



The Role of Horticultural Plants in Developing Healthy Foods Rich in Active Bioactive Compounds: A review

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Abstract

Horticultural crops are a major source of bioactive compounds that promote human health and protect against chronic diseases. Fruits, vegetables, and herbs contain high amounts of phenolics, flavonoids, carotenoids, and vitamins with strong antioxidant and anti-inflammatory activities. Recent developments in plant breeding, biotechnology, and sustainable cultivation have enhanced the accumulation levels as well as the stability of these compounds. In addition to this fact, postharvest management along with modern innovative food processing techniques ensure the functional integrity of these compounds; thus, allowing for an integration approach to develop functional foods based on nutritional quality combined with health-promoting benefits. In general terms horticultural plants act as a connector between horticultural science, biotechnology, and preventive nutrition towards a healthier world.

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1. Introduction

Consuming selected horticultural crops provides promoting health benefits owing to their bioactive components. Bioactive has been defined as a substance that stimulates physiological activity in living organisms and those that provide health benefits beyond basic nutrition (Minz *et al.*, 2023) ^[1]. Phytochemicals are included as bioactives among non-nutritive plant compounds (semiochemicals) that protect plants from biotic and abiotic environmental stressors and have been associated with prevention of numerous degenerative diseases in humans (Simsek & Whitney, 2024) ^[2]. The significant health benefits obtained from phytochemicals are commonly attributed to their antioxidant properties, the ability to reduce oxidative damage caused by free radicals (Chaudhary *et al.*, 2023) ^[3].

A growing body of epidemiological evidence has established an inverse relationship between the consumption of fruit and vegetable bioactives and the risk of chronic diseases, including cancer, obesity, cardiovascular disease, and diabetes. Epidemiological studies have shown that as little as 540 mg/day of flavonoids, 3500 µg/day of carotenoids, or 12.5 mg/day of glucosinolates are adequate to reduce the risk of chronic diseases (A. Quiñones-Muñoz *et al.*, 2022) ^[4]. Bioactive compounds are increasingly regarded as important functional foods for promoting human health; some government agencies such as the Food and Drug Administration worldwide have approved health claims for products containing bioactive components (Martirosyan, 2025) ^[5].

2. Bioactive Compounds in Horticultural Crops

Bioactive compounds, which are phytochemicals capable of influencing biological processes and enhancing health, are plentiful in horticultural crops (Simsek & Whitney, 2024)^[2]. These metabolites are generated in response to biotic and abiotic stresses; they play defense roles, e.g., phenolic compounds act against pathogens (A. Quiñones-Muñoz *et al.*, 2022)^[4] and antiherbivory compounds deter grazing. Particular classes—polyphenols (including flavonoids), carotenoids, glucosinolates, and alkaloids—are prominent in horticultural plants and have been linked with human health benefits. Modern diets rich in fruits, vegetables, tubers, grains, and legumes provide a variety of bioactive compounds with varying composition across crop species and accessions. These food matrices influence analysis and effectiveness of these bioactives (Tang *et al.*, 2024)^[6]. Bioactive contents can vary widely between groups of crops, within groups according to sub-type, and between diverse cultivars. The classes, compositions, concentrations, and range of values available across the horticultural spectrum therefore position these plants to contribute substantially to good health. Stable isotopes, primary metabolites, soil properties, climate, and imagery—among other variables—impact deposition but introduce complexity and uncertainty into assessments of how many active compounds foliage, roots, or tubers supply to different life stages. (Medina-Lozano and Díaz, 2021)^[7].

3. Factors Influencing Bioactive Content in Plants

The content of bioactive compounds in horticultural crops is influenced by environmental conditions, crop genetics, and chemical inputs. These factors affect not only the quantity of bioactives that accumulate but also the diversity of chemical structures present in the crops. Consumer preferences and perceptions of food quality are shaped by plant compounds affecting color, flavor, texture, and aroma. Horticultural crops are typically consumed fresh or minimally processed, so the phytochemical profile at harvest is especially important for developing functional foods that support consumer health. (ElGamal *et al.*, 2023)^[8].

In fruits and vegetables, carotenoids, flavonoids, glucosinolates, isothiocyanates, and other bioactive compounds contribute to color, taste, and aroma. They also protect against oxidative stress and the deterioration of postharvest quality. These compounds, among the most studied in the plant kingdom, accelerate senescence and play a crucial role in plant metabolism, physiology, and defense against environmental stresses as well as in protecting human health (Toscano *et al.*, 2019)^[9].

3.1. Genotype and Plant Breeding

Bioactive compounds in horticultural crops are frequently credited for the reputed health benefits associated with their consumption. This group of phytochemicals, or plant-derived chemicals, is broadly defined as compounds that have an effect on living tissues. They include antioxidants and other metabolites that affect oxidation processes in food, with certain phytochemicals believed to be associated with reduced risk of chronic diseases such as cancer or cardiovascular disease. Horticultural produce contributes a substantial fraction of daily phytochemical intake, and the prospective health benefits of horticultural crops have stimulated the development of functional foods marketed as

enriched in beneficial compounds (Sultanbawa & Sivakumar, 2022)^[10].

The term bioactive is commonly applied to any plant-derived chemical, but narrower definitions place emphasis on a demonstrated health benefit or antioxidant activity. Interest in bioactive compounds has grown in correlation with increasing knowledge of their physiological effects and with heightened public awareness of nutrition and health (Dar *et al.*, 2023). Bioactive compounds, defined as plant-derived compounds with a demonstrable effect on human physiology, have attracted great interest (Chintada and Golla, 2025)^[12]. Horticultural crops offer a source of bioactive compounds and exposure to daily diets. Dietary intake, altered significantly by changes in food supply or shifts in culinary practices and eating habits, has been correlated with agricultural patterns throughout history. (Medina-Lozano & Díaz, 2022)^[13].

3.2. Environmental Conditions and Agricultural Practices

Bioactive compounds are natural constituents of the diet that exert a biological effect, even if not essential for life, and are involved in the physiological regulation of the body (Treutter, 2010)^[14]. Phytochemicals are bioactive compounds produced by plants in response to biotic or abiotic stress and are classified into primary or secondary metabolites according to their functions (Khan *et al.*, 2025)^[15]. Only a few bioactive compounds, such as vitamins, are regarded as essential. Bioactive compounds are originated from secondary metabolites including phenolic compounds, carotenoids, flavonoids, glucosinolates, and others (Roy *et al.*, 2022)^[16]. They are primarily utilized by plants as protective compounds against biotic and abiotic stresses (Toscano *et al.*, 2019)^[9]. However, the presence of these bioactive compounds is also vital for human health by contributing to the prevention and mitigation of disease and the maintenance of function, wellness, and quality of life (Martirosyan, 2025)^[5]. Dietary intake of bioactive compounds influences physiological functions related to cardiovascular diseases, carcinogenesis, osteoporosis, diabetes, obesity, neurodegenerative disorders, and any other diseases related to aging (Mondal *et al.*, 2021)^[17].

The amount and variations of bioactive compounds among horticultural crops, varieties, and edible parts are considerable and characterized by differences in contents and compositions even within the same crop species. Certain crops, therefore, have been reported and recognized with high-medium and medium-low levels based the phytochemical richness and health implications (Minz *et al.*, 2023)^[1]. Phytochemical contents and profiles in a wide range of horticultural crops have been determined based on the peak consumer intake levels from common dishes and foods, enabling the identification of priority crops concerning dietary contribution and functional benefits (Sultanbawa & Sivakumar, 2022)^[10]. The need for dietary phytochemical is escalating due to the increased awareness of health issues related to the modern lifestyle and dietary changes from highly processed foods. Health-conscious consumers prefer horticultural food items enriched in phytochemicals and request products with maximized health promoting phytochemical contents. Consequently, it is of utmost importance to establish breeding programs geared toward increasing the functional quality of horticultural crops from the standpoints of maximizing the health promoting bioactive

compounds (Verma *et al.*, 2025)^[18].

Based on the desirable aspects and crop specificity, several approaches for inspection and characterization of health promoting bioactive compounds are available. Various health-related papers focus on single or a few crops and phytochemicals, whilst some provide comprehensive overviews characterizing multiple crops and multiple bioactive compounds simultaneously (Quitério *et al.*, 2021)^[19]. They include detailed descriptions on the health effects of each bioactive, the amounts and profiles of each bioactive detected from the phytochemicals, the health implications and recommended dietary levels of the bioactive compounds (Kusmann *et al.*, 2023)^[20]. Analyzing and evaluating the bioactive profiles in widely consumed horticultural crops therefore offer significant assistance for enhancing and improving human health through future breeding programs, cultivation practices, post-harvest operations and food processing approaches (Minz *et al.*, 2023)^[1].

3.3. Postharvest Handling and Storage

Fresh horticultural produce continues to grow in popularity as a healthy food choice, yet postharvest losses remain significant. In the supply chain from harvesting to consumption, 30%–65% of produce is lost depending on crop type, and activities during this period can greatly influence quality (Bisht & Singh, 2024)^[21]. Postharvest deterioration, which results from exposure to air, temperature changes, solar radiation, and physical damage, leads primarily to a decrease in quality (Dulce Antunes *et al.*, 2007)^[22]. The freshness of horticultural crops declines rapidly after harvest, and even under appropriate storage conditions, losses of several percent occur within a few days. Satisfactory product quality is essential to ensure consumer acceptance and maintain competitive prices. All edible horticultural items are highly perishable and need special care at harvest and immediately afterwards to minimize losses (Gomes-Araújo *et al.*, 2021)^[23]. The significance of postharvest processes goes beyond extending edible life. Preventing postharvest deterioration from either internal or external factors is vital for conserving nutritional quality and preventing the formation of harmful substances that threaten human health (Lalpekhlu *et al.*, 2024)^[24]. These processes are even more critical for bioactive-rich horticultural crops because the intake of such food items is still low among many people. Various technologies have been developed to reduce postharvest losses by controlling environmental factors such as temperature and relative humidity, disinfecting crops, or incorporating bioactive compounds that have antioxidant and antimicrobial properties to extend food freshness and safety (Pereira *et al.*, 2022)^[25].

4. Health Implications of Bioactive-Rich Foods

Nutrition science defines bioactive compounds as constituents of food that induce a physiological benefit beyond basic nutrition (Simsek & Whitney, 2024)^[2]. For plant foods, “bioactive” typically signifies non-nutritive compounds with potential health-promoting effects (A. Quiñones-Muñoz *et al.*, 2022)^[4]. Horticultural plants are rich sources of phytochemicals—secondary metabolites that confer advantages like resistance against pests and disease—many of which exhibit antioxidant properties. A diet abundant in bioactive-rich horticultural food is purported to positively affect human health, promote longevity, and

reduce the risk of major diseases (Pereira *et al.*, 2022)^[25].

The concepts of bioactive and phytochemical extend the definition of antioxidant. Antioxidants are molecules that protect cells from oxidative damage by neutralizing free radicals, such as peroxides, superoxides, or hydroxyl radical. Bioactive compounds may be antioxidants or also play a broader role in physiological processes, such as the expression of antioxidant enzymes (Dar *et al.*, 2023)^[11]. Horticultural crops constitute the main source of human exposure to natural, dietary bioactive compounds, and exposure levels achieved through consumption of typical fruit, vegetable, and flower diets are likely more than an order of magnitude greater than for synthetic compounds. The roles of dietary bioactive consumption in human health are evaluated through epidemiological, clinical, intervention, and *in vitro* studies (Minz *et al.*, 2023)^[1]. Four primary classes of horticultural crop bioactive compounds have emerged as pertinent to nutrition and health: polyphenols, carotenoids, flavonoids, glucosinolates, and alkaloids (Sharma *et al.*, 2024)^[26].

5. Cultivation Strategies to Enhance Bioactive Profiles

Major bioactive compounds of special interest in horticultural crops include polyphenols, carotenoids, flavonoids, glucosinolates, and alkaloids. Polyphenolic compounds comprise a wide range of naturally occurring bioactive molecules that contain more than one phenolic hydroxyl group in their structure, and they are classified accordingly as phenolic acids, flavonoids, stilbenes, and lignans. Flavonoids are an extensive group of phenolic compounds with around 6000 different structures that are involved in multiple metabolic processes and play vital roles on plant biochemistry and physiology (Pinto *et al.*, 2021)^[27]. Carotenoids are a class of organic pigments responsible for the characteristic red, yellow, and orange colouration of many horticultural crops. Glucosinolates and alkaloids are minor classes of bioactive compounds that are highly relevant to health and nutrition (Lu *et al.*, 2021). Glucosinolates are primarily present in members of the Brassicaceae family, while alkaloids are diverse organic compounds containing one or more nitrogen atoms and are present in many crops, including the Solanaceae and Fabaceae families (A. Quiñones-Muñoz *et al.*, 2022)^[4].

5.1. Breeding and Selection for Phytochemical Content

The considerable variation in phytochemical content between genera, species, varieties, and even different plant parts highlights the potential of breeding and selection to enhance these compounds (Berni *et al.*, 2018)^[29]. Different genotypes can differ in the accumulation of bioactives by an order of magnitude, making it feasible to produce cultivars containing much higher concentrations than those presently available. Additionally, introgression of wild or local landrace germplasm can broaden the genetic base of horticultural crops and augment existing breeding programs (Mousavi *et al.*, 2022)^[30]. A good deal of functional diversity exists among common horticultural crops, and further enriching their profiles of health-promoting compounds can impact consumer diets, health, and well-being (Treutter, 2010)^[14]. Breeding programs have begun to focus on the simultaneous selection of several bioactive compounds and on readily assessed traits that correlate with complex biochemical profiles. HPLC assays of antioxidant activity may provide a

useful example of a secondary trait that integrates the abundance of diverse bioactives and is already used in fruit-breeding programs. Berries, citrus fruits, leafy greens and herbs, and functional tubers and roots are key horticultural crops in which compounds linked to health benefits have been prioritized (Babu *et al.*, 2021)^[31].

5.2. Organic and Precision Agriculture Approaches

Optimization of crop growing strategies such as organic or precision agriculture allows maximum application of eco-efficient technologies capable of enhancing the biosynthesis of phenolic compounds and other phytochemicals in horticultural crops without compromising high yield (Plamada *et al.*, 2025)^[32]. On a broader perspective, the cultivation of locally adapted, functional crops is promoted as a part of a sustainable food system able to sustain or improve diet-quality while respecting or enhancing the cultural value of the territory (Berni *et al.*, 2019)^[33]. Organic agriculture aims at maintaining soil health through practices such as green manuring, crop rotations, and soil protection, providing long-term beneficial effects on crop physiology and visual quality based on improved foliar development and leaf chlorophyll content (Goicoechea & Carmen Antolín, 2017)^[34]. Efforts support organic and precision agriculture while maintaining horticultural biodynamic benefits and enhancing soil organisms and active compounds. (Afzal & Bell, 2023)^[35].

5.3. Harvest Timing and Postharvest Processing

Harvest timing and crop maturity stages significantly influence the presence of health-promoting phytochemicals in horticultural produce. Although much research focuses on phytochemical factors, the interplay of harvest timing and maturity is still poorly understood (Lin *et al.*, 2022)^[36]. Analyzing crops at different harvest times allows for observation of phytochemical variations without the confounding effects of cultivar or processing. Optimal harvesting strategies can help producers enhance postharvest management and maximize health benefits. (Toscano *et al.*, 2019)^[9].

Different horticultural crops display marked differences in phytochemical profile, accumulation pattern, and translocation among edible tissues, thereby offering notable opportunities for targeted breeding without compromising yield. Berries, citrus, leafy greens, herbs, and starch-based tubers and roots exemplify commercially significant and popular crops specifying just one or two health-targeted phytochemical classes (Gomes-Araújo *et al.*, 2021)^[23]. Detailed attention to crop selection and insight into phytochemical regulation can therefore guide the development of cultivation strategies that raise the consumable abundance of active bioactives (Gunaseelan *et al.*, 2025)^[37].

6. Case Studies: Key Horticultural Crops

Horticultural plants are increasingly recognised as essential to preventive nutrition and functional food trends because of their impressive capacity to provide and promote healthy foods containing bioactive compounds. Bioactive compounds refer to naturally occurring substances in foods that promote health and well-being without being essential nutrients (El-Ramady *et al.*, 2022)^[38]. Bioactive compounds can also be referred to as phytochemicals when they arise

from plants and typically possess antioxidant properties. Although consuming foods rich in bioactive compounds is good for overall well-being, it may be more efficient to consume specific biocompounds that confer targeted health benefits (Sruthi *et al.*, 2023)^[39]. Widely studied bioactive compounds that are abundant in horticultural crops include polyphenols (flavonoids, phenolic acids, stilbenes), carotenoids (ranging from provitamin A to lycopene), glucosinolates, and alkaloids (ElGamal *et al.*, 2023)^[8]. Bioactive compounds can be classified based on their origin; there are biotics that originate from living organisms and abiotics that originate from non-living organisms (A. Quiñones-Muñoz *et al.*, 2022)^[4]. Bioactive compounds can also be classified based on their structure, function, and activity; floral structure determines nectar and pollen while carbon source ribbons dictate the polysaccharide structure of exudates. Bioactive compounds derived from plants can inhibit unfavourable enzymes (hydrolases and polysaccharidases), substitute for missing phytohormones such as gibberellins, or serve as signalling compounds that trigger stress responses in neighbouring plants. Studies indicated that secondary plant metabolites are phytoalexins active against fungal and bacterial pathogens and protective against herbivory by mammals and insects, with many such metabolites also active against human pathogens (Berni *et al.*, 2019)^[33]. Bioactive compounds derived from crops that present health benefits to humans include antioxidants which ameliorate oxidative damage, antimicrobials which inhibit growth of pathogenic microorganisms, and antiallergic compounds that block histamine release. Because of the vast diversity of bioactive compounds, plants are an especially rich source of biocompounds (Samtiya *et al.*, 2021)^[40].

6.1. Berries and Citrus Fruits

Berries rank predominantly among horticultural crops owing to both their contribution to dietary intake of vitamins, minerals, and dietary fibre, and the health benefits attributed to their phytochemical content. In particular, berries—whether cultivated or wild—are known as rich sources of anthocyanins and other flavonoids, which are thought to confer health benefits including the regulation of inflammation and oxidative stress (Festa *et al.*, 2021)^[41]. Support for this hypothesis comes from epidemiological studies where berry intake is found to protect against several diseases—most notably cardiovascular diseases and certain cancer forms. Polyphenol-rich fruit juices are also associated with significant improvements in risk factors for cardiovascular diseases, metabolic syndrome, and neurodegenerative diseases (Ho Suh *et al.*, 2018)^[42].

Citrus is a major dietary source of vitamin C, potassium, flavonoids, and terpenes. Various epidemiological and experimental studies have revealed that citrus bioactives reduce inflammatory mediators and reactive oxygen species, thus mitigating risks for several diseases such as metabolic syndrome, neurodegenerative diseases, cardiovascular diseases, diabetes, and cancer (Silla *et al.*, 2025)^[43]. Prominent citrus bioactives include polymethoxylated flavones in peels of mandarin and grapefruit, naringin and hesperidin in grapefruit and orange juices, vitamin C, and carotenoids such as β -cryptoxanthin. Citrus juices and essential oils are also consumed on a large scale (Kumar Saini *et al.*, 2022)^[44].

6.2. Leafy Greens and Herbs

Leafy greens, including lettuce, kale, spinach, and arugula, represent an important group of horticultural crops that deliver health-promoting bioactive compounds to the human diet. Lettuce (*Lactuca sativa*) is consumed at a global scale, with over 26 million tons produced annually (Lipton & Ryder, 2021)^[45]. Emerging information extending the scope of lettuce bioactivity beyond traditional polyphenols supports development of crop varieties maximising the presence of these plant bioactives (Yang *et al.*, 2022)^[46]. The highest contents of bioactive compounds, including phenolic compounds, vitamins, and antioxidant activity, have been reported for leafy microgreens and baby leaves, highlighting their potential for human health and nutritional enhancement. Although iceberg lettuce ranks among the most popular cultivars, it provides a lower concentration of bioactive compounds than leafy types (Martínez-Ispizua *et al.*, 2022)^[47].

Herbs, which offer low-calorie flavour enhancements, are widely consumed in diverse culinary traditions. Basil, dill, mint, oregano, parsley, rosemary, sage, tarragon, and thyme are particularly present in Mediterranean diets, which benefit from the high antioxidant content of these crops (Barbouti & Goulas, 2021)^[48]. Among nutrient-dense herbs, dill, mint, parsley, and thyme are frequently reported health supplements, with sage and rosemary highlighted for potential therapeutic qualities (Marchioni *et al.*, 2021)^[49].

6.3. Functional Tubers and Roots

Tubers and roots, although primarily providing energy and a determinant of food security, are gaining prominence for their phytochemical compounds that confer nutraceutical properties and potential health benefits. Consumption of tubers and roots is widespread; among them potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), yam (*Dioscorea* spp.) and cassava (*Manihot esculenta*) are included in the ten most consumed crops (Chauhan *et al.*, 2022)^[50]. Tubers such as sweet potato contain significant levels of phytochemicals; forty of them including phenolic acids, flavonoids, carotenoids and anthocyanins have been identified in sweet potato with the specific composition being determined by cultivation and environmental conditions (P. Laveriano-Santos *et al.*, 2022)^[51]. Roots such as oca (*Oxalis tuberosa*), mashua (*Tropaeolum tuberosum*) and yacon (*Smallanthus sonchifolius*) have been shown to be rich in phytochemicals similar to those found in other crops (A. Choquechambi *et al.*, 2019)^[52]. Wide varieties of tubers and roots enriched with bioactive compounds are available for cultivation, each with specific and distinctive health benefits. Integration of these crops into daily diets contributes towards fulfilling nutritional requirements, thereby enhancing health (Gupta *et al.*, 2024)^[53].

7. Food Systems and Diet Integration

Designing menus featuring horticultural foods rich in bioactive compounds will introduce these foods to diets in wide varieties to address hunger and nutrition security. This includes fruits, vegetables, dried items, juices, and teas, especially from regions burdened by hunger and low dietary diversity, such as East and Southern Africa, South Asia, and Central America. Such foods may boost the consumption of micronutrients and other essential dietary compounds crucial for preventing malnutrition in vulnerable groups including

young children, pregnant women, and lactating mothers (Sultanbawa & E. Netzel, 2019)^[54].

To achieve seamless integration into food systems, food scientists and processors must assess the physicochemical properties of valuable horticultural foods. Matching these properties to ingredient characteristics specified in popular menu-development software enables formulation of cultivar-specific snack and beverage ideas that retain the same characteristics. Strategies to enhance acceptance among young children must be devised (Simsek & Whitney, 2024)^[2].

8. Challenges and Opportunities

The concentration of bioactive compounds in horticultural crops depends greatly on environmental factors, growing practices, and postharvest treatment. New agricultural techniques such as organic farming, precision agriculture, and the use of biostimulants have the potential to enhance bioactive accumulation without sacrificing productivity or sustainability (ElGamal *et al.*, 2023)^[8].

Climate, soil conditions, water availability, light intensity, and air composition all influence the type and amount of bioactive compounds produced by horticultural crops. During the horticultural crop cycle, numerous agronomic factors, including irrigation level, fertilization, mulching, and pest management, modulate the synthesis of bioactive compounds and other metabolites that define vegetable and fruit quality (Simsek & Whitney, 2024)^[2]. Harvest timing is another important factor affecting bioactive and nutritional contents (A. Quiñones-Muñoz *et al.*, 2022)^[4]. Differences in cultivars, pre-harvest factors, and postharvest handling methods lead to significant variations in bioactive content among horticultural products, emphasizing the need for specific guidelines that maximize health benefits while preserving quality (Fibiani *et al.*, 2022)^[55].

9. Conclusion

Growing concern worldwide over the quality of the food supply has generated increased interest in the role of horticultural crops, especially fruits and vegetables, as sources of dietary bioactive compounds linked to human health benefits. Bioactive compounds are defined as non-nutritive, naturally occurring chemicals in foods that have an impact on metabolic processes linked to health (Sultanbawa & E. Netzel, 2019)^[54]. The term phytochemical is sometimes used to refer to bioactive compounds but may not adequately reflect the many microbial metabolites produced by plant-associated microorganisms that are also becoming recognized as bioactive (A. Quiñones-Muñoz *et al.*, 2022)^[4]. Various horticultural crops are recognized as important sources of phytochemical classes that play a role in a nutritious diet and promote human health. These include polyphenols, carotenoids, flavonoids, glucosinolates, and alkaloids. Polyphenols and carotenoids, along with vitamins, are key antioxidant components found in horticultural crops. Antioxidants have the ability to reduce oxidative stress, which is associated with various health problems, thus making the intake of horticultural crops an effective strategy for adhering to dietary guidelines. With the global population projected to approach nine billion by 2050, it is increasingly vital to cultivate horticultural crops that are produced in a sustainable manner while also maximizing their contribution to a health-supportive diet.

10. References

1. Minz V, Behera SD, Jain S. Bioactive Compounds from Horticulture Crops and their Utilization: A Comprehensive Review. *Int J Plant Soil Sci.* 2023. Available from: researchgate.net
2. Simsek M, Whitney K. Examination of Primary and Secondary Metabolites Associated with a Plant-Based Diet and Their Impact on Human Health. 2024. Available from: ncbi.nlm.nih.gov
3. Chaudhary P, Janmeda P, Docea AO, Yeskaliyeva B, Abdull Razis AF, Modu B, *et al.*, Oxidative stress, free radicals and antioxidants: potential crosstalk in the pathophysiology of human diseases. *Front Chem.* 2023;11:1158198. Available from: frontiersin.org
4. Quiñones-Muñoz A, Villanueva-Rodríguez TJ, Torruco-Uco SG. Nutraceutical Properties of Medicago sativa L., Agave spp., Zea mays L. and Avena sativa L.: A Review of Metabolites and Mechanisms. 2022. Available from: ncbi.nlm.nih.gov
5. Martirosyan D. Functional food science and bioactive compounds. *Bioactive Compounds Health Dis.* 2025;8(6):218-29. Available from: ffdj.com
6. Tang H, Wang Q, Xie H, Li W. The function of secondary metabolites in resisting stresses in horticultural plants. *Fruit Res.* 2024. Available from: maxapress.com
7. Medina-Lozano I, Díaz A. Nutritional value and phytochemical content of crop landraces and traditional varieties. In: *Landraces-Traditional Variety and Natural Breed.* IntechOpen; 2021. Available from: intechopen.com
8. ElGamal R, Song C, Rayan AM, Liu C, Al-Rejaie S, ElMasry G. Thermal degradation of bioactive compounds during drying process of horticultural and agronomic products: A comprehensive overview. *Agronomy.* 2023;13(6):1580. Available from: mdpi.com
9. Toscano S, Trivellini A, Cocetta G, Bulgari R, Francini A, Romano D, *et al.*, Effect of Preharvest Abiotic Stresses on the Accumulation of Bioactive Compounds in Horticultural Produce. 2019. Available from: ncbi.nlm.nih.gov
10. Sultanbawa Y, Sivakumar D. Enhanced nutritional and phytochemical profiles of selected underutilized fruits, vegetables, and legumes. *Curr Opin Food Sci.* 2022. Available from: [HTML]
11. Dar RA, Shah Nawaz M, Ahanger MA, Majid IU. Exploring the diverse bioactive compounds from medicinal plants: a review. *J Phytopharm.* 2023;12(3):189-95. Available from: phytopharmajournal.com
12. Chintada V, Golla N. Exploring the therapeutic potential of bioactive compounds from plant sources. In: *Biotechnological Intervention in Production of Bioactive Compounds: Biosynthesis, Characterization and Applications.* Cham: Springer Nature Switzerland; 2025. p. 229-47. Available from: [HTML]
13. Medina-Lozano I, Díaz A. Applications of Genomic Tools in Plant Breeding: Crop Biofortification. 2022. Available from: ncbi.nlm.nih.gov
14. Treutter D. Managing Phenol Contents in Crop Plants by Phytochemical Farming and Breeding—Visions and Constraints. 2010. Available from: ncbi.nlm.nih.gov
15. Khan A, Kanwal F, Ullah S, Fahad M, Tariq L, Altaf MT, *et al.*, Plant secondary metabolites—Central regulators against abiotic and biotic stresses. *Metabolites.* 2025. Available from: mdpi.com
16. Roy A, Khan A, Ahmad I, Alghamdi S, Rajab BS, Babalghith AO, *et al.*, Flavonoids a bioactive compound from medicinal plants and its therapeutic applications. *Biomed Res Int.* 2022;2022(1):5445291. Available from: wiley.com
17. Mondal S, Soumya NPP, Mini S, Sivan SK. Bioactive compounds in functional food and their role as therapeutics. *Bioactive Compounds Health Dis.* 2021;4(3):24-39. Available from: ffdj.com
18. Verma H, Gangwar P, Yadav A, Yadav B, Rao R, Kumari S, *et al.*, Phytochemicals in Life Style Associated Human Diseases. In: *Advancing Biotechnology: From Science to Therapeutics and Informatics: Technological Advancements in Biosciences and Biotechnology.* Cham: Springer Nature Switzerland; 2025. p. 223-50. Available from: [HTML]
19. Quitério E, Soares C, Ferraz R, Delerue-Matos C, Grosso C. Marine health-promoting compounds: Recent trends for their characterization and human applications. *Foods.* 2021;10(12):3100. Available from: mdpi.com
20. Kussmann M, Abe Cunha DH, Berciano S. Bioactive compounds for human and planetary health. *Front Nutr.* 2023. Available from: frontiersin.org
21. Bisht A, Singh SP. Postharvest losses and management of horticultural produce: A review. *J Sci Res Rep.* 2024. Available from: hal.science
22. Dulce Antunes M, Graça Miguel M, Neves A. Sustainable postharvest handling of horticultural products. 2007. Available from: [PDF]
23. Gomes-Araújo R, Gabriela Martínez-Vázquez D, Verónica Charles-Rodríguez A, Rangel-Ortega S, Robledo-Olivo A. Bioactive Compounds from Agricultural Residues, Their Obtaining Techniques, and the Antimicrobial Effect as Postharvest Additives. 2021. Available from: ncbi.nlm.nih.gov
24. Lalpekhlu K, Tirkey A, Saranya S, Babu PJ. Post-harvest management strategies for quality preservation in crops. *Int J Veg Sci.* 2024;30(5):587-635. Available from: researchgate.net
25. Pereira JA, Berenguer CV, Andrade CF, Câmara JS. Unveiling the bioactive potential of fresh fruit and vegetable waste in human health from a consumer perspective. *Appl Sci.* 2022;12(5):2747. Available from: mdpi.com
26. Sharma M, Bithel N, Sharma KK, Sharma M. Potential of vegetables and plant metabolites in healthcare. In: *Plant metabolites and vegetables as nutraceuticals.* Apple Academic Press; 2024. p. 3-31. Available from: [HTML]
27. Pinto T, Aires A, Cosme F, Bacelar E, Morais MC, Oliveira I, *et al.*, Bioactive (poly) phenols, volatile compounds from vegetables, medicinal and aromatic plants. *Foods.* 2021;10(1):106. Available from: mdpi.com
28. Lu W, Shi Y, Wang R, Su D, Tang M, Liu Y, *et al.*, Antioxidant activity and healthy benefits of natural pigments in fruits: A review. *Int J Mol Sci.* 2021;22(9):4945. Available from: mdpi.com
29. Berni R, Cantini C, Romi M, Hausman JF, Guerriero G, Cai G. Agrobiotechnology Goes Wild: Ancient Local

- Varieties as Sources of Bioactives. 2018. Available from: ncbi.nlm.nih.gov
30. Mousavi S, Stanzione V, Mariotti R, Mastio V, Azariadis A, Passeri V, *et al.*, Bioactive compound profiling of olive fruit: The contribution of genotype. *Antioxidants*. 2022;11(4):672. Available from: mdpi.com
 31. Babu RR, Singh S, Harish D, Yadagiri J. Futuristic breeding strategies in vegetable for improved edible colour and bioactive compounds. *Adv Hortic*. 2021. Available from: researchgate.net
 32. Plamada D, Nemes AS, Teleky BE, Pascuta MS, Odocheanu R, Mitrea L, *et al.*, Microbial Production of Aromatic Phenolic Compounds. In: *Microbial Production of Food Bioactive Compounds*. Cham: Springer Nature Switzerland; 2025. p. 785-808. Available from: [HTML]
 33. Berni R, Berni R, Romi M, Cantini C, Hausman JF, Guerriero G, *et al.*, Functional Molecules in Locally-Adapted Crops: The Case Study of Tomatoes, Onions, and Sweet Cherry Fruits From Tuscany in Italy. 2019. Available from: [PDF]
 34. Goicoechea N, Carmen Antolín M. Increased nutritional value in food crops. 2017. Available from: ncbi.nlm.nih.gov
 35. Afzal A, Bell M. Precision agriculture: Making agriculture sustainable. *Precision agriculture*. 2023. Available from: [HTML]
 36. Lin Y, Tang H, Zhao B, Lei D, Zhou X, Yao W, *et al.*, Comparative changes of health-promoting phytochemicals and sugar metabolism of two hardy kiwifruit (*Actinidia arguta*) cultivars during fruit development and maturity. *Front Plant Sci*. 2022;13:1087452. Available from: frontiersin.org
 37. Gunaseelan RJ, Raj A, Nagarajan P, Perumal S, Kumar J, Patil SJ. Biotechnological Phytochemical Synthesis: Innovations, Challenges, Advantages, Implications. In: *Biotechnology and Phytochemical Prospects in Drug Discovery*. Singapore: Springer Nature Singapore; 2025. p. 83-101. Available from: [HTML]
 38. El-Ramady H, Hajdú P, Törös G, Badgar K, Llanaj X, Kiss A, *et al.*, Plant nutrition for human health: a pictorial review on plant bioactive compounds for sustainable agriculture. *Sustainability*. 2022;14(14):8329. Available from: mdpi.com
 39. Sruthi D, Dhanalakshmi M, Rao HCY, *et al.*, Extraction, isolation, and characterization of phytochemicals, the bioactive compounds of plants. ... of phytochemicals. 2023. Available from: [HTML]
 40. Samtiya M, Aluko RE, Dhewa T, Moreno-Rojas JM. Potential health benefits of plant food-derived bioactive components: An overview. *Foods*. 2021. Available from: mdpi.com
 41. Festa J, Da Boit M, Hussain A, *et al.*, Potential benefits of berry anthocyanins on vascular function. ... *Nutrition & Food* 2021. Available from: researchgate.net
 42. Ho Suh D, Sung Jung E, Min Lee G, Hwan Lee C. Distinguishing Six Edible Berries Based on Metabolic Pathway and Bioactivity Correlations by Non-targeted Metabolite Profiling. 2018. Available from: ncbi.nlm.nih.gov
 43. Silla A, Punzo A, Caliceti C, Barbalace MC, Hrelia S, Malaguti M. The Role of Antioxidant Compounds from Citrus Waste in Modulating Neuroinflammation: A Sustainable Solution. *Antioxidants*. 2025;14(5):581. Available from: nih.gov
 44. Kumar Saini R, Ranjit A, Sharma K, Prasad P, Shang X, Girinur Mallikarjuna Gowda K, *et al.*, Bioactive Compounds of Citrus Fruits: A Review of Composition and Health Benefits of Carotenoids, Flavonoids, Limonoids, and Terpenes. 2022. Available from: ncbi.nlm.nih.gov
 45. Lipton WJ, Ryder EJ. Lettuce. Quality and preservation of vegetables. 2021. Available from: [HTML]
 46. Yang X, Gil MI, Yang Q, Tomás-Barberán FA. Bioactive compounds in lettuce: Highlighting the benefits to human health and impacts of preharvest and postharvest practices. *Compr Rev Food Sci Food Saf*. 2022;21(1):4-45. Available from: wiley.com
 47. Martínez-Ispizua E, Calatayud Á, Ignacio Marsal J, Cannata C, Basile F, Abdelkhalik A, *et al.*, The Nutritional Quality Potential of Microgreens, Baby Leaves, and Adult Lettuce: An Underexploited Nutraceutical Source. 2022. Available from: ncbi.nlm.nih.gov
 48. Barbouti A, Goulas V. Dietary antioxidants in the Mediterranean diet. *Antioxidants*. 2021. Available from: mdpi.com
 49. Marchioni I, Martinelli M, Ascrizzi R, Gabbriellini C, Flamini G, Pistelli L, *et al.*, Small Functional Foods: Comparative Phytochemical and Nutritional Analyses of Five Microgreens of the Brassicaceae Family. 2021. Available from: mdpi.nlm.nih.gov
 50. Chauhan VBS, Mallick SN, Pati K, Arutselvan R, Nedunchezhiyan M. Status and importance of underexploited tuber crops in relation to nutritional security and economic prosperity. *Compendium for Winter School on "Unexpected Vegetables: Unexplored Treasure Trove for Food, Nutritional and Economic Security*. 2022:246-64. Available from: researchgate.net
 51. Laveriano-Santos EP, López-Yerena A, Jaime-Rodríguez C, González-Coria J, Lamuela-Raventós RM, Vallverdú-Queralt A, *et al.*, Sweet Potato Is Not Simply an Abundant Food Crop: A Comprehensive Review of Its Phytochemical Constituents, Biological Activities, and the Effects of Processing. 2022. Available from: ncbi.nlm.nih.gov
 52. Choquechambi LA, Roy Callisaya I, Ramos A, Bosque H, Mújica A, Jacobsen SE, *et al.*, Assessing the Nutritional Value of Root and Tuber Crops from Bolivia and Peru. 2019. Available from: ncbi.nlm.nih.gov
 53. Gupta A, Bobade H, Sharma R, Sharma S. Technological and analytical aspects of bioactive compounds and nutraceuticals from roots and tubers sources. In: *Bioactive Compounds and Nutraceuticals from Plant Sources*. Apple Academic Press; 2024. p. 121-55. Available from: [HTML]
 54. Sultanbawa Y, Netzel ME. Introduction to the Special Issue: Foods of Plant Origin. 2019. Available from: ncbi.nlm.nih.gov
 55. Fibiani M, Paolo D, Leteo F, Campanelli G, Picchi V, Bianchi G, *et al.*, Influence of year, genotype and cultivation system on nutritional values and bioactive compounds in tomato (*Solanum lycopersicum* L.). *Food Chem*. 2022;389:133090. Available from: cnr.it