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REVIEW ARTICLE

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PHARMACOGNOSTIC EVALUATION OF NATURAL ANTIOXIDANTS: IMPLICATIONS FOR AGING AND AGE-RELATED DISORDERS

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ABSTRACT: Oxidative stress, among other things, contributes to aging, which is an ordinary though multifactorial process in the cells of the body. Oxidative stress, which is the disturbance with an equilibrium between body-generated ROS and antioxidants, is the main causative agent of aging and age-related diseases including cancer, neurodegenerative diseases, cardiovascular illnesses, and diabetes. Polyphenol antioxidants in food and medicinal plants have come to limelight as weapons against oxidative stress in the recent past. Carotenoids, flavonoids, polyphenols, and other words are some of the bioactive compounds of foods, beverages, and herbs that perform several tasks that include scavenging of free radicals, alteration of the cellular signal transduction pathways, return of cellular oxidant balance, and boosting of the cells' automatic protective mechanisms. This review includes analysis of the plant origin, chemical constitutions and the healing and antagonism possessed by natural antioxidants and their pharmacognostic account. In an effort to have uniformity in analyzing these chemicals, newer techniques such as HPLC spectroscopy and chromatography are valued. The versatility of antioxidants in therapeutic applications is well illustrated in such examples as quercetien, resveratrol, curcumin. They highlighted that clinical research of the effects of geroprotectors is presented as a connection between pharmacognostic research and clinical practice, which can show their ability to fight age-related diseases and slow down aging. Innovative strategies to tackle problems such as unequal effectiveness and poor solubility are on the agenda, including features such as nanotechnology platform, ethosomal forms and bioenhancers. Only when entailing traditional pharmacognostic practices and advanced modern technology discoveries is the comprehensive recuperative significance of natural antioxidants best realized, as the present article underlines. With an aim to build a healthier and stronger populace for aging, this review attempts to encapsulate existing evidence base and forward-looking perspectives. It is made for the purpose of advancing knowledge and encourage future work in the area of anti-aging and diseases.

Keywords: Natural antioxidants, Oxidative stress, Pharmacognostic evaluation, Aging, Age-related disorders

1. INTRODUCTION

Several factors have proposed hypotheses related to the ageing process which is associated with the decline of the organism's ability to perform its functions; however, oxidative stress has been explored as one of the major mechanisms. Now the ageing is a complex biological process that eventually results in death [1].

OS is defined as the condition that results from the increased generation of ROSs, compared to the ability of the cells to detoxify these products through the use of endogenous and food-derived antioxidants. High level of ROS induces oxidative stress and damage important biomolecules like DNA, proteins and lipids thus alter their normal functioning and promote events such as inflammation, apoptosis, mitochondrial dysfunction [2]. They all add up to and contribute to the aging process as well as serving as major contributing factors to most age-related morbidity and mortality conditions such as neurodegenerative diseases like Alzheimer's and Parkinson's diseases, cardiovascular diseases, diabetes, and various cancers. Biological antioxidants from medicinal plants and food can be documented as recent discoveries which offer considerable promise in preventing and /or delaying oxidant induced injury [3]. These include polyphenols, flavonoids, carotenoids, vitamins and other essential nutrients, this compound has multifaceted antioxidant actions, which includes reducing power, chelating action against metal ions and also the ability to influence redox status of genes. Moreover, natural antioxidants have been said to possess the abilities to activate the cellular repair mechanisms as well as the endogenous antioxidant systems creating a potential therapy for combating aging and allied diseases [4].

The quests for the identification, standardization, and optimization of plant based-antioxidant medicines have been facilitated by the recent growing focus on pharmacognostic evaluation, which constitutes the qualitative as well as quantitative examination of the physical, chemical, and biological properties of natural products [5]. Thus, safety, effectiveness, and quality of the bioactive chemicals are increasingly determined by the above inventions and profound bioanalytical tools like chromatography and spectroscopy. To assess natural antioxidants, this review aims to discuss the plant origin, chemistry, mode of action and pharmacology of natural antioxidants [6]. Here in this essay through separating knowledge of both recent modern science and traditional wisdom, we will demonstrate how natural antioxidants delay the aging process and reduce the manifestation of age-related ailments. So, it also provides inventive solutions like nanotechnology or novel drug delivery approaches alongside essential issues as bioavailability, standardization, and translation to clinics. This paper emphasizes the significance of Interdisciplinary approach in investigation with the aid of natural antioxidants to promote healthy ageing and enhance the well-being of older folks [7].

2. Oxidative Stress and Its Role in Aging

2.1 Definition and Mechanisms of Oxidative Stress

Oxidative stress is a physiological state that exists in the body when the levels of antioxidant defenses are insufficient to support the production of reactive species as RNS and ROS. High accumulation of ROS and RNS in tissues produces oxidative damage, whereas, at base levels, these markers play roles in normal processes of cell communication and regulation [8].

In most cases, ROS's such as superoxide anion ($O_2 \cdot^{\cdot} \cdot$), hydrogen peroxide (H_2O_2) and hydroxyl radicals (OH^-) appear as metabolite of cellular metabolism particularly the mitochondrial electron transport chain. The same enzymatic processes that yield NO and $ONOO^-$ generates RNS, including nitric oxide (NO) and peroxynitrite ($ONOO^-$) [9].

Molecular pathways contributing to oxidative stress include:

Mitochondrial dysfunction: The source of a high level of reactive oxygen species (ROS) is electron leakage resulting from oxidative phosphorylation [10].

NADPH oxidases: In immunological reactions and in pathological conditions, these enzymes catalyze the formation of reactive oxygen species (ROS) [11].

Lipid peroxidation: Actual ROS damage lipids and ignite a chain of reactions that threatens cell survival when the lipid membranes are attacked [12].

Protein and DNA oxidation: Reactive Oxygen Species (ROS) alter DNA and proteins that affect transcription, genome stability and enzyme function effectively [13].

2.2 Oxidative Stress and Cellular Aging

Oxidative stress plays a crucial role in the molecular and cellular processes that drive aging.

Mitochondrial dysfunction: Reduced mitochondrial function has been observed in ageing cells; they produce greater amounts of ROS and lesser ATP than youthful cells, thus resulting in increased oxidative stress which maintains the loop [14].

Telomere shortening: Cellular aging is defined by telomere shortening which is compromised by oxidative damage to the telomeres. Failure of tissue is facilitated by shortening of the telomeres due to senescence or apoptosis as a result of continuous diminishing of the smear [15].

Autophagy impairment: Oxidative stress inhibits a process of removing damaged organelles and proteins from cells Autophagy. Damage like this makes cellular waste and malfunction in aged tissues even worse [16].

Together, these mechanisms highlight how oxidative stress compromises cellular homeostasis, thereby accelerating the aging process.

2.3 Oxidative Stress in Age-Related Disorders

The pathophysiology of many age-related diseases has been linked to oxidative stress because of its capacity to cause persistent inflammation, cell death, and tissue damage [17].

Neurodegenerative diseases

Alzheimer's disease: ROS are involved in the development of Alzheimer's disease through the facilitation of amyloid beta plaques formation, as well as handling tau proteins through hyperphosphorylation [18].

Parkinson's disease: Motor and cognitive dysfunction is adjuvant by oxidative stress which affects dopaminergic neurons of the substantia nigra [19].

Cardiovascular diseases

Conventional ROS promote the oxidation of lipids, plaques and inflammatory endothelial changes; they make the process of atherosclerosis, hypertension and ischemic events more rapid [20].

Metabolic syndromes

Diabetes and obesity-related disorders are for the most part insulin resistance, beta cell dysfunction, and chronic inflammation; oxidative stress goes hand in hand with these [21].

Table 1: Summary of Mechanisms Linking Oxidative Stress to Aging [22]

Mechanism	*Description*	*Impact on Aging*
Mitochondrial Dysfunction	ROS overproduction due to impaired mitochondrial electron transport chain.	Amplifies oxidative stress, reduces ATP production, and triggers apoptosis.
Telomere Shortening	Oxidative damage accelerates the loss of telomeric DNA during replication.	Induces cellular senescence and limits regenerative capacity.
DNA Damage	ROS-induced strand breaks and base modifications in nuclear and mitochondrial DNA.	Impairs genomic stability, promotes mutations, and activates repair pathways.
Protein Oxidation	Oxidative modifications disrupt protein structure and function.	Leads to loss of enzymatic activity, aggregation of misfolded proteins, and proteostasis imbalance.
Lipid Peroxidation	ROS attack polyunsaturated fatty acids in cell membranes.	Compromises membrane integrity, increases permeability, and generates toxic aldehyde byproducts.
Impaired Autophagy	ROS disrupt the clearance of damaged organelles and proteins.	Accumulates cellular debris, exacerbating dysfunction and inflammation.
Chronic Inflammation	ROS activate inflammatory signaling pathways (e.g., NF-κB, NLRP3 inflammasome).	Sustained inflammation contributes to tissue damage and aging-related diseases.
Endothelial Dysfunction	ROS impair nitric oxide bioavailability and promote oxidative injury in vascular endothelium.	Leads to hypertension, atherosclerosis, and cardiovascular aging.
Epigenetic Alterations	Oxidative stress influences DNA methylation and histone modifications.	Dysregulates gene expression, accelerating cellular aging processes.
Impaired Proteostasis	ROS damage chaperones and proteasomal degradation pathways.	Promotes protein aggregation and cellular dysfunction in aging tissues.
Calcium Homeostasis Disruption	ROS interfere with calcium signaling by damaging channels and pumps.	Alters cellular signaling, contributing to apoptosis and tissue degeneration.
Stem Cell Exhaustion	Oxidative stress damages stem cell niches and reduces regenerative potential.	Limits tissue repair and regeneration, exacerbating aging phenotypes.

3. Natural Antioxidants: Sources and Mechanisms

3.1 Definition and Classification of Natural Antioxidants

Plant derived nutrients and food constituents which can participate in the detoxification of reactive species and protect against oxidative stress are known as Natural antioxidants. These antioxidants are mainly grouped into two main groups according to the mechanism of action [23]:

Enzymatic Antioxidants: These naturally occurring proteins and enzymes help one defeat ROS and, thus, reverse or maintain the redox state [24].

Superoxide dismutase (SOD): Resulting in the formation of hydrogen peroxide from superoxide radicals (O_2^-).

Catalase: Decomposes H_2O_2 into its component elements, water and oxygen.

Glutathione peroxidase: Using glutathione as a substrate, it reduces peroxides [25].

Non-Enzymatic Antioxidants: Free radical scavengers are tiny molecules that can be found mostly in plants and food [26].

Polyphenols: Some of major components of these substances include flavonoids, tannin as well as phenolic acids.

Carotenoids: Abs African American men had higher levels of lycopene and beta-carotene which are pigments that scavenge singlet oxygen species.
Vitamins: Two forms of Vitamin C, ascorbic acid and tocopherol, are antioxidants with strong capacities [27].

3.2 Pharmacognostic Sources of Natural Antioxidants

Natural antioxidants are widely distributed across medicinal plants, fruits, vegetables, and nuts. Key sources include:

Medicinal Plants:

- **Curcumin (Turmeric):** Exhibits antioxidant, anti-inflammatory, and anti-carcinogenic effects.
- **Resveratrol (Grapes):** Prevents oxidative stress and promotes heart health.
- **Quercetin (Onions, Apples):** An effective flavonoid free radical scavenger [28].

Dietary Sources:

- **Fruits:** Vitamin C and polyphenols abound in pomegranates, blueberries, and oranges.
- **Vegetables:** Progoitrins, total glucosinolates, lutein, and hydroxylated flavonoids exist in broccoli, spinach, and kale.
- **Nuts:** Polyunsaturated fatty acids and vitamin E content rich ageing and nuts such as walnuts and almonds [29].

3.3 Mechanisms of Action of Natural Antioxidants

Natural antioxidants protect cells and tissues from oxidative stress through several well-defined mechanisms:

Free Radical Scavenging: To realize ROS less reactive, antioxidants donate an electron to reduce the reactivity of the ROS for normal metabolic reactions. Vitamin E interrupts certain chains of lipid peroxidation in membrane while vitamin C reduces superoxide radicals [31].

Metal Ion Chelation: Some antioxidants chelate to transition metals including iron and copper so that they don't cause ROS production through Fenton and Haber-Weiss reactions [32].

DNA Repair and Protection: In an attempt to avoid DNA strand breakage and base conversions, flavonoids and resveratrol act as oxidants and neutralize ROS. They also keep the DNA from degradation by activating the repair enzymes that belongs to each of the cells [33].

Table 2: List of Natural Antioxidants, Their Sources, and Pharmacological Activities [30]

Antioxidant	*Source*	*Pharmacological Activities*
Curcumin	Turmeric (Curcuma longa)	Anti-inflammatory, anti-carcinogenic, ROS scavenging
Resveratrol	Grapes, red wine	Cardioprotective, neuroprotective, anti-aging
Quercetin	Onions, apples	Anti-inflammatory, anti-diabetic, free radical scavenging
Epigallocatechin gallate (EGCG)	Green tea (Camellia sinensis)	Antioxidant, anti-cancer, neuroprotective
Lycopene	Tomatoes, watermelon	Singlet oxygen quenching, skin protection, anti-cancer
Vitamin C	Citrus fruits (oranges, lemons)	ROS scavenging, collagen synthesis, immune modulation
Vitamin E	Nuts, seeds (almonds, sunflower seeds)	Lipid peroxidation inhibition, cardioprotective
Beta-carotene	Carrots, sweet potatoes	Precursor of Vitamin A, singlet oxygen scavenging, vision support
Anthocyanins	Blueberries, blackberries	Anti-inflammatory, anti-diabetic, ROS scavenging
Glutathione	Endogenous (liver), spinach	Detoxification, ROS neutralization, DNA repair
Silymarin	Milk thistle (Silybum marianum)	Hepatoprotective, anti-inflammatory, ROS scavenging
Tannins	Tea, pomegranates	Anti-carcinogenic, antimicrobial, free radical scavenging

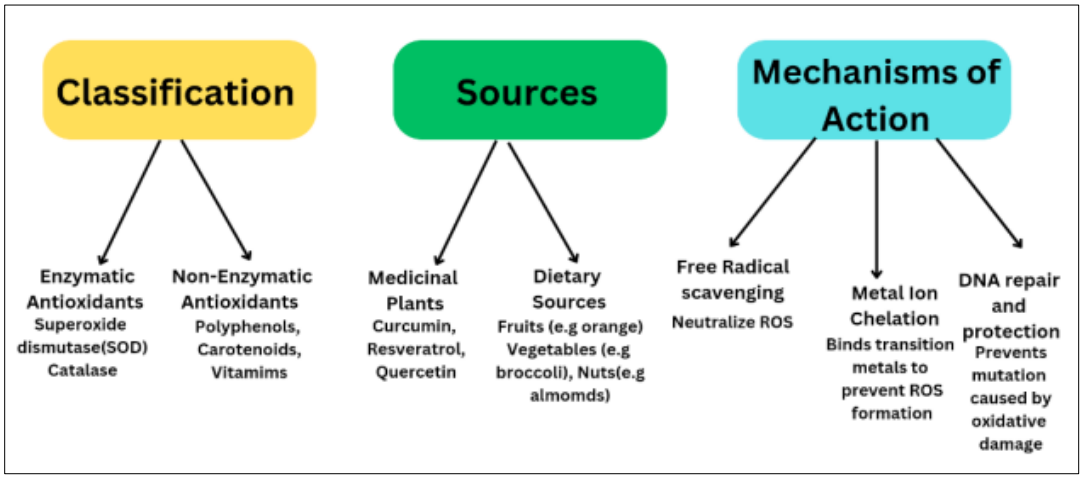

Fig. 1: Flowchart showing classification, sources, and mechanisms of natural antioxidants. [34]

4. Pharmacognostic Evaluation

4.1 Importance of Pharmacognostic Evaluation

Pharmacognostic evaluation involves the assessment of the chemical, biological and physical properties of bioactive substances derived from natural source. Natural antioxidants particularly those to be used in medicine should be of very high quality, safe, and effective [35].

Key reasons for its importance include:

Quality Assurance: In growing, harvesting, and processing conditions vary and this is the reason natural antioxidants differ in composition. Each of the active ingredients can be normalised and quality of business ingredients can be ascertained by pharmacognostic appraisal [36].

Safety Studies: Natural antioxidants have bioactivity and therefore require assessment of their toxicity, allergenic and drug interactions [37].

Efficacy Validation: Pharmacognostical standards help determine that the application of natural antioxidants as medicines is based on sound epidemiologic evidence, thus allowing clinical practice integration [38].

4.2 Techniques for Pharmacognostic Analysis

A variety of advanced and traditional techniques are employed to analyze and validate natural antioxidants.

Phytochemical Screening:

Demonstration of potential primary bioactive groups such as polyphenols, alkaloids, tannins and flavonoids from preliminary screening [39].

Chromatographic Methods

High-Performance Liquid Chromatography (HPLC): Used in the determination of some antioxidants, including resveratrol as well as curcumin.

Thin-Layer Chromatography (TLC): A fast and inexpensive method to de-emulsify bioactive substances [40].

Spectroscopic Techniques

UV-Vis Spectrophotometry: For use in calculating a compound's antioxidant capability from its light absorption properties.

Fourier-Transform Infrared Spectroscopy (FTIR): Finds the groups that antioxidant compounds include.

Nuclear Magnetic Resonance (NMR): Antioxidant chemicals are described in extensive structural terms [41,42].

All of these methods work together to let us evaluate the stability, effectiveness, and composition of natural antioxidants.

4.3 Case Studies of Pharmacognostic Evaluations

Important natural antioxidants can have their therapeutic potential better understood by pharmacognostic evaluation [43].

Curcumin (Turmeric)

- **Physical properties:** Crystalline powder of yellow color that is poorly soluble in water.
- **Chemical properties:** Contributes actively by chelation of metal and trapping of reactive oxygen species.
- **Analytical evaluation:** The active component that is curcumin in the turmeric preparations can be quantified using the high performing liquid chromatography (HPLC) methods [44].

Resveratrol (Grapes)

- **Physical properties:** White crystalline compound soluble in alcohol.
- **Chemical properties:** By its regulation of redox-sensitive signal transduction pathways, it exhibits its anti-inflammatory and antioxidant properties.
- **Analytical evaluation:** In order to separate it and determine in specific grapes-based products, two important methods are used Thin Layer Chromatography (TLC) and High-Performance Liquid Chromatography (HPLC) [45].

Table 3: Pharmacognostic Parameters of Selected Natural Antioxidants [46]

Antioxidant	*Source*	*Physical Properties*	*Chemical Properties*	*Analytical Methods*
Curcumin	Turmeric (Curcuma longa)	Yellow crystalline powder, poor solubility in water	Strong ROS scavenger, metal ion chelator	HPLC, UV-Vis Spectroscopy
Resveratrol	Grapes, red wine	White crystalline compound, soluble in alcohol	Modulates redox pathways, anti-inflammatory	HPLC, TLC, NMR
Quercetin	Onions, apples	Yellow crystalline powder, soluble in ethanol	Potent free radical scavenger	HPLC, FTIR
EGCG	Green tea (Camellia sinensis)	Fine green powder, water-soluble	Inhibits lipid peroxidation, anti-carcinogenic	UV-Vis, HPLC
Lycopene	Tomatoes, watermelon	Red oily substance, insoluble in water	Quenches singlet oxygen, antioxidant activity	HPLC, UV-Vis Spectroscopy
Vitamin C	Citrus fruits	White crystalline powder, water-soluble	Reduces ROS, promotes collagen synthesis	Titration, UV-Vis Spectroscopy
Vitamin E	Nuts, seeds	Yellow viscous oil, fat-soluble	Prevents lipid peroxidation, stabilizes membranes	HPLC, Gas Chromatography
Beta-Carotene	Carrots, sweet potatoes	Orange crystalline powder, fat-soluble	Quenches singlet oxygen, precursor of Vitamin A	HPLC, FTIR
Anthocyanins	Blueberries, blackberries	Purple crystalline powder, water-soluble	Antioxidant, anti-inflammatory properties	HPLC, UV-Vis Spectroscopy
Silymarin	Milk thistle (Silybum marianum)	Yellowish powder, soluble in methanol	ROS scavenger, hepatoprotective	HPLC, Mass Spectrometry

5. Therapeutic Potential of Natural Antioxidants

5.1 Natural Antioxidants in Delaying Aging

By reducing oxidative stress, which is a major cause of cellular and molecular degradation, natural antioxidants are vital in postponing the start of aging [47].

Anti-aging Skincare: A lot of the skincare item has natural antioxidants like polyphenols, vitamin C, and vitamin E to guard the skin from oxidative damage caused by pollution and UV radiation. In addition to fading fine lines and attain more elastic skin, they promptly halt collagen degradation [48].

Example: Vitamin C, when applied topically, can restore photodamaged skin and support collagen production [49].

Mitochondrial Health: Decrementing the production of dangerous ROS and removing damage molecules whilst sustaining ATP production, resveratrol and CoQ10 assist the function of mitochondria. However, to age healthily, efficiency of the mitochondria should be raised, because this exactly slows down the process of cell aging and maintains a balance of energy supply [50].

5.2 Role in Age-Related Disorders

As a result of their varied pharmacological effects, natural antioxidants have shown great promise as a treatment for age-related diseases [51].

Cardiovascular Protection: The two defenses that can seem to decrease oxidative stress within blood vessels, thus retarding atherosclerosis and endothelial dysfunction are lycopene, flavonoids and polyphenols. It also means that they can lower LDL oxidation and increase nitric oxide bioavailability as part of cardiovascular health [52].

Example: In hypertensive patients, resveratrol lowers blood pressure and increases vascular flexibility [53].

Neuroprotection: They decrease inflammation in the brain and reduce oxidative damage to neurons in conditions like Parkinson's disease or Alzheimer's disease. For instance, curcumin inhibits amyloids aggregation of beta and vitamin E inhibits lipid peroxidation in neuronal membranes [54].

Metabolic Syndrome Management: The condition of metabolic syndrome, there is persistent inflammation, antioxidants thus assist in restoring balance with regard to insulin regulation. Anthocyanin and quretertin for instance protect pancreatic beta cells from free radical and reduce glucose metabolism [55].

5.3 Evidence from Clinical Studies

Natural antioxidants have been shown to be effective in treating aging and age-related diseases in a large number of clinical trials [56]:

Vitamin C and Skin Aging: A research trial revealed that elderly, who are 40 years and above, who consumed vitamin C supplement daily for 4 weeks recorded an improvement in the skin texture and a slight disappearance of age spots.

Resveratrol and Cardiovascular Health: In a clinical study, supplementation with resveratrol improves blood pressure and endothelial function in those with pre-heart disease.

Curcumin in Alzheimer's Disease: Additional curcumin enhanced memory performance and reduced inflammation in the brains of patients with mild cognitive impairment dementia.

EGCG in Metabolic Syndrome: The obese metabolic syndrome patients who consumed EGCG-fortified green tea aqueous extracts boring weight, decreased their insulin resistance and low-density lipoprotein cholesterol levels [57].

6. Challenges and Future Perspectives

6.1 Limitations of Current Pharmacognostic Approaches

Despite the promising potential of natural antioxidants, several limitations hinder their widespread application:

Challenges in Standardization: Natural antioxidants extracted from plants might contain quite a different set of chemical compounds depending on the environmental conditions including growth and harvest and the way these plants are processed. Therapeutic inequivalence is a result of the inability to standardize active chemicals for this reason of uneven structure [58].

Poor Bioavailability: Curcumin is one of the well-known natural antioxidants which is readily metabolized in the body, while it has low solubility and absorption rate. That in turn reduces their ability to achieve therapeutically relevant concentrations in the tissues that many are meant to address [59].

Lack of Comprehensive Safety Data: Still, there is little information on the chronic effects of natural antioxidants, including toxicity, interactions, and potential adverse effects when applied in large doses or with prolonged use [60].

6.2 Innovative Strategies for Antioxidant Delivery

To overcome these limitations, advanced delivery systems are being developed to enhance the efficacy and bioavailability of natural antioxidants:

Nanotechnology:
Nano encapsulation makes antioxidants such as curcumin nanoparticles more bioavailable, stable and soluble. The other advantage of nanocarriers is that targeted delivery reduces the negative impact of the treatment on the overall body [61].

Liposomes:
Liposomes, which are structures based on phospholipids, are preferable for encapsulation of antioxidants and can deliver these components under controlled manner – by releasing them from the liposome structure. These play wonders specifically in delivering water insoluble antioxidants like, beta carotene and vitamin E [62].

Ethosomes:
By enhancing the penetration capabilities of the antioxidants through the skin, further improvement was made with creation of lipid-based carriers termed ethosomes containing ethanol. You can come across them in anti-aging and photoprotective skincare products you see everywhere [63].

To get the most therapeutic effect out of antioxidants, these new methods make sure they reach the target area at the right concentration.

6.3 Future Directions in Antioxidant Research

The future of antioxidant research lies in integrating pharmacognostic evaluation with modern scientific advancements to address current challenges and unlock new possibilities:

Multi-Omics Approaches: The molecular regulation of antioxidants and its probable influence on biological processes can be deep understood to clashing juxtaposed molecular mechanisms of genomes, proteomes, and metabolomes [64].

Integration with Modern Drug Development: New antioxidants can be identified and their molecular conformations, potentially capable of improving antioxidant activity, be enhanced by employing superior computational tools such as molecular docking and artificial intelligence [65].

Personalized Antioxidant Therapies: The future research could be devoted to the development of individual plans of taking antioxidant therapies depending on one's genotype, individual living conditions and specific health issues, which means that every client will get exactly what he/she needs [66].

Sustainability in Sourcing Antioxidants: Conservation of the species while providing for the long-term delivery of antioxidants entails support of environmentally friendly and sustainable methods of growing and extracting [67].

CONCLUSION

Oxidative stress is considered to be one of the main causes of onset of the many diseases linked to aging, and also contributes to aging. The pathophysiology of disorders such as neurodegenerative diseases, cardiovascular diseases, and metabolic diseases involves disturbed antioxidant-to-ROS ratio and initiates cell damage. Unless we restore this balance, we may not be able to promote good aging or reduce the intensity of these diseases.

New trustee is using the naturally occurring nutrient antioxidants in food and medicinal plants against oxidative stress. The many pharmacological effects observed in compounds such as quercetin, resveratrol, and curcumin include the removal of ROS, the binding of several metal ions, the activation of processes of cell repair. Besides reversing the aging method, they could be employed in preventing and treating age related diseases by controlling metabolism, providing the nervous system, and strengthening the cardiovascular system. Clinical trials add more evidence that these antioxidants help to enhance health and productivity.

Issues such as compositional uncertainty, low solubility, and a dearth of clinical applications carry forward from these modern advancements. Further work is required to set the recognized pharmacognosy metrics, construct complex delivery systems, and integrate the conventional healing modalities with the assisted science to maximize the utilization of antioxidants from natural resources. Consequently, natural antioxidants may be integral components of undertakings to enhance years to live, the quality of those years, and capacity for successful aging where those shortcomings are remedied, and additional advances are made. The possibilities of these bioactive chemicals for the treatment of age-related diseases and aging depend on the harmonizing pharmacognostic analysis with the recent trends of drug advancement.

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