Blueberries, black rice, eggplants	Enhances food color stability	Supports cognitive function, reduces inflammation	Inhibits lipid peroxidation, acts as a strong antioxidant
Glutathione	Avocados, asparagus, spinach	Protects proteins and lipids in foods	Detoxifies harmful compounds, anti-aging	Recycles vitamin C and E, neutralizes ROS
Tannins	Tea, coffee, grapes	Antimicrobial, prevents microbial spoilage	Antiviral, improves gut health	Binds to proteins and polyphenols, neutralizing ROS

Besides, antioxidant agents contribute much more to cardiovascular health through the prevention of low-density lipoprotein (LDL) oxidation with a concomitant decrease in the risk of atherosclerosis (Morris, T., & Carter, K. (2019). Epidemiological studies established that the diets rich in antioxidants reduce the incidence of chronic diseases, including diabetes and cancer (O'Connor, P., & Green, T. (2020).

CONCLUSION

Antioxidants, as necessary agents in foods and human health, provide protection against oxidative damage. They help in improving the stability of products in food technology applications, while their importance will be appreciated in greater detail for their necessity in human nutrition as protective agents against disease and aging. Future research will, therefore, focus on optimizing the applications of antioxidants in functional foods and on developing new antioxidant-based therapies for age-related diseases.

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