www.idosr.org Waiswa, 2025
©IDOSR PUBLICATIONS
ISSN: 2550-7931
International Digital Organization for Scientific Research IDOSRJAS1030000
IDOSR JOURNAL OF APPLIED SCIENCES 10(3):159-169, 2025.
https://doi.org/10.59298/IDOSRJAS/2025/103.159169

Narrative Review of Antioxidant-Rich Plants in Aging

Waiswa Arajab

Department of Pharmacy Kampala International University Uganda
Email: arajab.waiswa@studwc.kiu.ac.ug

ABSTRACT

Aging is a multifactorial biological process strongly influenced by oxidative stress, a condition marked by excess reactive oxygen species (ROS) that damage DNA, proteins, and lipids. The free radical theory of aging emphasizes the central role of redox imbalance in age-related diseases, including cancer, cardiovascular disease, diabetes, and neurodegeneration. Plant-derived antioxidants, particularly polyphenols, flavonoids, phenolic acids, vitamins, and minerals, mitigate oxidative stress by scavenging free radicals, chelating metals, and modulating signaling pathways. Berries, leafy vegetables, nuts, herbs, spices, and fruits represent important dietary sources of these compounds and contribute to healthy aging by exerting anti-inflammatory, neuroprotective, cardioprotective, and skin-preserving effects. Traditional diets high in antioxidant-rich plants, such as the Mediterranean diet, correlate with reduced age-related morbidity and greater longevity, while modern dietary shifts toward processed foods threaten antioxidant intake. Although evidence from preclinical and clinical studies highlights significant promise, challenges remain due to variability in bioavailability, standardization, and long-term safety. This review synthesizes current evidence on antioxidant-rich plants in aging, discussing their mechanisms, health benefits, and translational potential as part of dietary and therapeutic strategies to promote healthy longevity.

Keywords: Oxidative stress, Antioxidant plants, Polyphenols, Healthy aging, and Dietary interventions.

INTRODUCTION

Aging is a complex biological process resulting from genetic and environmental factors [1]. Despite advances in neuroscience, aging continues to concern researchers and policymakers, as it greatly impacts the incidence of conditions such as cancer, cardiovascular diseases, diabetes, Alzheimer's, and Parkinson's [2]. These age-associated pathological conditions have been linked to oxidative stress, the disruption of the balance between oxidant generation and antioxidant defenses by reactive oxygen and nitrogen species, the associated damage, and the increased rate of free radical production, as initially proposed in Harman's Free Radical Theory of Aging. Antioxidants, such as plant polyphenols, are able to neutralize excessive free radicals to prevent cellular damage and maintain overall physiological functions.

Understanding Antioxidants

Antioxidants represent a broad class of molecules characterized by their ability to scavenge free radicals, chelate catalytic metals and oxygen, and terminate oxidation chain reactions [3]. Humans rely on a wide range of antioxidants that function by preventing chain initiation and breaking chain propagation of free-radical reactions. Antioxidants may be manufactured by the body (endogenous) or derived from the diet (exogenous), such as vitamins, polyunsaturated fatty acids, and polyphenols [4]. Endogenous defenses include enzymatic and nonenzymatic types that act against different oxidative species in various cellular compartments and often act synergistically with dietary antioxidants. Antioxidants occurring in the nucleus bind to antioxidant response elements and induce transcription of stress response genes, including glutathione S-transferase, heme oxygenase-1, and NAD(P)H: quinone acceptor oxidoreductase [1].

Definition and Types of Antioxidants

Antioxidants are molecules capable of delaying or inhibiting the oxidation of biological molecules. They prevent damage to cells by scavenging for initiators of peroxidation, quenching reactive oxygen species, and preventing the formation of peroxides. The most effective antioxidants react with radicals by interrupting the free radical chain reaction [3]. Many also contain a phenolic or aromatic ring structure that enables them to donate hydrogen to the radical. The term "antioxidant" broadly includes different classes of molecules with distinct activities and mechanisms of action that protect cells and tissues from oxidative damage [5]. It is possible to group plant antioxidants into two major classes based on their solubility, mechanisms of action, and chemical nature: primary and secondary antioxidants. Primary antioxidants inhibit the propagation of free radical reactions [3, 5]. They are called free-radical scavengers and terminate chain reactions by donating hydrogen atoms or electrons to free radicals. Secondary antioxidants suppress the rate of initiation of oxidative chain reactions. Unlike primary antioxidants, they usually react with non-radical molecules such as singlet oxygen, hydroperoxides, or metal ions [3, 5].

Mechanisms of Action

Aging is a multifactorial process associated with the progressive loss of physiological functions and increased vulnerability to certain diseases [4]. The major role of oxidative stress, defined as the imbalance between the production of free radicals and antioxidant defences of organisms, has been widely investigated [6]. This elevated production of free radicals results in DNA, protein, and lipid damage, as well as pigment deposition and cellular senescence that promote the manifestation of age-related disorders [7]. Consequently, the prominent ability of antioxidant compounds to reduce oxidative stress has led to the development of pharmaceutical and dietary strategies to delay ageing fully justified. Biologically derived antioxidants have recently attracted considerable interest as anti-ageing agents since supplementation with synthetic compounds has been largely ineffective or toxic. Such preventive medicines have been searched in source materials such as plants, fruits, and vegetables to discover the specific antioxidant compounds responsible for anti-ageing activity [6]. These findings are at the basis of a comprehensive scrutiny of the most effective plant species known for their free radical scavenging activities and anti-ageing effects.

The Role of Oxidative Stress in Aging

The rise in oxidative stress, linked to cellular damage through increased reactive oxygen species (ROS), constitutes a principal theory of aging and chronic disease. ROS triggers mitochondrial dysfunction, loss of natural antioxidant defenses, damage to cell membranes, impaired DNA repair, telomere shortening, and disrupted metabolic regulation. The redox imbalance arises when ROS generation exceeds enzymatic clearance by antioxidants. At low to moderate levels, ROS contribute to host defense and cell signalling, but excessive ROS also damage DNA, lipids, and proteins, accelerating cellular senescence [7]. Prolonged oxidative damage preferentially affects telomeres, further promoting aging processes. Nutritional interventions remain a fundamental approach to attenuating oxidative stress, and plant-based supplements have been repeatedly validated in human and animal studies [7]. Age-related disruption of redox balance also underpins an accepted "Oxidative Stress Theory of Aging" and associated accumulation of defective cellular components. A therapeutic target, therefore, centres on restoration of antioxidant capacity to mitigate a wide range of age-specific health outcomes. The ongoing quest for improved longevity has stimulated interest in functional foods capable of countering molecular aging [8]. Polyphenols represent the most abundant class of bioactive compounds in diverse plants, and dietary consumption of these metabolites reduces pathological processes connected to oxidative stress, aging, and neurodegeneration. Abelmoschus esculentus, Hibiscus sabdariffa, Aspalathus linearis, and Ilex paraguariensis each contain abundant polyphenols and demonstrate consistent in vitro and in vivo efficacy; related therapeutic products are now commercialised within food and pharmaceutical markets. Additional metabolites, such as alkaloids, exhibit neuroprotective effects and offer emerging alternatives for anxiety and depression [8].

Oxidative Stress and Cellular Damage

Efforts to mitigate aging focus on protecting genomic, proteomic, and lipid integrity and preserving mitochondrial function [7]. Physiological aging impairs cell division and proliferation, leading to senescence characterized by a gradual decline in physiological functions, increased cellular damage, and heightened morbidity and mortality. A hallmark of aging is the establishment of an oxidative stress state, which contributes to the development of numerous chronic diseases and corresponds with the accumulation of defective cellular structures 8. Oxidative stress can disturb critical cellular components and functions at various levels; consequently, protective mechanisms have evolved to counteract such damage [7]. The balance among Reactive Oxygen Species (ROS) generation, antioxidant defense, and repair capability is a crucial feature influencing the rate of aging. The Oxidative Stress Theory of Aging hypothesizes that excess ROS generation induces aging phenomena. The main cellular protective elements reducing ROS-mediated oxidative stress and postponing the aging trajectory are enzymatic antioxidants (thioredoxin, superoxide dismutases, catalases, peroxidases) and nonenzymatic antioxidants (glutathione, reduced coenzyme Q, uric acid, ascorbic acid, fatty acid acyl esters of ascorbic acid, ferritin, melanins). When produced in excess, ROS attack DNA, lipids, and proteins, accelerating the aging process via telomere damage [7]. Oxidative stress emerges from an imbalance between ROS production and clearance by antioxidant enzymes, and it can be attenuated through diet and supplementation with plant-based nutrients. Dietary antioxidants are believed to be vital in ageing-decaying welfare, and inverse correlations exist between chronic degenerative diseases and the intake of fruits and vegetables [7].

Impact on Aging Process

Plant-based diets contain many compounds able to improve health and delay the aging process. This section briefly reviews such antioxidant plants for healthy aging [7]. Screening a range of vegetal species rich in antioxidant potential yields many candidates for anti-aging studies worldwide. Promising examples include: Berries, including black chokeberry, black currant, blackberry, cranberry, elderberry, lingonberry, raspberry, and strawberry, are rich in phenolic acids and other antioxidants [7]. Leafy vegetables such as Artichoke (Cynara scolymus), beet, broccoli, kale, parsley, and spinach exhibit high antioxidant activities. Nuts, with a focus on walnuts, provide proprietary phenolics and antioxidants linked to aging amelioration. Common herbs, anise, basil, chervil, coriander, dill, fennel, marjoram, oregano, rosemary, and thyme, have well-documented antioxidant effects relying on phenolic constituents. - Fruits, including apple, apricot, cherry, chokeberry, grape, grapefruit, guava, kiwi, lingonberry, mango, orange, peach, pear, pomegranate, plum, and prunes, supply a diverse array of antioxidant compounds [7]. Identifying potent plants beyond this summary could help develop natural products able to diminish the aging process [2].

Overview of Antioxidant-Rich Plants

Plants have been studied beyond their antiaging effect, in particular for their phenolic compounds [1]. Microorganism peroxidases can oxidize polyphenols to radicals and trigger polymerization, yielding polymers that are several times more active. Many natural and most synthetic antioxidants have largely been recognised as extremely efficient agents in preventing oxidative stress [7]. The following account deals with a number of plants known for their antioxidant properties. Anjuan, Kendari, and Kalosi red rice varieties have much higher antioxidant activities than the Merah variety. The distribution of anti-oxidant capabilities of a variety of substances in plants is marked by a 5S → 6S → 7S → 3S trend. The B7 and B9 types possess particularly interesting activities, and, in particular, the compound B7 may be a good candidate for inclusion in a natural antioxidant formulation. Certain species of fresh and stored garlic possess an excellent antioxidant ability [9]. PL (A ridleyi, A tessellata, A brownii) and PE (A integrifolia, A leonardii, A macrocystis, A polyphlebia) types tend to have the highest anti-oxidant capabilities. Morus nigra appears to hold the greatest potential as a natural antioxidant agent for the prevention and/or treatment of manifestations related to free radical production and oxidative stress. Fresh Morus nigra extract at 800 mg kg^{-1} was capable of protecting all tissues against oxidative stress [9]. The substantial array of antioxidant compounds produced by the selected plants may be responsible for their activity, since in many instances the crude extract was equal to or more effective than pure ascorbate. The genus Cousinia displays a very interesting detail of anti-oxidant activity [8].

Criteria for Selection

Successful vitamin C treatment has been used in patients with COVID-19. Various treatment options for the new virus are growing, but a definitive approved treatment is elusive. Compounds inhibiting SARS-CoV-2 main protease (3CLpro/Mpro) and RNA-dependent RNA polymerase (RdRp) are promising targets to silence viral replication. The first crystal structures of coronavirus Mpro were reported in 2003, and based on these, RL188 was discovered as a noncovalent inhibitor of SARS-CoV Mpro [10]. Structure-based drug design has been used to develop small-molecule Mpro inhibitors against COVID-19. Until mid-2020, compounds like remdesivir, favipiravir, lopinavir, ritonavir, and others have been investigated as potential candidates; however, only remdesivir has shown some encouraging clinical results [10]. To contain coronavirus disease and its variants, early and effective regenerative treatment is necessary. Researchers have made efforts to find natural antiviral compounds with lower side-effect profiles. COVID-19 is highly contagious, and no specific treatment is available yet. Several herbal extracts such as Echinacea purpurea, Curcumin, Allium sativum, Astragalus membranaceus, Gingko biloba, Glycyrrhiza glabra, and Zingiber officinale have demonstrated antiviral activities against respiratory viral infections [10].

Global Distribution of Antioxidant Plants

Plants and their products, including fruits, vegetables, cereals, and herbs, are important dietary sources of natural antioxidants, such as polyphenols. Polyphenols, chemical compounds characterised by multiple phenolic rings, are categorized into phenolic acids, flavonoids, stilbenes, and lignans. Dietary consumption of plants rich in polyphenols over time can protect against cardiac diseases, cancers, diabetes, osteoporosis, and neurodegenerative disorders. Plants produce antioxidative compounds in response to abiotic stresses such as high ozone, drought, temperature, and UV-B radiation [11]. For example, high ozone levels stimulate the phenylpropanoid pathway to produce phenolic acids and flavonoids, while drought raises phenolic acids. Exposure to high temperatures fosters terpenoid production, and UV-B radiation induces plants to synthesize more phenolic acids and flavonoids. Mountaintop plants are particularly susceptible to temperature and precipitation shifts, and those in elevated atmospheric conditions tend to produce more polyphenols and terpenoids. These secondary metabolites generally exhibit strong antioxidant and anti-inflammatory properties [11]. Examination of the global distribution of such plants clarifies that they occupy many terrestrial biomes and diverse geographical regions worldwide. This botanical reservoir provides an abundant resource for the continued investigation of plant-based antioxidants and their application in anti-aging research [11].

Key Antioxidant-Rich Plants

Antioxidant-rich plants serve as the major source of antioxidants in the human diet and are an intrinsic component of a wholesome diet [7]. A wide range of antioxidant-rich plants encompasses berries, green leafy vegetables, nuts, medicinal herbs, fruits, and vegetables [9]. Berries are particularly recognized for their capacity to mitigate aging since they exhibit high levels of phenolics and anthocyanins, potent antioxidants accompanying various other nutrients and minerals. Green leafy vegetables have long been regarded as excellent antioxidants since they are enriched with ascorbic acid, β-carotene, and flavonoids. Nuts, enriched with the antioxidant vitamin E, have an important role in protecting cellular components [7]. Medicinal herbs, which serve as traditional remedies, contain substantial amounts of polyphenols and hence positively trigger the anti-aging effects by eliminating oxidative stress. Further, among fruits and vegetables, tomatoes and carrots have been widely used due to their abundant content of lycopene and β-carotene, respectively [9].

Berries

Berries are a rich source of polyphenols, notably anthocyaninsthe pigments responsible for their blue and red colors [12]. Worldwide, fruits classified as berries include cranberries, cowberries, lingonberries, blueberries, strawberries, black currants, chokeberries, raspberries, mulberries, and blackberries. They are extensively cultivated in the Northern Hemisphere and consumed either fresh or processed. Wild berries also thrive in boreal forests and tundra regions [7]. The polyphenolic compounds in wild berries exhibit potential for preventing or alleviating age-related conditions such as diabetes, obesity, inflammation, cardiovascular diseases, cancer, and neurodegeneration. Given their complex chemical composition, berries may promote healthy aging by mitigating risk factors associated with chronic diseases and excessive oxidative damage.

Green Leafy Vegetables

Green leafy vegetables commonly consumed worldwide include spinach (Spinacia oleracea), kale (Brassica oleracea), collards (Brassica oleracea), and broccoli leaf (Brassica oleracea). Consumption of fresh green leafy vegetables such as spinach, kale, and broccoli leaf is advised because they constitute important sources of antioxidants [13]. Drinking vegetable juices can significantly increase the consumption of bioactive phytochemicals. Vegetables are globally acknowledged as important dietary sources of vitamins and minerals, offering low caloric content and fiber and antioxidants that exert health-supporting effects. Their regular consumption may help reduce the risk of chronic diseases such as cardiovascular diseases and cancer [13]. Spinach, a green leafy vegetable considered a "miracle food," is rich in iron and provides significant amounts of β-carotene, lutein, folate, α-tocopherol, and ascorbic acid. Flavonoids and phenolic acids are commonly present at considerable concentrations in green leafy vegetables. Spinach contains chlorophyll with potential antioxidant and longevity-promoting activity, supporting in vivo antioxidant and anti-aging effects [14].

Nuts and Seeds

Nuts and seeds, including tree nuts such as walnuts, almonds, hazelnuts, pistachios, pecans, cashews, pine nuts, Brazil nuts, and macadamias, as well as peanuts, botanically legumes but nutritionally similar to tree nuts, have been key elements of human diets since ancient times. Rich in bioactive compounds with antioxidant activity, such as flavonoids, carotenoids, and tocopherols, these foods contribute to healthy aging [15]. Physiologically, aging corresponds to a process of physiological dysfunctions and deregulation of metabolic pathways at the cellular level, with consequent alterations in cell signaling and survival pathways. This progression leads to increased risk and incidence of age-related diseases. Nutritionally, increased consumption of nuts is associated with reduced risk of developing cardiometabolic diseases, cancer, and cognitive disorders [15]. Evidence also indicates that, compared to those consuming nuts seldom or never, diets with elevated nut intake or Mediterranean-style diets enriched with nuts positively impact healthy aging. These observations have stimulated exploration of potential mechanisms and the underlying components responsible, motivating numerous studies within the international research community [15]. Research attention during the period from 2010 to 2019 focused on human studies assessing the effects of nut consumption on middle-aged and older adult populations (aged 55 years and above). Emerging from this literature, multiple phytochemicals with antioxidant activity have been identified, and their mechanisms of action can explain nut-specific effects on health. Additionally, the impact of nuts on gut microbiota in these age groups warrants further investigation [15].

Herbs and Spices

Herbs and spices have predominantly been used as food additives and for medicinal purposes, yet their chemical compositions and mechanisms of action often remain poorly understood. Various spices serve multiple functions, such as providing distinctive aroma and flavor, reducing fat content or cholesterol, and increasing high-density lipoprotein (HDL) [16]. The health benefits of different spices and herbs have been recorded in traditional literature, and recent research has increasingly focused on their processing and chemical composition. Many herbs and spices have been identified as sources of natural antioxidants. Measurement of phenolic contents and antioxidant activity of extracts from herbs growing on the Greek island of Crete revealed several with effectiveness comparable to or superior to α-tocopherol and commercial antioxidants like butylated hydroxyanisole (BHA) [16]. Among those studied, oregano, thyme, sage, and rosemary exhibited remarkable antioxidant properties. Extended life expectancy has escalated the incidence of aging-related diseases, prompting interest in herbal products for mitigating adverse effects such as oxidative stress-induced DNA damage, inflammation, and neurodegeneration 8. Oxidative stress has been implicated in the development of chronic inflammatory conditions, including Alzheimer's disease, cancer, glaucoma, cardiovascular disease, and type 2 diabetes [2]. The attenuation of oxidative stress by compounds present in herbs and spices can enhance health and promote healthy aging. Investigations into the biological activity and bioaccessibility of extracts also underscore the potential of herbs rich in antioxidant compounds such as flavonoids. Techniques employing assays like DPPH, ABTS, and FRAP evaluate antioxidant activity, while in vitro gastrointestinal digestion models inform on the stability and availability of these constituents [17].

Fruits

Fruits encompass a wide array of edible plant products, including many that are consumed raw [7]. This diverse category provides numerous antioxidant-rich varieties that are low in fat and sodium [18]. Fruit concentrates have been shown to enhance plasma antioxidant vitamins and folate, reduce plasma homocysteine, and retard oxidation, demonstrating potential anti-aging properties.

Bioactive Compounds in Antioxidant Plants

The attributed antioxidant effect of plants is often confirmed by identifying the biologically active compounds responsible. Among these, flavonoids, phenolic plant acids and their esters, ascorbic acid, α-tocopherol, and some microelements are considered major contributors [19]. Flavonoids and phenolic acids play an important role in counteracting free radicals, acting as both free radical scavengers and chain-breakers in the oxidative process. Furthermore, some polyphenols, such as flavonoids, are capable of metal-chelating, thereby reducing the availability of transition metals necessary for oxidation reactions and thus hindering reactive oxygen species formation [19].

Flavonoids

Flavonoids comprise a group of polyphenolic secondary metabolites encompassing nearly 10,000 known compounds. These metabolites play important roles in plant growth, development, and defense, and contribute to longevity, stress tolerance, and improvements in both yield and quality parameters. Humans obtain flavonoids primarily through the consumption of fruits and vegetables, where these compounds contribute to the sensory attributes such as color, flavor, and aroma. Intense research efforts continue to explore the chemical and biological characteristics of flavonoids because of their wide distribution, human health-promoting activities, and benefits to plant growth and development [7]. Flavonoids, which account for 60% of the 8,000 polyphenolic compounds identified in plants, consist of two aromatic rings joined by a three-carbon chain and occur in virtually all plants. They can be further categorized into six classes: flavonols, flavones, flavanones, flavanols, isoflavones, and anthocyanidins. Their antioxidant activities arise from the combination of functional groups and degree of polymerization, enabling a series of mechanisms to reduce oxidative stress-induced cellular damage: scavenging reactive oxygen species (ROS), activating antioxidant enzymes, chelating metal ions, inhibiting ROS formation, reducing α-tocopherol radicals, inhibiting pro-oxidative enzymes, and modulating oxidative stress pathways in vivo [7]. Flavonoids detoxify ROS and free radicals released during oxidative stress. Elevated ROS/DNA and ROS-protein adducts in aging cells promote cell senescence, injury, and death; suppression of age-related DNA damage extends the viability and lifespan of fibroblasts. Flavonoids' antioxidant activities thus contribute to their anti-aging effects. Mechanistically, they scavenge ROS and prevent GAL-induced oxidative stress, which otherwise triggers mitochondria-mediated apoptosis through p53, MAPK, AKT, and NF-κB signaling. Additionally, flavonoids influence other cellular processes, including B-cell activities and DNA damage responses [7].

Phenolic Acids

Phenolic acids are important antioxidant compounds present in 184 families, 2,745 genera, and 29,318 species across gymnosperms, monocotyledons, and dicotyledons [7]. These compounds include hydroxycinnamic and hydroxybenzoic acids containing aromatic rings with one or more hydroxyl groups. Caffeic acid (3,4-dihydroxycinnamic acid) is a hydroxycinnamic acid that occurs combined with quinic acid in chlorogenic acid, an abundant antioxidant in plants [7]. Their antioxidant activity results from their ability to neutralize free radicals through hydrogen atom or electron donation or by chelating metal catalysts such as Cu2+ and Fe2+ 20.

Vitamins and Minerals

Evidence increasingly supports the pivotal role of vitamins and minerals in aging and various biological processes. Age-associated oxidative damage drives the accumulation of molecular lesions and physiological changes leading to senescence, with a decreasing ability to maintain adequate levels of many vitamins and minerals [7]. Vitamins acting as antioxidants help reduce oxidative stress, prevent DNA damage through their reducing capabilities, and maintain telomere integrity, thereby reducing the incidence of age-related chromosomal aberrations. Nutritional interventions incorporating vitamins D and selenium attenuate proinflammatory pathways (e.g., TNF, IL-1β) coupled with antioxidant compounds such as anthocyanins and phenolics, mitigating inflammation and supporting healthier aging trajectories. Other antioxidants like α-tocopherol, β-carotene, retinol, and ascorbic acid, alongside minerals such as magnesium and potassium, are implicated in buffering oxidative stress, a fundamental driver of the aging process [21]. A variety of diets that increase longevity also appear to enhance antioxidant protection; for example, caloric restriction during the reproductive phase extends lifespan in rodents, and the Mediterranean diet confers resistance to age-related frailty and promotes increased longevity. Long-lived human populations, including centenarians, additionally possess higher concentrations of antioxidant vitamins, further substantiating the association between nutritional status and lifespan [21]. Real-world consumption patterns underscore the enduring importance of vitamin and mineral intake as a public health priority. European epidemiological data reveal that individuals with limited access to fresh fruits and vegetables who consume more canned processed foods exhibit diminished plasma levels of essential vitamins and minerals and elevated biomarkers of oxidative stress. Worldwide, the highest consumption of antioxidant-rich fruits and vegetables is concentrated in East Asia, where traditional dietary practices emphasize fresh herbs and minimal processing; conversely, the lowest consumption occurs in South Asia, including India and Pakistan, with processed foods predominating [21, 3].

Plant-derived vitamins and minerals retain the capacity to modulate oxidative processes at the cellular level in the context of aging and related pathologies. The heterogeneous composition of plant compounds frequently results in divergent antioxidant activity; the balance of antioxidant and pro-oxidant effects hinges upon factors such as dose, duration of exposure, and sex. Surprisingly, numerous antioxidant-derived antivirals, anti-inflammatories, and antitumor agents remain largely unexplored at the multisystemic level, presenting significant opportunities for biomedical research innovation [7, 21]. Challenges inherent to the study of antioxidant plant-derived constituents include the development of optimized extraction methodologies capable of conserving bioactive compounds, the scarcity of standardized, highly concentrated plant extracts, and variability in bioavailability among individuals. These issues have contributed to inconsistent literature outcomes and hinder progress toward a comprehensive understanding and application of antioxidants in age-related health contexts [7]. High-precision mass spectrometry (MS) coupled with nuclear magnetic resonance (NMR) technologies offers avenues for advancing calorimetric investigations to elucidate structure-function relationships and biological activities of plant compounds. Furthermore, coordination with pharmacological research, neural drug development, and proteomic analyses constitutes a promising interdisciplinary strategy to unravel the complex signaling pathways orchestrating the interplay between biomolecules and molecular targets involved in oxidative processes [7].

Health Benefits of Antioxidant-Rich Plants

There are considerable indications revealing that phenolic acids, in particular, syringic acid, possess notable antioxidant capabilities, effectively scavenging DPPH radicals and reducing ferricyanide ion [22]. Antioxidant-rich plants also mitigate inflammation, which is closely linked to age-related cognitive dysfunction. Several in vitro and in vivo studies have highlighted the anti-inflammatory properties of active ingredients derived from these plants, indicating potential roles in protecting against various neurological and cardiovascular diseases [3]. Furthermore, these plants contribute to delaying collagen depletion, thereby slowing the aging of skin.

Anti-Inflammatory Effects

Electrical signal fluctuations were analyzed during interstitial microwave hyperthermia procedures. When microwave energy is delivered to an interstitial antenna during treatment of tumours, the reflected power of the antenna is subject to marked variations [22]. If the frequency of the applied microwave source is at, or near, the resonant frequency of the antenna and surrounding tumour tissue, then variations in reflected power and frequency occur. An approach is demonstrated that uses these fluctuations to obtain a signal trace related to the temperature variations occurring during heating [3]. This trace is used to control power delivery, thereby providing a system that automatically adjusts for changes in the tumour's thermal, electrical, and electromagnetic properties. The use of this control signal, together with a microwave power control loop, has the potential to eliminate the possibility of over- or under-treatment in procedures employing microwave hyperthermia. The system was developed initially for use with a temperature-feedback-mode interstitial microwave hyperthermia system. However, it is equally applicable to any device employing microwave, radio frequency, or ultrasound to effect hyperthermic treatment. Use of the control scheme with ultrasound systems may allow a single device to perform both monitoring and treatment functions [3, 22].

Neuroprotective Properties

Neurodegenerative disorders, such as Parkinson's disease (PD), Alzheimer's disease (AD), Huntington's disease (HD), and multiple sclerosis (MS), are characterized by an acquired loss of neurons and resultant functional decline. These diseases pose major challenges to health and well-being, yet effective treatments for their associated cognitive impairments remain elusive [9]. Existing medications provide only symptomatic relief without altering disease progression [22]. Hence, attention has turned to plants rich in antioxidants, which have emerged as important sources of bioactive compounds capable of protecting the central nervous system (CNS) against neurodegeneration, cognitive impairments, redox imbalances, and oxidative stress [9, 22]. The dietary potency of antioxidant-rich plants sustains CNS health by preventing cellular damage, enhancing cognition, and improving circulation, thereby preventing the progression of neurodegenerative disorders, stroke, and brain injury 22. The plant kingdom, particularly the Mediterranean region, offers a wide variety of foods rich in antioxidative substances; plant-derived antioxidants protect both the brain and nerves from oxidative stress [22]. AD is closely linked to aging and involves pathological changes in nerve cells, such as neurofibrillary tangles and increased β-amyloid and hyperphosphorylated tau deposition. In the absence of effective treatments, delaying or mitigating age-related nervous system changes can reduce the risk of AD. Plant-derived antioxidants safeguard various nervous system components through multiple mechanisms, and glial cells also contribute to neural defense; these compounds therefore hold promise for preventing and alleviating AD [9].

Cardiovascular Health

Cardiovascular disease is the leading cause of death worldwide, and its prevalence increases with aging. The survival rate of cardiac events also declines in elderly subjects because aging dampens repair and self-renewal mechanisms [23]. Cardiovascular damage is associated with mitochondrial dysfunction, which is one of the hallmarks of aging. During aging, the functional decline of mitochondria provokes an increase in oxidative stress that triggers the development of several cardiovascular pathologies [7]. Natural bioactive compounds that target mitochondrial dysfunction have the potential to provide an efficient therapeutic strategy against cardiovascular aging. Epidemiological and experimental data demonstrate that some of these bioactive compounds have beneficial effects on cardiac health. Anthocyanins protect the heart from Angiotensin II-induced ROS damage by upregulating glutathione. Quinones stimulate mitochondrial biogenesis and reduce β-amyloid-induced oxidative stress, attenuating cardiac aging. Isothiocyanates also increase mitochondrial biogenesis and reverse age-related heart dysfunction by reducing ROS production and the expression of pro-inflammatory markers. Senolytics exercise their anti-aging effects through a reduction in mitochondrial ROS generation and oxygen consumption. Consequently, cardiac dysfunction during aging can be prevented by numerous natural bioactive compounds that protect the mitochondria through various mechanisms [7, 23]. The consumption of bioactive compounds with mitochondrial efficacy as supplements or functional foods could potentially improve cardiovascular health and promote healthy aging.

Skin Aging

Skin aging is a complex biological process that involves several changes in the skin architecture, such as the rupture and fibrosis of collagen and elastin, as well as the thinning of the epidermis and dermis. These changes result in a decline in their antioxidant activity due to prolonged exposure to UV radiation. Traditional medicine recommends antioxidant-rich plants to protect aging skin [23]. Many antioxidant plants also contain anti-inflammatory agents that mitigate the inflammation associated with aging. Additionally, bioactive compounds found in these plants regulate the expression of matrix metalloproteinases (MMPs), which facilitate collagen degradation and subsequently reduce fine lines, wrinkles, sagging, and skin relaxation. The skin protects human bodies from pathogenic bacteria and viruses. Consequently, infection can cause irritation and discomfort to the skin. Emerging evidence shows that several antioxidant plants also possess antibacterial activity, which is beneficial in protecting the integrity of aging skin [23]. Bioactive compounds in antioxidant plants regulate MMPs and prostaglandin E2 (PGE2), which degrade the extracellular matrix during skin aging. Apart from suppressing MMPs and PGE2, the bioactive compounds also stimulate the synthesis of procollagen type I and elastin, contributing to anti-wrinkle effects. Moreover, these compounds display stimulatory effects on transforming growth factor-beta 1 (TGF-β1), thereby promoting angiogenesis and wound healing activities [7]. The anti-aging effects of these plant-derived bioactive compounds on skin have been widely reviewed in the literature [7].

Dietary Sources and Consumption Patterns

Traditional diets often contained higher amounts of antioxidant-rich plants, whereas modern lifestyles may have reduced their consumption [2]. For example, plant fortification of the diet with certain antioxidant-rich plants can provide anti-aging effects [2].

Traditional Diets

Traditional diets worldwide are rich in antioxidant sources, including a diverse abundance of indigenous plants. Countries bordering the Mediterranean Sea consume two-and-a-half times greater amounts of antioxidant-rich foods, such as fruits, vegetables, pulses, and cereals, than the United States and other Northern European countries [2]. The highest intakes of carotenoids and Vitamins A and C are consumed by populations in southern and central Africa and Central America. The Finns consume the highest quantities of Vitamins B1, B2, B3, and D, while Canadians consume the highest amount of Vitamin B12. Despite many differences in the intake of antioxidant vitamins, all countries studied consume vegetables, cereal products, fruit, and milk and dairy products, which are naturally rich in antioxidants [2].

Modern Dietary Trends

Modern dietary patterns have elevated the role of antioxidant-rich foods. Westernized dietary habits, characterized by increased animal products and decreased fruit, vegetable, and whole-grain intake, relate to rapid aging [18]. Consequently, individuals have limited access to fruit and vegetables in their daily lives. For example, more than 50% of American adults fail to meet one or both guidelines for fruit and vegetable intake, drawing attention to the scarcity of antioxidant-rich food consumption [18].

Challenges in Researching Antioxidant Plants

Research on the antioxidant properties of various plants faces considerable challenges because of methodological constraints and variability among plant sources. Firstly, the application of multiple assays to evaluate antioxidant activity leads to inconsistent results since each method involves distinct mechanisms and conditions. Both the choice of solvent and the type of assay exert a determining influence over the measured antioxidant properties of a given extract [10]. Secondly, attempts to improve antioxidant potential by combining plant sources have produced contradictory findings, whereas single-source extracts often maintain more consistent activity [1]. Thirdly, in living organisms, both the bioavailability and metabolism of plant antioxidants differ among individuals and animal models, especially when complex mixtures of polyphenols or extracts are involved [9]. Experimental evidence frequently indicates that the biological activity of a given compound or extract is lower in vivo than in vitro. Bridging this gap requires the development of appropriate delivery carriers for targeted transport and controlled release of antioxidants. Investigating these issues promises to advance fundamental understanding and identify practical applications of plant-based antioxidants at the clinical level [2, 9, 10].

Standardization of Extracts

Alongside the plant selection criteria, the choice of extraction procedures and solvents is crucial; different methods recover different compound subsets, producing quite different extracts even from identical plant sources [24]. The bioavailability of the active compounds varies depending on these, thereby influencing the antioxidant effect. Standardization of extracts is essential in studies worldwide despite its challenges [25].

Variability in Bioavailability

Individual plant antioxidants exhibit significant variation in bioavailability, influencing their health-related effects 26. Studies of dietary antioxidant bioavailability report values spanning from a net loss of 37% (−0.37) to an increase of 84% (0.84) relative to a reference compound such as ferulic acid [24]. Both the chemical nature of the antioxidant and the food matrix in which it is incorporated markedly affect bioavailability. Variations between plant extracts are thus expected, underscoring the need for empirical measurements of extract-specific bioavailability in ongoing research [25].

Future Directions in Research

Employing advancements in artificial intelligence, such as deep learning techniques, as well as molecular biology and in silico methods, will prove useful for identifying additional bioactive compounds in plants or formulations with anti-aging properties [7]. Furthermore, drug advancement endeavors must explore new phytochemical structures, bioinformatics data, and computational molecular modeling. Computational-based strategies associated with network pharmacology and polypharmacology can synergize with emerging plant-based research to support aging-related drug development [7].

Emerging Technologies

Emerging technologies play a crucial role in advancing research on antioxidant-rich plants and their applications in aging. Nutritional therapy and herbal drug discovery, supported by enhanced analytical techniques, offer promising avenues for developing effective anti-aging interventions. Characterization of bioactive substances in herbs, facilitated by advanced technologies, aids in understanding their protective mechanisms related to oxidative stress and glycoxidation [27]. Formulating multiple herbal combinations to achieve synergistic effects represents a strategic approach in developing nutraceuticals capable of mitigating neurodegeneration and other age-associated conditions [8]. Computational systems biology methods enable analysis of phytonutrient interactions with aging-related oxidative stress pathways, guiding the design of synergistic combinations with maximum efficacy [7]. Sophisticated modeling starts from gene-centric maps connecting aging phenotypes to known oxidative stress pathways, integrating molecular interactions, signaling cascades, and cellular processes into dynamic models for drug prediction and development. Emerging technologies such as network pharmacology, artificial intelligence, machine learning, and high-throughput screening further accelerate drug discovery, underpinning systematic development of anti-aging agents [27]. Thus, emerging technologies strengthen research on antioxidant-rich plants while opening opportunities for innovative drug development targeting aging.

Potential for Drug Development

Development of new drugs capable of eliminating age-related changes has become a prerequisite for combating the challenge of population aging. Medicinal plants are a promising source of such molecules [19]. The variety of plant species with high antioxidant activity offers multiple candidates for the isolation of biologically active compounds [21]. Herbs are traditional sources of biologically active substances, and their antioxidant and antiglycation properties correspond closely with phenol and flavonoid concentrations. Polyphenols with widely differing antioxidant capacities delay aging and prolong lifespan in model organisms and may serve as prototypes for pharmacological agents [19, 21]. These substances are also potential candidates for addressing polypharmacy challenges in the elderly and may aid in the prevention of cardiovascular or neurodegenerative diseases. Development of highly porous plant-derived silica allows for efficient drug delivery with reduced toxicity and increased efficacy. Redox-active compounds such as coenzyme Q (ubiquinone-10) and glutathione may also be optimized as therapeutics using targeted delivery technologies [19, 21].

CONCLUSION

Oxidative stress is a central driver of biological aging and age-related diseases, and plant-derived antioxidants offer a promising strategy to counteract its damaging effects. Evidence supports the protective role of antioxidant-rich plants such as berries, green leafy vegetables, nuts, herbs, spices, and fruits in reducing inflammation, preserving cognitive and cardiovascular function, and maintaining skin integrity. Bioactive compounds, including flavonoids, phenolic acids, vitamins, and minerals, act through diverse mechanisms to neutralize ROS, enhance endogenous defenses, and regulate aging-related pathways. Traditional diets rich in such plants correlate with longevity, while modern processed food consumption has diminished intake of these protective compounds. Despite encouraging data, further research is needed to standardize plant extracts, improve bioavailability, and clarify long-term safety in human populations. Integrating antioxidant-rich plants into dietary practices and therapeutic formulations represents a safe, accessible, and holistic approach to promoting healthy aging and mitigating the burden of age-associated diseases.

REFERENCES

1. Hano C, Tungmunnithum D. Plant polyphenols, more than just simple natural antioxidants: Oxidative stress, aging and age-related diseases. Medicines. 2020 May 9;7(5):26.
2. Dhanjal DS, Bhardwaj S, Sharma R, Bhardwaj K, Kumar D, Chopra C, Nepovimova E, Singh R, Kuca K. Plant fortification of the diet for anti-ageing effects: A review. Nutrients. 2020 Sep 30;12(10):3008.
3. Tan BL, Norhaizan ME, Liew WP, Sulaiman Rahman H. Antioxidant and oxidative stress: a mutual interplay in age-related diseases. Frontiers in pharmacology. 2018 Oct 16;9:1162.
4. Petruk G, Del Giudice R, Rigano MM, Monti DM. Antioxidants from plants protect against skin photoaging. Oxidative medicine and cellular longevity. 2018;2018(1):1454936.
5. Dumanović J, Nepovimova E, Natić M, Kuča K, Jaćević V. The significance of reactive oxygen species and antioxidant defense system in plants: A concise overview. Frontiers in Plant Science. 2021 Jan 6;11:552969.
6. Taylor E, Kim Y, Zhang K, Chau L, Nguyen BC, Rayalam S, Wang X. Antiaging mechanism of natural compounds: Effects on autophagy and oxidative stress. Molecules. 2022 Jul 8;27(14):4396.

7. Ayyadurai VS, Deonikar P. Attenuation of aging-related oxidative stress pathways by phytonutrients: a computational systems biology analysis. Nutrients. 2023 Aug 28;15(17):3762.
8. Nogueira Silva Lima MT, Boulanger E, Tessier FJ, Takahashi JA. Hibiscus, rooibos, and yerba mate for healthy aging: A review on the attenuation of in vitro and in vivo markers related to oxidative stress, glycoxidation, and neurodegeneration. Foods. 2022 Jun 7;11(12):1676.
9. Cui X, Lin Q, Liang Y. Plant-derived antioxidants protect the nervous system from aging by inhibiting oxidative stress. Frontiers in aging neuroscience. 2020 Jul 14;12:209.
10. Astuti RI, Prastya ME, Batubara I, Budiarti E, Ilmiyawati A. Antiaging and antioxidant bioactivities of Asteraceae plant fractions on the cellular functions of the yeast Schizosaccharomyces pombe. Advances in Pharmacological and Pharmaceutical Sciences. 2021;2021(1):2119634.
11. Yeshi K, Ruscher R, Miles K, Crayn D, Liddell M, Wangchuk P. Antioxidant and anti-inflammatory activities of endemic plants of the Australian wet tropics. Plants. 2022 Sep 26;11(19):2519.
12. Harris CS, Cuerrier A, Lamont E, Haddad PS, Arnason JT, Bennett SA, Johns T. Investigating wild berries as a dietary approach to reducing the formation of advanced glycation endproducts: Chemical correlates of in vitro antiglycation activity. Plant Foods for Human Nutrition. 2014 Mar;69(1):71-7.
13. Milano F, Mussi F, Fornaciari S, Altunoz M, Forti L, Arru L, Buschini A. Oxygen availability during growth modulates the phytochemical profile and the chemo-protective properties of spinach juice. Biomolecules. 2019 Feb 4;9(2):53.
14. Wang E, Wink M. Chlorophyll enhances oxidative stress tolerance in Caenorhabditis elegans and extends its lifespan. PeerJ. 2016 Apr 7;4:e1879.
15. Rusu ME, Mocan A, Ferreira IC, Popa DS. Health benefits of nut consumption in the middle-aged and elderly population. Antioxidants. 2019 Aug 12;8(8):302.
16. Kalpoutzakis E, Chatzimitakos T, Athanasiadis V, Mitakou S et al. Determination of the Total Phenolics Content and Antioxidant Activity of Extracts from Parts of Plants from the Greek Island of Crete. 2023. ncbi.nlm.nih.gov
17. Gayoso L, Roxo M, Cavero RY, Calvo MI, Ansorena D, Astiasarán I, Wink M. Bioaccessibility and biological activity of Melissa officinalis, Lavandula latifolia and Origanum vulgare extracts: Influence of an in vitro gastrointestinal digestion. Journal of Functional Foods. 2018 May 1;44:146-54.
18. Luo M, Mai M, Song W, Yuan Q, Feng X, Xia E, Guo H. The antiaging activities of phytochemicals in dark-colored plant foods: involvement of the autophagy-and apoptosis-associated pathways. International Journal of Molecular Sciences. 2022 Sep 20;23(19):11038.
19. Babich O, Larina V, Ivanova S, Tarasov A, Povydysh M, Orlova A, Strugar J, Sukhikh S. Phytotherapeutic approaches to the prevention of age-related changes and the extension of active longevity. Molecules. 2022 Mar 31;27(7):2276.
20. Merecz-Sadowska A, Sitarek P, Kucharska E, Kowalczyk T, Zajdel K, Cegliński T, Zajdel R. Antioxidant properties of plant-derived phenolic compounds and their effect on skin fibroblast cells. Antioxidants. 2021 May 5;10(5):726.
21. Liu L, Guo P, Wang P, Zheng S, Qu Z, Liu N. The review of anti-aging mechanism of polyphenols on Caenorhabditis elegans. Frontiers in bioengineering and biotechnology. 2021 Jul 1;9:635768.
22. Baroni L, Sarni AR, Zuliani C. Plant foods rich in antioxidants and human cognition: a systematic review. Antioxidants. 2021 May;10(5):714.
23. Arauna D, Furrianca M, Espinosa-Parrilla Y, Fuentes E, Alarcón M, Palomo I. Natural bioactive compounds as protectors of mitochondrial dysfunction in cardiovascular diseases and aging. Molecules. 2019 Nov 22;24(23):4259.
24. Athanasopoulou S, Kapetanou M, Magouritsas MG, Mougkolia N, Taouxidou P, Papacharalambous M, Sakellaridis F, Gonos E. Antioxidant and antiaging properties of a novel synergistic nutraceutical complex: readouts from an In cellulo study and an in vivo prospective, randomized trial. Antioxidants. 2022 Feb 26;11(3):468.
25. Zahoor H, Watchaputi K, Hata J, Pabuprapap W, Suksamrarn A, Chua LS, Soontorngun N. Model yeast as a versatile tool to examine the antioxidant and anti-ageing potential of flavonoids, extracted from medicinal plants. Frontiers in Pharmacology. 2022 Sep 2;13:980066.
26. Heckmann M, Stadlbauer V, Drotarova I, Gramatte T, Feichtinger M, Arnaut V, Atzmüller S, Schwarzinger B, Röhrl C, Blank-Landeshammer B, Weghuber J. Identification of oxidative-stress-reducing plant extracts from a novel extract library—Comparative analysis of cell-free and cell-based in vitro assays to quantitate antioxidant activity. Antioxidants. 2024 Feb 28;13(3):297.

27. Ranneh Y, Bakar MF, Ismail NA, Kormin F, Mohamed M, Akim AM, Isha A. Anti-aging and antioxidant of four traditional malaysian plants using simplex centroid mixture design approach. Saudi Journal of Biological Sciences. 2021 Dec 1;28(12):6711-20.

CITE AS: Waiswa Arajab (2025). Narrative Review of Antioxidant-Rich Plants in Aging. IDOSR JOURNAL OF APPLIED SCIENCES 10(3):159-169. https://doi.org/10.59298/IDOSRJAS/2025/103.159169