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NUTRITIONAL AND THERAPEUTIC IMPORTANCE OF BIOACTIVE COMPOUNDS PRESENT IN FRUITS AND VEGETABLES

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ABSTRACT

Fruits and vegetables (FVs) are recognized for their potential to mitigate the risk of various diseases owing to the abundance of bioactive compounds such as polyphenols, flavonoids, oligosaccharides, dietary fiber, vitamins, and minerals. Regular consumption of FVs is inversely associated with chronic diseases, including cancer, cardiovascular ailments, macular degeneration, and neurodegenerative disorders. This paper delves into the nutritional and therapeutic significance of key bioactive compounds, emphasizing their sources and health implications. The World Health Organization recommends a daily intake of approximately 400 g of FVs to prevent non-communicable diseases. The paper elucidates the role of carotenoids, lycopene, lutein and zeaxanthin, anthocyanins, polyphenols, dietary fiber, and phytosterols, providing insights into their contributions to human health.

INTRODUCTION

Fruits and vegetables (FVs) stand as essential components of a healthy diet, credited for their role in disease prevention due to the presence of various bioactive compounds. This study explores the nutritional and therapeutic importance of specific bioactive compounds found in FVs. Carotenoids, lycopene, lutein and zeaxanthin, anthocyanins, polyphenols, dietary fiber, and phytosterols are discussed in detail, highlighting their dietary sources and health benefits. The World Health Organization's recommendation of a daily 400 g intake of FVs underscores the global recognition of their preventive potential against non-communicable diseases. Therefore, here some of the nutritional and therapeutic importance of bioactive compounds and their good sources has been given for understanding of how important to include FVs in our daily diet.

Sl.No.	Bioactive compound	Horticulture source
1	**Carotenoids**	Lettuce, Spinach, Brussels sprouts, Beans, Broccoli Pepper, Pumpkin, Potato, Tomato, Carrot, Onion, Pineapple, Banana, Grape, Mango, Melon, Orange, Watermelon, Pear, Olive, Palm

Nutritional/therapeutic importance:

- Carotenoids play a crucial role in enhancing immunocompetence and bolstering disease resistance in humans. Their supplementation has been observed to positively impact thymus gland growth in children and augment the number and activity of T-lymphocytes in healthy adults.
- The levels of carotenoids tend to diminish in individuals afflicted with conditions such as HIV and malaria, as well as in those with elevated levels of serum α1 antichymotrypsin—an indicator of infection. While the precise mechanisms underlying these immune-enhancing properties remain unclear, it is postulated that the antioxidant attributes of carotenoids might be instrumental in neutralizing the elevated levels of reactive oxygen species (ROS) generated by immune function. The benefits derived from the antioxidant properties of carotenoids may be amplified through synergistic interactions with other endogenous or diet-derived antioxidants, such as vitamins C and E (Ian D. Stephen et al., 2011).
- Recent studies indicate that carotenoids may exert their effects through various mechanisms, including gap junction communication, regulation of cell growth, modulation of gene expression, influence on immune response, and modulation of Phase I and II drug-metabolizing enzymes.
- Notably, certain carotenoids like α and β-carotene and β-cryptoxanthin possess the added advantage of being convertible to Vitamin A. Intriguingly, β-carotene has been reported to exhibit pro-oxidant properties under specific circumstances.
- Caution is warranted, as evidenced by studies indicating that supplementation of β-carotene at pharmacological levels increased lung cancer incidences in smokers in the Alpha-Tocopherol Beta-Carotene (ATBC) trial. Similarly, increased mortality from cardiovascular disease (CVD) was observed in a group comprising smokers, former smokers, and asbestos-exposed individuals in the β-carotene and retinol efficacy trial (CARET). These findings suggest a potential biphasic response of β-carotene, promoting health when consumed at dietary levels but potentially yielding adverse effects at higher amounts (Rao and Rao, 2007).

2	**Lycopene**	Tomato, tomato-based products, watermelon, pink grapefruit, pink guava, and papaya

Nutritional/therapeutic importance:

- Lycopene's salutary effects against diseases are attributable to various mechanisms: i) its role as an antioxidant, ii) augmentation of cell-cell communication, iii) mitigation of mutagenesis, iv) inhibition of tumor cell proliferation, and v) enhancement of antitumor immune responses.
- Experimental gastric carcinogenesis is impeded by lycopene through the upregulation of GSH (glutathione)-dependent hepatic detoxification systems, thus affording protection against carcinogen-induced oxidative damage.
- Hypotheses have been posited regarding the potential hormone-like actions of lycopene derivatives at low concentrations, functioning as ligands for nuclear receptors akin to retinoic acid derived from β-carotene.
- Lycopene exhibits a substantial 40% inhibition in cell growth in human leukemia cell lines.
- Among studied carotenoids, lycopene stands out as distinctly associated with protection against prostate cancer.
- Lycopene treatment manifests improved survival and suppression of lipid peroxidation in rat hepatocytes exposed to CCl4.
- Inhibition of the growth and development of C-6 glioma cells (malignant brain cells) transplanted into rats is evident with lycopene, and this growth inhibitory effect is more pronounced when administered before the inoculation of glioma cells.
- Epidemiological studies corroborate the hypothesis that the consumption of heat-processed tomatoes may diminish the risk of coronary heart disease by averting the oxidation of low-density lipoprotein. In a recent study utilizing the J–774 A.1 macrophage cell line, both lycopene and β-carotene demonstrated the suppression of 60–70% of cholesterol synthesis by acetate, implicating them as moderate hypocholesteremic agents (Kun Yang et al., 2006).

3	**Lutein and Zeaxanthin**	Spinach, kale, and collard greens, corn, nectarines, oranges, papaya, squash, goji berry, turnip greens, romaine lettuce, broccoli, zucchini, kiwifruit, garden peas, Swiss chard, Brussels sprouts, orange pepper was recently found to have a high amount of zeaxanthin

Nutritional/ therapeutic importance:

- The macular pigments, namely lutein, zeaxanthin, and mesozeaxanthin, collectively constitute approximately 36%, 18%, and 18%, respectively, of the overall carotenoid composition within the retina.
- Lutein and zeaxanthin function to safeguard the retina from photo-induced damage by serving as antioxidants and providing protection against potentially deleterious short-wave radiation through their role as blue light filters.
- Numerous studies corroborate the potential of lutein and zeaxanthin in mitigating the onset and progression of age-related macular degeneration (AMD) (Shannon et al., 2009).

4	**Anthocyanins**	Apple, berries (blackcurrant, boysenberry, blueberry, bilberry, strawberry, blackberry, raspberry, cranberry, elderberry, lingonberry, chokeberry etc.), black carrot, cabbage, cherry, grape, radish, red onions and sweet potato

Nutritional/therapeutic importance:

- Structural variances in anthocyanins have been identified as influential factors in determining antioxidant activities. Notably, anthocyanin mixtures have demonstrated higher radical scavenging potencies compared to purified pigments at equivalent quantitative levels, suggesting the existence of synergistic effects. This implies that whole extracts, encompassing a spectrum of anthocyanins, exhibit greater biological activity than their isolated counterparts.
- Despite the fact that the absorption rate of anthocyanins falls considerably below 1%, these compounds, once transported to sites of heightened metabolic activity, may attain concentrations conducive to systemic effects. Such effects include antineoplastic, anticarcinogenic, antiatherogenic, antiviral, and anti-inflammatory outcomes, along with reductions in capillary permeability and fragility, inhibition of platelet aggregation, and immune stimulation. These systemic effects primarily hinge on the antioxidant properties inherent in anthocyanins (Stintzin and Carl, 2004).
- The linkage between grape phenolics and coronary heart disease has been attributed, in part, to the presence of anthocyanins in red wine. Various epidemiological studies have underscored that moderate consumption of red wine can contribute to a reduction in coronary heart disease mortality. This observed risk reduction is believed to stem from mechanisms such as diminished platelet coagulability (Mazz, 2007).

5	**Polyphenols**	Apple, pear, cherry grape and grape products, olives, berries, tomato skin, chocolate, tea, coffee, red cabbage, kiwi, peanuts, pistachios, plum, potato, chicory

Nutritional/therapeutic importance:

- Polyphenols, particularly flavonoids, exhibit a myriad of beneficial effects on human health. Within the realm of polyphenols, flavanols, encompassing epicatechin, catechin, and specific procyanidins, possess the capacity to modulate the expression of numerous NF-κB-regulated genes implicated in inflammation and carcinogenesis (Fraga et al., 2010).
- Polyphenols inherent in food exert a protective role against oxidative damage by direct interaction with reactive oxygen species or by eliciting responses from endogenous defense systems.
- The potential of polyphenols to safeguard against low-density lipoprotein (LDL) oxidation in vivo bears significant implications for atherosclerosis, while concurrently shielding DNA from oxidative harm, thereby influencing the age-related development of certain cancers.
- Polyphenols showcase antimicrobial properties, manifesting in the inhibition or eradication of microorganisms such as bacteria, fungi, or protozoans.
- Phenolic compounds demonstrate anti-inflammatory activity through the modulation of pro-inflammatory gene expression, including cyclooxygenase, lipoxygenase, nitric oxide synthases, and pivotal cytokines. This modulation is primarily achieved through interactions with nuclear factor-kappa B and mitogen-activated protein kinase signaling pathways.
- Dietary polyphenols may exert notable effects on colonic flora, bestowing a prebiotic effect. For instance, Resveratrol promotes an increase in Bifidobacterium and Lactobacillus counts, concurrently suppressing the expression of virulence factors in Proteus mirabilis associated with the invasion of human urothelial cells.
- In healthy individuals, flavanol-rich cocoa induces vasodilation by activating the nitric-oxide system, potentially constituting the mechanism underpinning the coronary protection conferred by foods rich in flavanols.
- Some polyphenols also function as antinutrients, impeding nutrient absorption, particularly of iron and zinc, while concurrently inhibiting digestive enzymes and precipitating proteins (Landete, 2011).

6	**Dietary fibre**	Peach dietary fibre concentrate, Orange dietary fibre concentrate, Lime peel, Apple pomace, Orange peel, Grapefruit peel, Date dietary fibre, Mango dietary fibre concentrate, tomato, date, potato, carrot, leafy vegetables etc

Nutritional/therapeutic importance:

- Dietary fiber (DF), constituting a compound class, encompasses a blend of plant carbohydrate polymers, inclusive of both oligosaccharides and polysaccharides. These include cellulose, hemicelluloses, pectic substances, gums, resistant starch, and inulin, potentially associated with lignin and other non-carbohydrate components such as polyphenols, waxes, saponins, cutin, and phytates.
- Clinically, an array of investigations involving type 1 and 2 diabetics has substantiated that diets characterized by low glycemic index (GI) and high fiber content enhance levels of glycated proteins, specifically hemoglobin A1c (HbA1c) and fructosamine—established markers of glycemic control.
- Empirical evidence from numerous studies establishes a positive correlation between heightened dietary fiber intake and more effective management of body weight.
- Elevated consumption of viscous fibers has demonstrated efficacy in diminishing the risk of coronary heart diseases, particularly through its impact on low-density lipoprotein cholesterol (LDL-Cholesterol) levels, as indicated in studies by Kendall et al. (2010).
- Dietary fiber contributes to the reduction of total cholesterol and LDL levels in plasma, attributed to a heightened dilution and excretion of bile acids.
- The scarcity of dietary fiber content leads to the formation of densely compacted feces, potentially fostering oncogenesis through prolonged exposure of the intestinal mucosa to cancer-risk agents. Consequently, an inverse relationship emerges between fiber intake and the incidence of colon cancer, as delineated by Rodríguez et al. (2006).

7	**Phytosterols**	Corn oil, Rapeseed oil, Sunflower oil, Soya oil, peanuts, cauliflower, broccoli, romaine lettuce, navel orange, tangerine, and mango

Nutritional/therapeutic importance:

- Phytosterols, also known as plant sterols, share functional and structural similarities with cholesterol, serving the function of stabilizing phospholipid bilayers in cell membranes. Their structure comprises

a steroid nucleus, a 3b-hydroxyl group, and a 5,6-double bond. The primary plant sterols include b-sitosterol (24a-ethylcholesterol), campesterol (24a-methylcholesterol), stigmasterol (D 22, 24a-ethylcholesterol), and ergosterol (D 7,22, 24a-methylcholesterol). Phytosterols have been employed as agents for lowering blood cholesterol levels.

- Spreads containing esters of hydrogenated phytosterols (stanols) derived from wood pulp, tall oil, or vegetable phytosterols (sterols) have demonstrated efficacy in lowering cholesterol levels. A meta-analysis of 41 trials involving various enriched food products determined that the optimal daily dosage of sterols or stanols is 2 g/day, resulting in a 10% reduction in LDL-C. Higher doses provide only marginal additional effects (Kritchevsk and Chen, 2005). The principal mechanism of action involves interference with the solubilization of cholesterol in intestinal micelles, thereby reducing the absorption of LDL-C. A potential side effect is the interference with carotenoid absorption, which can be mitigated through dietary adjustments or incorporating these compounds in suitable carriers.
- Additionally, studies have reported that phytosterols exhibit anticancer properties and function as immune system modulators (QuÍlez et al., 2003).

CONCLUSION

In conclusion, the consumption of fruits and vegetables emerges as a pivotal strategy for promoting human health and preventing chronic diseases. The diverse array of bioactive compounds found in these foods contributes significantly to their nutritional and therapeutic value. Carotenoids, lycopene, lutein and zeaxanthin, anthocyanins, polyphenols, dietary fiber, and phytosterols offer various health benefits, from immune enhancement to cardiovascular protection. However, caution is warranted, as seen in the case of β-carotene supplementation, indicating a potential biphasic response at higher levels. Overall, a balanced and varied intake of FVs remains crucial for harnessing the full spectrum of bioactive compounds and reaping their health advantages.

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