

Role Of Antioxidants In Human Health

¹Punar Dutt Meena and ²Vipul Kumar Parewa

¹Associate Professor, Dept. of Zoology, Baba Gangadas Govt. Girls College Shahpura, Jaipur, Rajasthan (India)

²Assistant Professor, Dept. of Zoology, SPNKS Govt. PG. College, Dausa, Rajasthan (India)

Abstract

Antioxidants are molecules that protect biological systems from oxidative damage caused by reactive oxygen species (ROS) and free radicals. In human health, oxidative stress is implicated in aging and various chronic diseases such as cancer, cardiovascular diseases, neurodegenerative disorders, diabetes and inflammation. This paper reviews the chemistry of antioxidants, sources, mechanisms of action, health benefits, clinical evidence and potential risks associated with antioxidant supplementation. Emphasis is given to dietary antioxidants, endogenous defense systems and the significance of antioxidants in disease prevention and therapy.

1. Introduction

Oxidative stress arises when there is an imbalance between pro-oxidants (free radicals and ROS) and the body's ability to neutralize them with antioxidants. ROS include superoxide (O_2^-), hydrogen peroxide (H_2O_2), hydroxyl radicals ($\bullet OH$), and singlet oxygen. These species can damage cellular lipids, proteins and DNA, leading to dysfunction and disease. Antioxidants neutralize free radicals, thereby preventing cellular damage. Understanding antioxidants is vital for preventive medicine and nutritional science.

2. Oxidative Stress and Free Radical Biology

2.1 Reactive Oxygen Species (ROS) and Free Radicals: Free radicals are atoms or molecules with unpaired electrons, making them highly reactive. Major sources of ROS in the human body include mitochondrial respiration, immune cell activation, environmental pollution, radiation, smoking and xenobiotics.

2.2 Oxidative Damage Mechanisms

- **Lipid peroxidation:** ROS attack polyunsaturated fatty acids in membranes.
- **Protein oxidation:** Causes enzyme inactivation and structural changes.
- **DNA damage:** Leads to mutations and carcinogenesis.

Oxidative stress has been implicated in aging and many diseases including cardiovascular disorders, neurological diseases, diabetes and cancer. (Halliwell and Gutteridge, 2015).

3. Antioxidant Defense Systems

Antioxidant defenses are categorized as:

3.1 Endogenous Antioxidants: Produced within the body-

- **Enzymatic antioxidants:** Superoxide dismutase (SOD), catalase, glutathione peroxidase (GPx).
- **Non-enzymatic antioxidants:** Glutathione (GSH), uric acid, bilirubin.

3.2 Exogenous Antioxidants

Obtained from diet:

- **Vitamins:** Vitamin C (ascorbic acid), Vitamin E (tocopherols and tocotrienols), pro-vitamin A (β -carotene).
- **Minerals:** Selenium, zinc, manganese (cofactors for antioxidant enzymes).
- **Phytonutrients:** Flavonoids, polyphenols, carotenoids, resveratrol, curcumin.

4. Mechanisms of Antioxidant Action

Antioxidants protect cells through:

4.1 Free Radical Scavenging

Neutralizing radicals by electron donation:

- Vitamin C donates electrons to neutralize ROS.
- Vitamin E interrupts lipid peroxidation.

4.2 Metal Chelation

Binding transition metals (iron, copper) that catalyze ROS formation.

4.3 Enzyme Regulation

Upregulating endogenous antioxidant enzymes via gene expression pathways (e.g., Nrf2 pathway).

5. Dietary Sources of Antioxidants

Antioxidant, Major Dietary Sources, Vitamin C, E, Citrus fruits, berries, peppers, Nuts, seeds, vegetable oils, β -Carotene, Carrots, sweet potatoes, spinach, Flavonoids, Tea, cocoa, apples, onions, Polyphenols,

Berries, grapes, olive oil, Selenium, Brazil nuts, seafood. A diet rich in fruits, vegetables, nuts and whole grains significantly increases antioxidant intake and reduces disease risk. (Prior and Cao, 2000)

6. Antioxidants and Human Health

6.1 Cardiovascular Health

Oxidative modification of LDL cholesterol is a key step in atherosclerosis. Vitamin E and C may reduce LDL oxidation. Flavonoids improve endothelial function and reduce blood pressure.

Clinical Evidence: Long-term dietary patterns rich in antioxidants correlate with lower incidence of heart disease. However, large trials with supplements alone showed mixed results. (Vitamins E and C studies, 2004–2012)

6.2 Cancer Prevention

Oxidative DNA damage contributes to carcinogenesis:

- Antioxidants like carotenoids and polyphenols can reduce DNA damage.
- Epidemiological studies link high fruit/vegetable intake with lower cancer risk.
- Important Note: Isolated high-dose antioxidant supplementation did not consistently reduce cancer risk and, in some cases (e.g., β -carotene in smokers), increased risk. (Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study, 1994)

6.3 Neurodegenerative Diseases

- Oxidative stress plays a role in Alzheimer's, Parkinson's:
- Brain tissue is vulnerable to ROS due to high oxygen use and lipid content.
- Dietary antioxidants (vitamin E, polyphenols) show neuroprotective potential in observational studies.
- Clinical trials have had limited success; more research is needed. (Butterfield *et al.*, 2002)

6.4 Diabetes and Metabolic Syndrome

- Chronic hyperglycemia increases ROS production and inflammation:
- Antioxidants can improve glucose metabolism and insulin sensitivity.
- Polyphenol-rich foods (tea, berries) have beneficial effects on metabolic health.

6.5 Aging

Free radical theory of aging suggests cumulative oxidative damage contributes to age-related functional decline. Antioxidants may slow biological aging processes. Caloric restriction increases endogenous antioxidant defenses (animal studies).

7. Clinical Evidence and Human Studies

7.1 Dietary Patterns vs. Supplements

Whole foods rich in antioxidants consistently show health benefits. Supplements show inconsistent outcomes and sometimes adverse effects when taken in isolation or in high doses.

7.2 Notable Trials

- β -Carotene in male smokers increased lung cancer risk.
- Heart Protection Study- Vitamin E + C no significant cardiovascular benefit.
- Mediterranean diet (polyphenol-rich)- Reduced cardiovascular events

8. Safety and Risks of Antioxidant Supplementation

- Certain high-dose supplements may interfere with normal ROS signaling.
- Overuse of antioxidants can suppress beneficial oxidative processes (e.g., exercise-induced adaptation).
- Some trials showed increased mortality with high doses of vitamin E.

Conclusion: Antioxidants are safer and more beneficial when consumed from food rather than high-dose supplements.

9. Future Directions and Research Needs

- Precision nutrition: tailoring antioxidant intake based on genetics and lifestyle.
- Long-term randomized trials to test efficacy of food-based antioxidants.
- Understanding synergistic effects of antioxidant networks.

10. Conclusion

Antioxidants play a crucial role in neutralizing ROS and protecting cells from oxidative damage. A diet rich in natural antioxidants from fruits, vegetables, nuts and whole grains contributes to the prevention of chronic diseases, supports cardiovascular and neurological health, and may slow aging processes. While antioxidant supplements have been widely studied, evidence supports food sources over isolated high doses for long-term health benefits.

References

1. Halliwell, B. and Gutteridge, J. M. (2015). Free Radicals in Biology and Medicine. Oxford University Press.
2. Prior, R. L. and Cao, G. (2000). Antioxidant phytochemicals in fruits and vegetables: diet and health implications. Horticultural Science.
3. Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study Group (1994). The effect of vitamin E and β -carotene on the incidence of lung cancer and other cancers. New England Journal of Medicine.
4. Butterfield, D. A., *et al.* (2002). Oxidative stress in Alzheimer's disease brain: new insights from redox proteomics. European Journal of Pharmacology.
5. Heart Protection Study Collaborative Group (2002). MRC/BHF Heart Protection Study of antioxidant vitamin supplementation. Lancet.
6. Estruch, R., *et al.* (2013). Primary Prevention of Cardiovascular Disease with a Mediterranean Diet. New England Journal of Medicine (Predimed Study).
7. Podmore, I. D., *et al.* (1998). Vitamin C exhibits pro-oxidant properties. Nature.
8. Halliwell, B. (2007). Dietary polyphenols: good, bad, or indifferent for your health? British Journal of Nutrition.
9. Ristow, M. and Zarse, K. (2010). How increased oxidative stress promotes longevity and metabolic health. Experimental Gerontology.
10. Lobo, V., *et al.* (2010). Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy Reviews.
11. Valko, M., *et al.* (2007). Free radicals and antioxidants in normal physiological functions and human disease. International Journal of Biochemistry and Cell Biology.