Naqbi KA, Manoharan R, Nair CS, Kandhan K, Alyafei MS, Jaleel A. Exploring the antioxidant potential of medicinal plants in the United Arab Emirates (UAE): Emphasizing their significance in novel drug development. Pharmacy Practice 2025 Jan-Marc;23(1):3113.
https://doi.org/10.18549/PharmPract.2025.1.3113

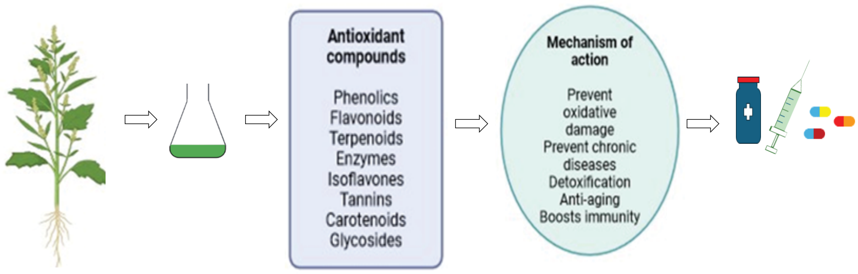
Review Article

Exploring the antioxidant potential of medicinal plants in the United Arab Emirates (UAE): Emphasizing their significance in novel drug development

Khalfan Al Naqbi, Ramya Manoharan, Chythra Somanathan Nair, Karthishwaran Kandhan, Mohammed Salem Alyafei, Abdul Jaleel

Received (first version): 08-May-2024 Accepted: 20-Aug-2024 Published online: 03-Mar-2025

Abstract
Recent scientific investigations across the globe have unveiled the medicinal attributes of plants, subject to scrutiny due to their effective pharmacological properties, economic feasibility, and less toxicity. Compounds such as polyphenols demonstrate the ability to scavenge free radicals and enhance a balance between oxidative stress and antioxidant property. The mode of action of antioxidants involves suppressing the formation of reactive oxygen species either through enzyme inhibition or by chelating trace elements. Antioxidant assays such as DPPH, FRAP, ABTS have been used to evaluate the scavenging effect of antioxidants. Natural antioxidants from plants play a crucial role in human health and are beneficial in combating various diseases like cardiovascular disorders, lung damage, and inflammation. Native plants in the United Arab Emirates (UAE) have served as a valuable resource in traditional medicine. However, there are still gaps in understanding and research regarding the phytochemical and pharmacological aspects of these plants. This review aims to explore the researches in medicinal plants in the UAE as a potential source of antioxidants, highlighting their value for the development of new drugs.



Keywords: plant extracts; antioxidant; free radical scavenger; immune booster; drug development

Khalfan Al Naqbi. Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, PO Box No. 15551, Al Ain, United Arab Emirates. 200909946@uaeu.ac.ae
Ramya Manoharan. Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, PO Box No. 15551, Al Ain, United Arab Emirates. 700039316@uaeu.ac.ae
Chythra Somanathan Nair. Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, PO Box No. 15551, Al Ain, United Arab Emirates. 202190114@uaeu.ac.ae
Karthishwaran Kandhan. Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, PO Box No. 15551, Al Ain, United Arab Emirates. kandhan_k@uaeu.ac.ae
Mohammed Salem Alyafei. Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, PO Box No. 15551, Al Ain, United Arab Emirates.
Abdul Jaleel*. Associate Professor, Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, PO Box No. 15551, Al Ain, United Arab Emirates. abdul.jaleel@uaeu.ac.ae

INTRODUCTION

The current scientific landscape has extensively explored the therapeutic attributes of plants, driven by their robust antioxidant properties, no adverse effects, and economic feasibility.[1,2] Herbal medicine plays a crucial role in sustaining both the health and prosperity of humanity, with a significant portion of the global population relying on herbal remedies. The World Health Organization (WHO) states that around 21,000 plants have been utilized for medicinal purposes, and according to the Food and Agriculture Organization (FAO), over 50,000 plant species are employed in traditional medicine worldwide.[3,4] Medicines are derived from various plant parts such as leaves, stems, flowers, bark, tubers, seeds and roots, Notably, over 30% of all plant species have been employed for medicinal purposes at some point. In developing nations, traditional medicine practices, incorporating ethnomedicine, have evolved into a more scientific and comprehensive approach.[5] Many plants used in traditional medicine exhibit potent antioxidant property.[6] This therapeutic efficacy of certain plants is attributed to specific secondary metabolites collectively known as phytochemicals, which hold the potential for development into herbal medicines or as precursors for modern drugs.[7] Phytochemicals are categorized into primary metabolites like proteins, amino acids, sugars and chlorophyll, and secondary metabolites.[8] Certain phytochemicals like flavonoids and phenols, known for their robust antioxidant properties, contribute significantly to the healthcare system.[9]

For years, researchers have been on the quest for potent, yet non-toxic antioxidants sourced from natural origins, particularly from edible or medicinal plants. Consequently, there's a push for novel drug formulations derived from natural substitutes of plant origin. The medicinal significance of plants largely stems from their production of substances with defensive properties formed because of metabolic processes.[10] Recently, there has been a surge of interest in exploring the healing potential of plants as antioxidants, aiming to reduce tissue damage caused

Table 1. Antioxidant potential of plants in the United Arab Emirates

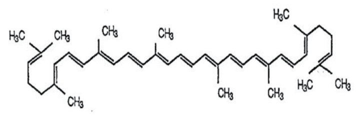
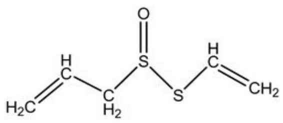
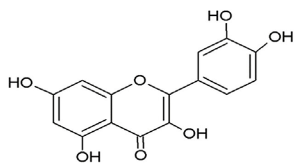
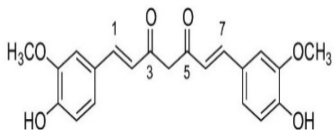
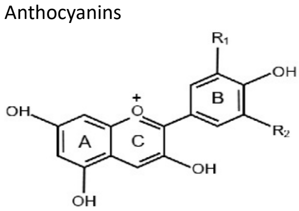
Author [Reference]	Plant species	Family	Plant parts used	Plant sample	Antioxidant potential
Marwan *et al.*[24]	*Aerva javanica* (Burm. f.) Juss.	Amaranthaceae	Flower	Essential oil	Best antioxidant activity expressed in flowers during the spring season
Al-Snafi [25]	*Ammi majus*	Apiaceae	Whole plant	Methanol extract	In DPPH, highest inhibition percentage of 88.65% in seeds, 83.14% in roots and 78.6% in stem
Armin *et al.*[26]	*Calotropis procera*	Apocynaceae	Leaves	Aqueous extract	Highest IC_{50} value of 366.33 µg/mL in DPPH assay
Samira *et al.*[27]	*Cynodon dactylon* (L.)	Poaceae	Rhizomes	Methanol extract	Free radical scavenging activity equal to 48.93%
Alabri *et al.*[28]	*Datura metel* L.	Solanaceae	Leaves	Butanol extract	Presence of high antioxidant activity ranging between 47-71%
Shaheen *et al.*[29]	*Dipterygium glaucum*	Capparidaceae	Aerial parts	Methanol extract	High scavenging activity with EC_{50}value of 152.0 ± 2µg/mL
El-Amier *et al.*[30]	*Emex spinosa* (L.) Campd.	Polygonaceae	Leaves	Methanol extract	Highest antioxidant activity with IC_{50} = 29.92 mg mL^{-1}
Moneim *et al.*[31]	*Fagonia indica*	Zygophyllaceae	Aerial parts	Methanol extract	Significant antioxidant activity at IC_{50} value of 0.06±3.53 mg/mL
Mujic *et al.*[32]	*Ficus carica*	Moraceae	Fruit	Methanol extract	High antioxidant activity with TPC 11.17 mg GAE/g
Ullah *et al.*[33]	*Haloxylon salicornicum*	Amaranthacea	Whole plant	Aqueous extract	Highest inhibition of 26.69% was observed at 200 µg/ml
Elsharkawy *et al.*[34]	*Hyoscyamus muticus* L.	Solanaceae	Aerial parts	Methanol extract	Antioxidant activity with IC_{50} and EC_{50} value of 8.1±0.65 mg/ml and 12.74±1.12 mg/ml
Jacob *et al.*[35]	*Lawsonia inermis* L.	Lythraceae	Seeds	Ethanol extract	High antioxidant activity with TPC value 141.65±0.29mg of GAE
Faris *et al*.[36]	*Maerua crassifolia*	Capparaceae	Aerial parts	Methanol extract	Highest antioxidant activity with IC_{50} value 448µg/mL
Obaid *et al.*[37]	*Ochradenus arabicus*	Resedaceae	Whole plant	Essential oil	Highest antioxidant activity with IC_{50} value 106.40±0.19 µg/mL
Uddin *et al.*[38]	*Portulaca olerecea*	Portulacaceae	Aerial parts	Methanol extract	60-days old plant showed high antioxidant activity with high TPC 348.5 ± 7.9mg GAE/100g
Salama *et al.*[39]	*Reichardia tingitana*	Asteraceae	Shoots	Methanol extract	Free scavenging activity of 71.91% with IC_{50} value 30.77mgL^{-1}
Khan *et al.*[40]	*Rumex vesicarius* L.	Polygonaceae	Whole plant	Methanol extract	TPC is 21.80±0.03 mg gallic acid/g, TFC is 43.00±0·03, DPPH % inhibition is 96·55±0·03
Mohamed and Khan[41]	*Salvadora persica* L.	Salvadoraceae	Root	Methanol extract	Presence of scavenging activity at IC50 values of 4.8 and 1.6µg in DPPH and ABTS assays
Almoulah *et al.*[42]	Solanum nigrum	Solanaceae	Leaves	Steroidal glycoalkaloid fraction	Strong antioxidant activity with IC_{50} value of $3.5±0.2_{DPPH}$ and $3.5±0.3_{ABTS}$ µg/mL
Cheruth *et al.*[43]	*Tephrosia apollinea*	Fabaceae	Whole plant	Methanol extract	Significant antioxidant activity with IC_{50} 29.41µg/ml
Sonibare [44]	*Vernonia cinerea* (L.) Less	Asteraceae	Leaves	Ethyl acetate extract	Presence of high antioxidant activity with an IC_{50} value of 6.50 µg/mL

by free radicals.[11] Many studies have demonstrated that natural plant antioxidants can suppress oxidation and decrease the effects of age-related illnesses.[12] Antioxidant phytochemical constituents play an important role in the prevention and control of diseases.[13] Antioxidant properties such as lipid peroxidation and free radical scavenging are associated with antimutagenic, anticarcinogenic and cardioprotective properties of phenolic compounds.[14] Polyphenols, identified as the primary antioxidant components found in numerous medicinal and edible plants, are subjected to variations in yield and stability during the extraction process.[15] Polyphenols are potential antioxidants that protect our living system from various stress factors and cures many ailments.[16,17] Flavonoids, functioning as antioxidants, neutralize free radicals such as lipid hydroxyl peroxide and hydroperoxide. This action helps inhibit oxidation that might otherwise cause degenerative diseases.[18,19] Terpenoids as antioxidant compounds exhibit different pharmacological effects such as anti-inflammatory, antimalarial, anticancer, antiviral, inhibition of cholesterol synthesis and antibacterial activities.[20] Conducting proximate and nutrient analysis on these plants offers insights into their nutritional significance. If a plant meets the standards for all proximate composition parameters, it can be considered safe for use as a dietary supplement or herbal drug.[21]

Medicinal plants in the United Arab Emirates (UAE) with antioxidant potential

Arab has a rich tradition of using plants in the traditional medicine blended with Greek practices which is known as the Unani (Greco-Arab prescription). A study by Ghazanfar[22] reported different ethnomedical practices that were commonly found in Arabian Peninsula. Approximately 678 plant species have been documented in the UAE, with a considerable number demonstrating resilience to thrive in harsh environments. In a study by Sakkir *et al.* [23], a total of 132 plant species were found to have medicinal properties out of which some plants belonging to polygonaceae family were used in traditional medicine. However, the studies on plants in the UAE, their antioxidant

Table 2. Antioxidants against Chronic diseases

Author [Reference]	Classification	Phytochemical name/structure	Chronic disease
Weberling *et al.*[60] Gajendragadkar *et al.*[61] Elango and Asmathulla[62]	Carotenoids	Lycopene 	Enhanced endothelial function among patients with cardiovascular disease undergoing optimal secondary prevention
Yan *et al.*[63] Ojha *et al.*[64]	Organosulphur compounds	Allicin 	Decreased overall blood cholesterol levels, lowered LDL, and elevated HDL
Perez-Vizcaino, Francisco *et al.*[65] McKay *et al*.[66]	Flavonols	Quercetin 	Lowered blood pressure among individuals with stage I hypertension
Sung and Park [67] Chanin *et al.*[68]	Polyphenols	Curcumin 	Potential therapeutic capability for individuals with ulcerative colitis
Aedín *et al.*[69] Risa *et al*.[70]	Flavonoids	Anthocyanins 	Contributed to hypertension prevention in men and women

potential and utilization in modern drug development remains underexploited. Table 2 presents the list of plants found in the UAE, emphasizing the need for further exploration of their antioxidant compounds and its application in new drug development.

Antioxidants in the development of new drug

Prevention of oxidative damage

Plants possessing antioxidant potential play a pivotal role in advancing new drug development. With their rich array of biologically active compounds, these plants exert diverse pharmacological effects on humans. Traditional medicinal practices remain a cornerstone in treating common ailments, with approximately 60–80% of the global population adhering to these traditions. Plant-derived antioxidants, crucial for combating reactive oxygen species (ROS), are central in drug development research. Elevated ROS levels contribute to heightened oxidative stress, disrupting cellular redox balance, and fostering age-related conditions such as type 2 diabetes, cancer, and neurodegenerative disorders. While plant-derived medications exist to mitigate these ailments, living cells employ defense mechanisms against ROS-induced damage, with antioxidant enzymes pivotal in neutralizing free radicals and aiding in stress management. Phytochemicals harboring antioxidant properties hold promise in modulating stress responses by scavenging ROS. Research conducted has unveiled the antioxidant potential of many plants found in the UAE, which can be harnessed in treating various chronic diseases. These plants contain antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPX), alongside nonenzymatic molecules that aid in removing toxic peroxides.[45] Various methods have been employed to assess antioxidant compounds, including total phenols, total flavonoids, phenolic acids, tannins, and others. The DPPH (1,1-diphenyl-2-picrylhydrazine) assay measures antioxidant activity by observing the reaction between DPPH and hydrogen atom-donating compounds. This reaction scavenges the DPPH free radicals and leads to the decolorization of the solution. The antioxidant capacity is quantified by the reduction in absorbance at 515 nm. Additionally, the ABTS radical scavenging method, widely utilized for assessing antioxidant potential, entails the generation of the ABTS radical cation followed by its reduction in the presence of hydrogen-donating antioxidants, with reduction measured spectrophotometrically at 734 nm. Given the significance of total phenolic content in plants, the Folin-Ciocalteu reagent assay is crucial for its determination. In this assay, the sample is combined with diluted Folin-Ciocalteu reagent and saturated sodium carbonate solution, with the mixture left to stand before measurement at 725 nm. A standard curve using Gallic acid is prepared, and the total phenolic content is expressed as mM gallic acid equivalents (GAE) per liter of sample (mM/L). Table 2 illustrates the antioxidant potential of plants in the UAE, as evidenced by their positive results in various antioxidant assays. The radical scavenging activity of antioxidant compounds contributes to the treatment of diseases such as cancer, diabetes, atherosclerosis, inflammatory diseases, and aging, highlighting the growing importance of antioxidants in disease management. Numerous studies have underscored the wide-ranging antioxidant capacities of plants, with phenolic compounds emerging as major contributors to their antioxidant activity.[46,47] These findings emphasize the promising potential of plants in the UAE as valuable sources of natural antioxidants and other bioactive compounds for applications in the food and pharmaceutical sectors, particularly in new drug development.

Prevention of chronic diseases

Plants engage in synthesizing a variety of beneficial compounds through their metabolic processes, yielding primary outcomes like proteins and cellulose. Furthermore, secondary metabolites such as phenolic compounds, terpenoids, and nitrogen-containing compounds constitute significant products.[48] These secondary metabolites are classified based

Table 3. Plants antioxidant with detoxification, anti-ageing, and immune booster properties

Author [Reference]	Compounds	Beneficial effects
Juanjuan *et al.*[95] Jain *et al.*[96]	Flavonoids	cofactor of enzymes, angiogenic and inflammatory process, moisturize and soften skin, anti-ageing, anti-cellulite
Zillich *et al.*[97] İlhami[98]	Phenolic acids	depigmentation properties, stimulate synthesis of collagen and elastic fibers, anti-allergic, anti-cancer, anti-inflammatory, antimicrobial, anti-ageing
Elwira[99]	Tannins	reduce elastase activity, protects skin from inflammation, wound healing properties
Paulina[100] Tsao[101]	Stilbenes	protects skin cells against oxidative damage, reduce hyperpigmentation, regulation of melanogenic genes
Yu-Tang *et al.*[102] Faghihzadeh *et al.*[103]	Resveratrol	inhibits pro-inflammatory cytokines, anti-inflammatory activity, hepatoprotective property
Ji-Hye *et al.*[104]	Quercetin	prevents paracetamol induced liver and kidney damage with anti-inflammatory and hepatoprotective effects
Joyce *et al.*[105] Usharani *et al.*[106] Christopher *et al.*[107]	Curcumin	hepatoprotective, nephroprotective, anti-inflammatory and synergistic effects
Gómez-Zorita *et* al.[108]	Isoflavones	bone health
Bahonar *et al.*[109]	Lutein	ischemic stroke
Khanna *et al.*[110]	Genistein	rheumatoid arthritis
George *et al.*[111]	Apigenin	Increases apoptosis altering cell cycle

on their biosynthetic pathways, encompassing polyphenols, phenolic compounds, terpenoids, steroids, and alkaloids.[49-51] The antioxidant properties of these phytochemicals have been observed not only in controlled laboratory experiments but also in human studies. Excessive production of oxidants within the human body can disrupt balance, leading to oxidative damage to essential biomolecules such as lipids, DNA, and proteins. This damage is a significant contributor to the development of various human diseases, including cardiovascular diseases, specific cancer types, and the aging process.[52] Consequently, phytochemical antioxidants may play a significant role in preventing and managing chronic illnesses.[53] Phytochemicals like polyphenols and flavonoids augment the overall antioxidant activity. Persistent inflammation is a significant factor that may contribute to or exacerbate the development of various chronic conditions, including cardiovascular diseases, cancers, and type 2 diabetes (T2D).[54,55] Most antioxidant phytochemicals have demonstrated anti-inflammatory properties. Compounds such as resveratrol, anthocyanins, and curcumin exhibit inflammation-reducing effects by inhibiting prostaglandin production and nuclear factor-κB activity, enzyme inhibition, and promoting cytokine production.[56,57] Typically, antioxidant phytochemicals possess robust abilities in scavenging free radicals and acting as antioxidants, alongside their anti-inflammatory properties, forming the basis for various other bioactivities and health benefits.[58,59]

As per table 2 above, conducting phytochemical screening of plants is significant to discover and develop novel therapeutic drugs. Numerous research studies worldwide have emphasized the necessity for such evaluations. Over recent decades, there has been a growing interest in plant research, particularly in assessing antioxidant phytochemicals such as phenols, flavonoids, and tannins, due to their potential role in preventing human diseases.[71] Many indigenous or native plants serve as cost-effective and readily available sources of essential nutrients, including minerals, vitamins, hormone precursors, proteins, energy, and essential amino acids.[72]

Detoxification, Anti-aging and Immunity booster

Recent research suggests that a wide variety of plants containing antioxidant compounds have the capacity to neutralize toxins and protect the human body from the adverse effects of drugs and chemicals. Antioxidants primarily neutralize reactive species within the body, thereby preventing substrate oxidation at low concentrations. They possess stability that enables them to prevent themselves from acting as chain-propagating radicals.[73] Various factors such as smoking, unhealthy dietary habits, stress, and lifestyle changes induce oxidative stress, resulting in DNA damage. Antioxidants found in plants can mitigate oxidative damage by scavenging free radicals. For instance, extracts from both standard and genetically modified roots of *Rhaponticum carthamoides* have shown DNA repair and antioxidant properties in Chinese hamster ovary (CHO) cells under oxidative stress .[74] The methanolic fraction of *Pseudomugii furcatus, Tamarind indica, , Centella asiatica, Kocuria indica* and *Adhatoda vasica* also exhibit protective effects against DNA damage. Additionally, trans-resveratrol and p-coumaric acid extracted from the ethanolic fraction of germinated peanuts offer protection against DNA damage.[75] Curcumin, a natural antioxidant, acts as a lipophilic molecule that scavenges peroxyl radicals. Plant alkaloids inhibit NADPH oxidase activity in macrophages by lowering the mRNA levels of gp91phox.[76] Eugenol derived from *Ocimum sanctum* demonstrates 97% inhibition of cyclooxygenase activity at a concentration of 1000-microM.[77] Lipid peroxidation, which produces damaging products leading to the propagation of free radical reactions, can be mitigated by natural agents like rosmarinic acid, which can penetrate cell membranes and inhibit lipid peroxidation *in situ*.[78]

Plants represent promising reservoirs of antioxidants and anti-inflammatory compounds that hold potential for various disease management strategies. Extracts derived from therapeutic plants, along with their isolated compounds, have demonstrated efficacy in treating both acute and chronic disorders. Alkaloids, polyphenols, terpenoids, and flavonoids have been extensively investigated for their antioxidant properties and anti-inflammatory effects. Antioxidants play a crucial role as anticancer agents by scavenging free radicals, which can induce DNA damage, DNA/protein cross-links, and DNA conformational changes, which may result in cell mutations, transformations, and development of cancer.[79] Additionally, numerous studies have explored the effects of antioxidants on diabetes-related complications, revealing encouraging potential for using antioxidant-rich plants in diabetes management. In their natural form, antioxidants exhibit remarkable antibacterial properties against common microbes, without any signs of microbial resistance development, prompting further research into natural products as alternatives to synthetic antibiotics. Although antioxidants may act slowly to inhibit microbial growth, their consistent effects warrant thorough evaluation to determine the antimicrobial profile of isolated antioxidants, offering potential in combating microbial infections with minimal toxicity and risk of bacterial resistance. Certain compounds like resveratrol have been found to protect the liver from cholestasis, alcohol-related damage, and toxicity by improving lipid profiles and reducing liver fibrosis and cirrhosis.[80] Phenolic compounds offer protection against neurological and cardiovascular disorders, including dementia, Parkinson's and motor neuron disease. Supplementation with antioxidants has the potential to alleviate stress-related mental health issues and severe anxiety. Natural antioxidants have also been utilized as therapeutic agents to to delay the advancement of cataracts.[81] These antioxidants work by reducing damage caused by free radicals. Ensuring sufficient intake of antioxidant nutrients may enhance quality of life and promote longevity .[82]

Natural compounds found in plants possessing antioxidant properties have been used in skin care. Skin cells are consistently subjected to harmful free radicals produced by internal metabolic processes and external environmental factors.[83] While the skin possesses inherent defenses against free radicals, excessive production of these radicals can still compromise its natural protection mechanism.[84,85] Free radicals damage the skin by interrupting the lipid structure of sebum and directly affecting the DNA and lipids found in epidermal keratinocytes.[86] This oxidative stress triggers various pathways in keratinocytes, including the extracellular signal-regulated kinases (ERKs), mitogen-activated protein kinase (MAPK) pathways, p38 MAPK and c-Jun N terminal kinases (JNKs). Additionally, oxidative stress stimulates the expression of numerous proteolytic enzymes, leading to the degradation of collagen and melanocytes. Free radicals significantly impact skin health, with oxidative stress identified as a key mechanism in skin aging. The skin's antioxidant defense mechanism plays a crucial role in safeguarding against oxidative damage.[87-90] Plants possess a wide range of properties, including medicinal attributes for certain skin conditions and the promotion of overall skin health, largely attributable to their antioxidant effects.[91,92] The ability of plants to scavenge free radicals and exhibit antioxidant properties is associated with a range of components, including tocopherols, polyphenols, ascorbic acid, carotenoids, macromolecules such as peptides and polysaccharides and essential oil constituents.[91,93,94]

Numerous research studies have demonstrated that plants containing flavonoids, alkaloids, terpenoids, diterpenes, glycosides, tannins and other phenolic compounds exhibit potent antioxidant activity surpassing that of synthetic antioxidants, thereby aiding in protecting cells against oxidative damage induced by free radicals.[112] Free radicals and Reactive Oxygen Species such as hydroxyl radical, superoxide anion and hydrogen peroxide interact with wide range of biological substances including proteins, lipids and deoxyribonucleic acids, resulting in oxidative stress. Nevertheless, plants possess a range of antioxidants and metabolites that neutralize these free radicals, thereby aiding in safeguarding human health from various diseases.[113] Plants are increasingly recognized as readily available and potent sources of antioxidants, comprising a blend of phytochemical compounds that act individually or synergistically to treat diseases and promote health. A single plant may harbor a diverse array of phytochemicals with different beneficial effects.[114] In the UAE, many plants remain unidentified, neglected, or underutilized for their antioxidant potential. This review highlights some studies on the antioxidant activity of plants found in the UAE. These plants warrant further investigation for their antioxidant potential, including the isolation and identification of antioxidant compounds, and subsequent testing of their efficacy for drug development.

CONCLUSION

The utilization of plants for treating diseases dates to the early existence of the human species. Valuable insights gained from the widespread observation of plant usage significantly contribute to uncovering their therapeutic properties. Traditional medicine has extensively employed numerous plants to address a variety of ailments. Phytochemicals, including polyphenols, carotenoids, flavonoids, and terpenoids, exhibit diverse biological activities and health benefits, encompassing antioxidant and free radical scavenging abilities, anti-inflammatory actions, as well as protective effects against conditions such as diabetes mellitus, cardiovascular diseases, obesity, and neurodegenerative diseases. This review focuses on exploring the antioxidant activity of extracts from various medicinal plants in the UAE, an area that has remained relatively unexplored. Research investigations into these plants have identified the existence of substances like polyphenols (including alkaloids, flavonoids, terpenoids, and phenols) that exhibit antioxidant properties. These substances have the ability to engage with free radicals, thereby enhancing the equilibrium between oxidative stress and antioxidant levels. Additionally, these studies highlight variations in antioxidant activity among different plant species and plant materials used. These findings create an avenue for further investigation into the potent medicinal properties of plants in the UAE, presenting them as a valuable source for the development of novel drugs.

CONFLICTS OF INTEREST: Authors declare no conflicts of interest.

FUNDING: Authors received no specific funding for this work. APC was covered by Research and Sponsored Projects Office of United Arab Emirates University.

References

1. Auddy B, Ferreira M, Blasina F, Lafon L, Arredondo F, Dajas F, Tripathi PC, Seal T, Mukherjee B. Screening of antioxidant activity of three Indian medicinal plants, traditionally used for the management of neurodegenerative diseases. Journal of Ethnopharmacology. 2003;84(2-3):131-8. https://doi.org/10.1016/S0378-8741(02)00322-7
2. Waswa EN, Ding SX, Wambua FM, Mkala EM, Mutinda ES, Odago WO, Amenu SG, Muthui SW, Linda EL, Katumo DM, Waema CM. The genus actinidia Lindl. (Actinidiaceae): A comprehensive review on its ethnobotany, phytochemistry, and pharmacological properties. Journal of Ethnopharmacology. 2023:117222. https://doi.org/10.1016/j.jep.2023.117222 https://doi.org/10.1016/j.jep.2023.117222
3. Cathrine L, Nagarajan NP. Preliminary phytochemical analysis and antibacterial activity of leaf extracts of Vitex leucoxylon LF. International Journal of Current Pharmaceutical Research. 2011;3:71-3.
4. Schippmann U, Leaman DJ, Cunningham AB. Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues. Biodiversity and the Ecosystem Approach in Agriculture, Forestry and Fisheries. 2002 Oct 12.
5. Falodun A, Irabor EE. Phytochemical, proximate, antioxidant and free radical scavenging evaluations of Calliandria surinamensis. Acta Poloniae Pharmaceutica-Drug Research. 2008;65(5):571-5.
6. Sivakumar K, Mohandass S, Devika V. In vitro Antioxidant and free radical scavenging activity of root extracts of Uraria lagopoides. International Journal of Pharma and Biosciences. 2012;3(2):B1-9.

7. Raj J, Bala SS. Antioxidative activity and phytochemical investigation on a high altitude medicinal plant *Dracocephalum heterophyllum* Benth. Pharmacognosy Journal. 2010;2(6).
8. Kumar RS, Gupta M, Mazumdar UK, Rajeshwar Y, Kumar TS, Gomathi P, Roy R. Effects of methanol extracts of *Caesalpinia bonducella* and *Bauhinia racemosa* on hematology and hepatorenal function in mice. The Journal of Toxicological Sciences. 2005;30(4):265-74. https://doi.org/10.2131/jts.30.265
9. Prakash D, Suri S, Upadhyay G, Singh BN. Total phenol, antioxidant and free radical scavenging activities of some medicinal plants. International Journal of Food Sciences and Nutrition. 2007;58(1):18-28. https://doi.org/10.1080/09637480601093269
10. Edeoga HO, Okwu DE, Mbaebie BO. Phytochemical constituents of some Nigerian medicinal plants. African Journal of Biotechnology. 2005;4(7):685-8. 10.5897/AJB2005.000-3127
11. Veeru P, Kishor MP, Meenakshi M. Screening of medicinal plant extracts for antioxidant activity. Journal of Medicinal Plants Research. 2009;3(8):608-12. 10.1016/S0024-3205(03)00259-5
12. Zou Y, Lu Y, Wei D. Antioxidant activity of a flavonoid-rich extract of *Hypericum perforatum* L. in vitro. Journal of Agricultural and Food Chemistry. 2004;52(16):5032-9. https://doi.org/10.1021/jf049571r
13. Tharaniya M, Karthikeyan K, Sandhiya S, Shalini K, Rabiya S. Evaluating nutritional values for lemongrass (*Cymbopogon citratus*) herb tea formulation used in tea bags. Innovations in Agriculture 2023;6;e32870. https://doi.org/10.25081/ia.2023-090
14. Potter JD. Vegetables, fruit, and cancer. The Lancet. 2005;366(9485):527-30. https://doi.org/10.1016/S0140-6736(05)67077-8
15. Marete EN, Jacquier JC, O'Riordan D. Effects of extraction temperature on the phenolic and parthenolide contents, and colour of aqueous feverfew (*Tanacetum parthenium*) extracts. Food Chemistry. 2009;117(2):226-31. https://doi.org/10.1016/j.foodchem.2009.03.103
16. Zaveri NT. Green tea and its polyphenolic catechins: medicinal uses in cancer and noncancer applications. Life Sciences. 2006;78(18):2073-80. https://doi.org/10.1016/j.lfs.2005.12.006
17. Škerget M, Kotnik P, Hadolin M, Hraš AR, Simonič M, Knez Ž. Phenols, proanthocyanidins, flavones and flavonols in some plant materials and their antioxidant activities. Food Chemistry. 2005;89(2):191-8. https://doi.org/10.1016/j.foodchem.2004.02.025
18. Samatha T, Shyamsundarachary R, Srinivas P, Swamy NR. Quantification of total phenolic and total flavonoid contents in extracts of *Oroxylum indicum* L. Kurz. Asian Journal of Pharmacy and Clinical Research. 2012;5(4):177-9.
19. Yadav RN, Agarwala M. Phytochemical analysis of some medicinal plants. Journal of Phytology. 2011;3(12).
20. Mahato SB, Sen S. Advances in triterpenoid research, 1990–1994. Phytochemistry. 1997;44(7):1185-236. https://doi.org/10.1016/S0031-9422(96)00639-5
21. Pandey M, Abidi AB, Singh S, Singh RP. Nutritional evaluation of leafy vegetable paratha. Journal of Human Ecology. 2006;19(2):155-6. https://doi.org/10.1080/09709274.2006.11905871
22. Ghazanfar AS. Arabian medicinal plants. InUSA: Library of Congress cataloging in the USA 1994.
23. Sakkir S, Kabshawi M, Mehairbi M. Medicinal plants diversity and their conservation status in the United Arab Emirates (UAE). Journal of Medicinal Plants Research. 2012;6(7):1304-22. DOI: 10.5897/JMPR11.1412
24. Shahin SM, Jaleel A, Alyafei MA. Yield and in vitro antioxidant potential of essential oil from *Aerva javanica* (burm. F.) juss. Ex schul. flower with special emphasis on seasonal changes. Plants. 2021;10(12):2618. https://doi.org/10.3390/plants10122618
25. Al-Snafi AE. Pharmacological importance of *Clitoria ternatea*–A review. IOSR Journal of Pharmacy. 2016;6(3):68-83.
26. Ahmad Nejhad A, Alizadeh Behbahani B, Hojjati M, Vasiee A, Mehrnia MA. Identification of phytochemical, antioxidant, anticancer and antimicrobial potential of *Calotropis procera* leaf aqueous extract. Scientific Reports. 2023;13(1):14716. https://doi.org/10.1038/s41598-023-42086-1
27. Savadi S, Vazifedoost M, Didar Z, Nematshahi MM, Jahed E. Phytochemical analysis and antimicrobial/antioxidant activity of *Cynodon dactylon* (L.) Pers. rhizome methanolic extract. Journal of Food Quality. 2020;(1):5946541. https://doi.org/10.1155/2020/5946541
28. Alabri TH, Al Musalami AH, Hossain MA, Weli AM, Al-Riyami Q. Comparative study of phytochemical screening, antioxidant and antimicrobial capacities of fresh and dry leaves crude plant extracts of *Datura metel* L. Journal of King Saud University-Science. 2014 ;26(3):237-43. https://doi.org/10.1016/j.jksus.2013.07.002
29. Shaheen U, Shoeib NA, Temraz A, Abdelhady MI. Flavonoidal constituents, antioxidant, antimicrobial, and cytotoxic activities of Dipterygium glaucum grown in Kingdom of Saudi Arabia. Pharmacognosy Magazine. 2017 (Suppl 3):S484. 10.4103/pm.pm_44_16
30. El-Amier YA, El-Halawany EF, Soliman HM, El Hayyany LY. Primary GC-MS chemical analysis of alcoholic extract of *Emex spinosa* (L.) Campd. and screening of their antioxidant, antibacterial, and cytotoxic characteristics. Bulletin of the Chemical Society of Ethiopia. 2023;37(1):101-14. 10.4314/bcse.v37i1.9
31. Sulieman AM, Alanaizy E, Alanaizy NA, Abdallah EM, Idriss H, Salih ZA, Ibrahim NA, Ali NA, Ibrahim SE, Abd El Hakeem BS. Unveiling chemical, antioxidant and antibacterial properties of *Fagonia indica* grown in the hail mountains, Saudi Arabia. Plants. 2023;12(6):1354. https://doi.org/10.3390/plants12061354
32. Mujić I, Dudas S, Skutin HM, Perusic D, Zeković Z, Lepojević Z, Radojković M, Vidović S, Milošević S, Mesic EO. Determination of antioxidant properties of fig fruit extracts (*Ficus carica* L.). Acta Horticulturae 940: 10.17660/ActaHortic.2012.940.52
33. Ullah R, Alsaid MS, Alqahtani AS, Shahat AA, Naser AA, Mahmood HM, Ahamad SR, Al-Mishari AA, Ahmad S. Anti-inflammatory, antipyretic, analgesic, and antioxidant activities of *Haloxylon salicornicum* aqueous fraction. Open Chemistry. 2019;17(1):1034-

42. https://doi.org/10.1515/chem-2019-0113
34. Elsharkawy ER, Ed-dra A, Abdallah EM, Ali AM. Antioxidant, antimicrobial and antifeedant activity of phenolic compounds accumulated in *Hyoscyamus muticus* L. African Journal of Biotechnology. 2018;17(10):311-21.
35. Philip JP, Madhumitha G, Mary SA. Free radical scavenging and reducing power of *Lawsonia inermis* L. seeds. Asian Pacific Journal of Tropical Medicine. 2011;4(6):457-61. https://doi.org/10.1016/S1995-7645(11)60125-9
36. Yonbawi AR, Abdallah HM, Alkhilaiwi FA, Koshak AE, Heard CM. Anti-proliferative, cytotoxic and antioxidant properties of the methanolic extracts of five Saudi Arabian flora with folkloric medicinal use: *Aizoon canariense*, *Citrullus colocynthis, Maerua crassifolia, Rhazya stricta* and *Tribulus macropterus*. Plants. 2021;10(10):2073. https://doi.org/10.3390/plants10102073
37. Ullah O, Shah M, Rehman NU, Ullah S, Al-Sabahi JN, Alam T, Khan A, Khan NA, Rafiq N, Bilal S, Al-Harrasi A. Aroma profile and biological effects of *Ochradenus arabicus* essential oils: A comparative study of stem, flowers, and leaves. Molecules. 2022;27(16):5197. https://doi.org/10.3390/molecules27165197
38. Uddin MK, Juraimi AS, Ali ME, Ismail MR. Evaluation of antioxidant properties and mineral composition of purslane (*Portulaca oleracea* L.) at different growth stages. International Journal of Molecular Sciences. 2012;13(8):10257-67. https://doi.org/10.3390/ijms130810257
39. Salama SA, Al-Faifi ZE, El-Amier YA. Chemical composition of *Reichardia tingitana* methanolic extract and its potential antioxidant, antimicrobial, cytotoxic and larvicidal activity. Plants. 2022;11(15):2028. https://doi.org/10.3390/plants11152028
40. Khan TH, Ganaie MA, Siddiqui NA, Alam A, Ansari MN. Antioxidant potential of *Rumex vesicarius* L.: *In vitro* approach. Asian Pacific Journal of Tropical Biomedicine. 2014;4(7):538-44. https://doi.org/10.12980/APJTB.4.2014C1168
41. Mohamed SA, Khan JA. Antioxidant capacity of chewing stick miswak Salvadora persica. BMC Complementary and Alternative Medicine. 2013 Dec;13:1-6. https://doi.org/10.1186/1472-6882-13-40
42. Almoulah NF, Voynikov Y, Gevrenova R, Schohn H, Tzanova T, Yagi S, Thomas J, Mignard B, Ahmed AA, El Siddig MA, Spina R. Antibacterial, antiproliferative and antioxidant activity of leaf extracts of selected Solanaceae species. South African Journal of Botany. 2017;112:368-74. https://doi.org/10.1016/j.sajb.2017.06.016
43. Cheruth AJ, Al Baloushi SA, Karthishwaran K, Maqsood S, Kurup SS, Sakkir S. Medicinally active principles analysis of *Tephrosia apollinea* (Delile) DC. growing in the United Arab Emirates. BMC Research Notes. 2017 Dec;10:1-6. https://doi.org/10.1186/s13104-017-2388-0
44. Sonibare MA, Aremu OT, Okorie PN. Antioxidant and antimicrobial activities of solvent fractions of *Vernonia cinerea* (L.) Less leaf extract. African Health Sciences. 2016;16(2):629-39. 10.4314/ahs.v16i2.34
45. Halliwell B. Reactive species and antioxidants. Redox biology is a fundamental theme of aerobic life. Plant physiology. 2006;141(2):312-22. https://doi.org/10.1104/pp.106.077073
46. Boulanouar B, Abdelaziz G, Aazza S, Gago C, Miguel MG. Antioxidant activities of eight Algerian plant extracts and two essential oils. Industrial Crops and Products. 2013;46:85-96. https://doi.org/10.1016/j.indcrop.2013.01.020
47. Gonçalves S, Gomes D, Costa P, Romano A. The phenolic content and antioxidant activity of infusions from Mediterranean medicinal plants. Industrial Crops and Products. 2013;43:465-71. https://doi.org/10.1016/j.indcrop.2012.07.066
48. Borrelli GM, Trono D. Molecular approaches to genetically improve the accumulation of health-promoting secondary metabolites in staple crops—A case study: The Lipoxygenase-B1 genes and regulation of the carotenoid content in pasta products. International Journal of Molecular Sciences. 2016;17(7):1177. https://doi.org/10.3390/ijms17071177
49. Al-Jaber NA, Awaad AS, Moses JE. Review on some antioxidant plants growing in Arab world. Journal of Saudi Chemical Society. 2011;15(4):293-307. https://doi.org/10.1016/j.jscs.2011.07.004
50. Pandey KB, Rizvi SI. Plant polyphenols as dietary antioxidants in human health and disease. Oxidative medicine and cellular longevity. 2009;2(5):270-8. https://doi.org/10.4161/oxim.2.5.9498
51. Bourgaud F, Gravot A, Milesi S, Gontier E. Production of plant secondary metabolites: a historical perspective. Plant science. 2001;161(5):839-51. https://doi.org/10.1016/S0168-9452(01)00490-3
52. Poulose SM, Miller MG, Shukitt-Hale B. Role of walnuts in maintaining brain health with age. The Journal of nutrition. 2014;144(4):561S-6S. https://doi.org/10.3945/jn.113.184838
53. Sung J, Lee J. Antioxidant and antiproliferative activities of grape seeds from different cultivars. Food Science and Biotechnology. 2010;19:321-6. https://doi.org/10.1007/s10068-010-0046-6
54. Dahlén EM, Tengblad A, Länne T, Clinchy B, Ernerudh J, Nystrom FH, Östgren CJ. Abdominal obesity and low-grade systemic inflammation as markers of subclinical organ damage in type 2 diabetes. Diabetes & metabolism. 2014;40(1):76-81. https://doi.org/10.1016/j.diabet.2013.10.006
55. Steinberg GR, Schertzer JD. AMPK promotes macrophage fatty acid oxidative metabolism to mitigate inflammation: implications for diabetes and cardiovascular disease. Immunology and cell biology. 2014;92(4):340-5. https://doi.org/10.1038/icb.2014.11
56. Hutchins-Wolfbrandt A, Mistry AM. Dietary turmeric potentially reduces the risk of cancer. Asian Pacafic Journal of Cancer Prevention. 2011;12(12):3169-73.
57. Costa AG, Garcia-Diaz DF, Jimenez P, Silva PI. Bioactive compounds and health benefits of exotic tropical red–black berries. Journal of Functional Foods. 2013;5(2):539-49. https://doi.org/10.1016/j.jff.2013.01.029
58. Wu S, Li S, Xu XR, Deng GF, Li F, Zhou J, Li HB. Sources and bioactivities of astaxanthin. Int. J. Mod. Biol. Med. 2012;1:96-107.
59. Deng GF, Xu XR, Li S, Li F, Xia EQ, Li HB. Natural sources and bioactivities of resveratrol. International Journal of Modern

Biological Medicine. 2012;1:1-20.
60. Weberling A, Boehm V, Froehlich K. Nutraceuticals-The relation between lycopene, tomato products and cardiovascular diseases. Agro Food Industry Hi Tech. 2011;22(4):21.
61. Gajendragadkar PR, Hubsch A, Mäki-Petäjä KM, Serg M, Wilkinson IB, Cheriyan J. Effects of oral lycopene supplementation on vascular function in patients with cardiovascular disease and healthy volunteers: a randomised controlled trial. PloS one. 2014;9(6):e99070. https://doi.org/10.1371/journal.pone.0099070
62. Elango P, Asmathulla S. A Systematic Review on Lycopene and its Beneficial Effects". Biomedical and Pharmacology Journal. 2017;10(4):2113-20. https://dx.doi.org/10.13005/bpj/1335
63. Chan JY, Yuen AC, Chan RY, Chan SW. A review of the cardiovascular benefits and antioxidant properties of allicin. Phytotherapy research. 2013;27(5):637-46. https://doi.org/10.1002/ptr.4796
64. Ojha LK, Tüzün B, Bhawsar J. Experimental and theoretical study of effect of allium sativum extracts as corrosion inhibitor on mild steel in 1 M HCl medium. Journal of bio-and tribo-corrosion. 2020;6:1-0. https://doi.org/10.1007/s40735-020-00336-z
65. Perez-Vizcaino F, Duarte J, Jimenez R, Santos-Buelga C, Osuna A. Antihypertensive effects of the flavonoid quercetin. Pharmacological Reports. 2009;61(1):67-75. https://doi.org/10.1016/S1734-1140(09)70008-8
66. McKay TB, Lyon D, Sarker-Nag A, Priyadarsini S, Asara JM, Karamichos D. Quercetin attenuates lactate production and extracellular matrix secretion in keratoconus. Scientific reports. 2015;5(1):9003. https://doi.org/10.1038/srep09003
67. Sung MK, Park MY. Nutritional modulators of ulcerative colitis: clinical efficacies and mechanistic view. World journal of gastroenterology: WJG. 2013;19(7):994. 10.3748/wjg.v19.i7.994
68. Nantasenamat C, Simeon S, Hafeez A, Prachayasittikul V, Worachartcheewan A, Songtawee N, Srungboonmee K, Isarankura-Na-Ayudhya C, Prachayasittikul S, Prachayasittikul V. Elucidating the structure-activity relationship of curcumin and its biological activities. Curcumin: Synthesis, Emerging Role in Pain Management and Health Implications; Pouliquen, DL, Ed. 2014:49-86.
69. Cassidy A, O'Reilly ÉJ, Kay C, Sampson L, Franz M, Forman JP, Curhan G, Rimm EB. Habitual intake of flavonoid subclasses and incident hypertension in adults. The American Journal of Clinical Nutrition. 2011;93(2):338-47. https://doi.org/10.3945/ajcn.110.006783
70. Araki R, Yada A, Ueda H, Tominaga K, Isoda H. Differences in the effects of anthocyanin supplementation on glucose and lipid metabolism according to the structure of the main anthocyanin: A meta-analysis of randomized controlled trials. Nutrients. 2021;13(6):2003. https://doi.org/10.3390/nu13062003
71. Upadhyay NK, Kumar MY, Gupta A. Antioxidant, cytoprotective and antibacterial effects of Sea buckthorn (*Hippophae rhamnoides* L.) leaves. Food and Chemical Toxicology. 2010;48(12):3443-8. https://doi.org/10.1016/j.fct.2010.09.019
72. Amaechi NC. Nutritive and anti-nutritive evaluation of wonderful kola (*Buccholzia coricea*) seeds. Pakistan Journal of Nutrition. 2009;8(8):1120-2.
73. Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy Reviews. 2010;4(8):118. 10.4103/0973-7847.70902
74. Sharifi-Rad M, Anil Kumar NV, Zucca P, Varoni EM, Dini L, Panzarini E, Rajkovic J, Tsouh Fokou PV, Azzini E, Peluso I, Prakash Mishra A. Lifestyle, oxidative stress, and antioxidants: back and forth in the pathophysiology of chronic diseases. Frontiers in Physiology. 2020;11:694. 10.3389/fphys.2020.00694
75. Sandesh P, Velu V, Singh RP. Antioxidant activities of tamarind (*Tamarindus indica*) seed coat extracts using in vitro and in vivo models. Journal of food Science and Technology. 2014;51:1965-73. 10.1007/s13197-013-1210-9
76. Chaudhary P, Janmeda P, Docea AO, Yeskaliyeva B, Abdull Razis AF, Modu B, Calina D, Sharifi-Rad J. Oxidative stress, free radicals and antioxidants: Potential crosstalk in the pathophysiology of human diseases. Frontiers in Chemistry. 2023;11:1158198. 10.3389/fchem.2023.1158198
77. Kelm MA, Nair MG, Strasburg GM, DeWitt DL. Antioxidant and cyclooxygenase inhibitory phenolic compounds from *Ocimum sanctum* Linn. Phytomedicine. 2000;7(1):7-13. 10.1016/S0944-7113(00)80015-X
78. Nam TG. Lipid peroxidation and its toxicological implications. Toxicological research. 2011 Mar;27(1):1-6.
79. Messenlehner J, Hetman M, Tripp A, Wallner S, Macheroux P, Gruber K, Daniel B. The catalytic machinery of the FAD-dependent AtBBE-like protein 15 for alcohol oxidation: Y193 and Y479 form a catalytic base, Q438 and R292 an alkoxide binding site. Archives of Biochemistry and Biophysics. 2021;700:108766. https://doi.org/10.1016/j.abb.2021.108766
80. Naqvi SA, Nadeem S, Komal S, Naqvi SA, Mubarik MS, Qureshi SY, Ahmad S, Abbas A, Zahid M, Raza SS, Aslam N. Antioxidants: natural antibiotics. In: Antioxidants 2019. IntechOpen.
81. Neha K, Haider MR, Pathak A, Yar MS. Medicinal prospects of antioxidants: A review. European Journal of Medicinal Chemistry. 2019;178:687-704. https://doi.org/10.1016/j.ejmech.2019.06.010
82. Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy Reviews. 2010;4(8):118. 10.4103/0973-7847.70902
83. Godic A, Poljšak B, Adamic M, Dahmane R. The role of antioxidants in skin cancer prevention and treatment. Oxidative medicine and cellular longevity. 2014;2014(1):860479. https://doi.org/10.1155/2014/860479
84. Masaki H. Role of antioxidants in the skin: anti-aging effects. Journal of Dermatological Science. 2010;58(2):85-90. https://doi.org/10.1016/j.jdermsci.2010.03.003
85. Nichols JA, Katiyar SK. Skin photoprotection by natural polyphenols: anti-inflammatory, antioxidant and DNA repair mechanisms.

Archives of Dermatological Research. 2010;302:71-83. https://doi.org/10.1007/s00403-009-1001-3
86. Nakai K, Tsuruta D. What are reactive oxygen species, free radicals, and oxidative stress in skin diseases?. International Journal of Molecular Sciences. 2021;22(19):10799. https://doi.org/10.3390/ijms221910799
87. Godic A, Poljšak B, Adamic M, Dahmane R. The role of antioxidants in skin cancer prevention and treatment. Oxidative medicine and cellular longevity. 2014;(1):860479. https://doi.org/10.1155/2014/860479
88. Wölfle U, Seelinger G, Bauer G, Meinke MC, Lademann J, Schempp CM. Reactive molecule species and antioxidative mechanisms in normal skin and skin aging. Skin Pharmacology and Physiology. 2014;27(6):316-32. https://doi.org/10.1159/000360092
89. Pai VV, Shukla P, Kikkeri NN. Antioxidants in dermatology. Indian Dermatology Online Journal. 2014;5(2):210-4. 10.4103/2229-5178.131127
90. Shindo Y, Witt E, Han D, Epstein W, Packer L. Enzymic and non-enzymic antioxidants in epidermis and dermis of human skin. Journal of Investigative Dermatology. 1994;102(1):122-4. https://doi.org/10.1111/1523-1747.ep12371744
91. Jadoon S, Karim S, Asad MH, Akram MR, Kalsoom Khan A, Malik A, Chen C, Murtaza G. Anti-aging potential of phytoextract loaded-pharmaceutical creams for human skin cell longetivity. Oxidative Medicine and Cellular Longevity. 2015;(1):709628. https://doi.org/10.1155/2015/709628
92. Menaa, F. Skin anti-aging benefits of phytoterapeutics-based emulsions. Pharmaceutica Analytica Acta. 2014;5;168.
93. Nichols JA, Katiyar SK. Skin photoprotection by natural polyphenols: anti-inflammatory, antioxidant and DNA repair mechanisms. Archives of dermatological research. 2010 Mar;302:71-83. https://doi.org/10.1007/s00403-009-1001-3
94. Song R, Wu Q, Yun Z, Zhao L. Advances in antioxidative bioactive macromolecules. In: IOP Conference Series: Earth and Environmental Science 2020;512;p. 012094). 10.1088/1755-1315/512/1/012094
95. Chen J, Liu Y, Zhao Z, Qiu J. Oxidative stress in the skin: Impact and related protection. International Journal of Cosmetic Science. 2021;43(5):495-509. https://doi.org/10.1111/ics.12728
96. Jain PK, Kharya MD, Gajbhiye A, Sara UV, Sharma VK. Flavonoids as nutraceuticals. A review. Herba Polonica. 2010;56(2).
97. Zillich OV, Schweiggert-Weisz U, Eisner P, Kerscher M. Polyphenols as active ingredients for cosmetic products. International Journal of Cosmetic Science. 2015;37(5):455-64. https://doi.org/10.1111/ics.12218
98. Gülçin İ. Antioxidant properties of resveratrol: A structure–activity insight. Innovative Food Science & Emerging Technologies. 2010;11(1):210-8. https://doi.org/10.1016/j.ifset.2009.07.002
99. Sieniawska E. Activities of tannins–from in vitro studies to clinical trials. Natural Product Communications. 2015;10(11):1934578X1501001118. https://doi.org/10.1177/1934578X1501001118
100. Malinowska P. Effect of flavonoids content on antioxidant activity of commercial cosmetic plant extracts. Herba Polonica. 2013;59(3):63-75. 10.2478/hepo-2013-0017
101. Tsao R. Chemistry and biochemistry of dietary polyphenols. Nutrients. 2010;2(12):1231-46. https://doi.org/10.3390/nu2121231
102. Chin YT, Cheng GY, Shih YJ, Lin CY, Lin SJ, Lai HY, Whang-Peng J, Chiu HC, Lee SY, Fu E, Tang HY. Therapeutic applications of resveratrol and its derivatives on periodontitis. Annals of the New York Academy of Sciences. 2017;1403(1):101-8. https://doi.org/10.1111/nyas.13433
103. Faghihzadeh F, Hekmatdoost A, Adibi P. Resveratrol and liver: A systematic review. Journal of research in medical sciences. 2015;20(8):797-810. 10.4103/1735-1995.168405
104. Kim JH, Kang MJ, Choi HN, Jeong SM, Lee YM, Kim JI. Quercetin attenuates fasting and postprandial hyperglycemia in animal models of diabetes mellitus. Nutrition Research and Practice. 2011;5(2):107. 10.4162/nrp.2011.5.2.107
105. Trujillo J, Chirino YI, Molina-Jijón E, Andérica-Romero AC, Tapia E, Pedraza-Chaverrí J. Renoprotective effect of the antioxidant curcumin: Recent findings. Redox Biology. 2013;1(1):448-56. https://doi.org/10.1016/j.redox.2013.09.003
106. Usharani P, Mateen AA, Naidu MU, Raju YS, Chandra N. Effect of NCB-02, atorvastatin and placebo on endothelial function, oxidative stress and inflammatory markers in patients with type 2 diabetes mellitus: a randomized, parallel-group, placebo-controlled, 8-week study. Drugs in R & D. 2008;9:243-50. https://doi.org/10.2165/00126839-200809040-00004
107. Lao CD, Ruffin MT, Normolle D, Heath DD, Murray SI, Bailey JM, Boggs ME, Crowell J, Rock CL, Brenner DE. Dose escalation of a curcuminoid formulation. BMC complementary and alternative medicine. 2006 Dec;6(1):10. https://doi.org/10.1186/1472-6882-6-10
108. Gómez-Zorita S, González-Arceo M, Fernández-Quintela A, Eseberri I, Trepiana J, Portillo MP. Scientific evidence supporting the beneficial effects of isoflavones on human health. Nutrients. 2020;12(12):3853. https://doi.org/10.3390/nu12123853
109. Bahonar A, Saadatnia M, Khorvash F, Maracy M, Khosravi A. Carotenoids as potential antioxidant agents in stroke prevention: a systematic review. International journal of preventive medicine. 2017;8. 10.4103/ijpvm.IJPVM_112_17
110. Khanna S, Jaiswal KS, Gupta B. Managing rheumatoid arthritis with dietary interventions. Frontiers in Nutrition. 2017 Nov 8;4:52. https://doi.org/10.3389/fnut.2017.00052
111. George BP, Chandran R, Abrahamse H. Role of phytochemicals in cancer chemoprevention: Insights. Antioxidants. 2021;10(9):1455. https://doi.org/10.3390/antiox10091455
112. Krishnaiah D, Sarbatly R, Nithyanandam R. A review of the antioxidant potential of medicinal plant species. Food and bioproducts processing. 2011;89(3):217-33. https://doi.org/10.1016/j.fbp.2010.04.008
113. Gutteridge JM. Role of free radicals and catalytic metal ions in human disease: an overview. Methods in Enzymology.

1990;186:1-85. 10.1016/0076-6879(90)86093-b
114. Miguel MG. Antioxidant activity of medicinal and aromatic plants. A review. Flavour and Fragrance Journal. 2010;25(5):291-312. https://doi.org/10.1002/ffj.1961