IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876
 Journal UGC CARE Listed (Group-I) Volume 11, Iss 12, Dec 2022

Therapeutic Potential of Natural Antioxidants from Medicinal Plants: A Comprehensive Review

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Abstract

Oxidative stress, resulting from an imbalance between free radicals and antioxidants in the body, is a critical factor in the pathogenesis of various chronic diseases such as cancer, cardiovascular ailments, diabetes, and neurodegenerative disorders. In recent years, medicinal plants have garnered significant attention as a rich source of natural antioxidants, owing to their diverse phytochemical constituents, including flavonoids, phenolic acids, tannins, tocopherols, carotenoids, and alkaloids. These bioactive compounds play a crucial role in neutralizing reactive oxygen species (ROS), thereby offering protective effects against oxidative cellular damage. This review explores the antioxidant potential of various medicinal plants and highlights the mechanisms by which plant-derived compounds mitigate oxidative stress. Additionally, the limitations of synthetic antioxidants—such as their toxicity and carcinogenic potential—underscore the necessity for safer, natural alternatives. The therapeutic implications of plant-based antioxidants are also discussed, particularly their roles in anti-inflammatory, anti-carcinogenic, antimicrobial, and antidiabetic applications. This comprehensive overview reinforces the relevance of phytochemicals in developing safe, effective and economically viable antioxidant therapies from plant origins.

Introduction

Numerous agricultural and food products, such as grains, fruits, vegetables and oil seeds, have been found to contain antioxidants. Since antioxidants directly combat oxidative processes, they are increasingly advocated to prevent illnesses and other age-related health issues (Aguire and Borneo, 2010). Since dietary and natural antioxidants are safer than their manufactured analogues, the food industry is working hard to identify novel sources of low-cost, safe antioxidants of plant origin (Rechc Cho et al., 2011).

According to Deckkers et al. (1996), an antioxidant is any agent that slows down or stops deterioration, damage, or destruction brought on by oxidation. One antioxidant molecule can interact with a single free radical and neutralize it by donating one of its own electronsthus defending against excessive free radical damage to cells and tissues.

Antioxidants in medicinal plants

Natural antioxidants like flavonoids, tocopherols, folic acid, carotenoids, ascorbic acid, cinnamic acid, benzoic acid, tocotrienols, etc. are abundant in plants and are produced for their survival. The most often used antioxidants are -carotene, ascorbic acid, and alpha tocopherol

(Mc Call and Frei, 1999). Interacting with free radicalsand catalytic metals, oxygen scavengers can obstruct the oxidation process (Buyukokuroglu *et al.,*2001).The oxidation process has been stopped using a variety of synthetic antioxidants, including butylated hydroxyl anisole (BHA) and butylated hydroxy toluene (BHT). However, rigorous guidelines must be followed while applying synthetic antioxidants because of the possible health risks they pose (Park et al., 2001). The biggest drawback of synthetic antioxidants is that they can cause cancer when consumed in vivo (Chen *et al.,*1992).Therefore, the search for natural antioxidants is a source of alternate interest to scientists. Vitamins, terpenoids, phenolics, lignins, tannins, flavonoids, quinones, coumarins, alkaloids, amines and other compounds that scavenge free radicals are abundant in plants and have antioxidant action (Zheng and Wang, 2001; Cai *et al.,*2003). Numerous anti-inflammatory, anti-atherosclerotic, anti-tumor, anti-mutagenic, anti-carcinogenic, anti-diabetic, anti-bacterial, and anti-viral properties of these antioxidant compounds have been highlighted in studies (Rice- Evans *et al.,*1995; Sala *et al.,*2002).

The therapeutic potentials of medicinal plants as antioxidants in preventing tissue damage caused by free radicals are currently generating considerable interest. Additionally, in the quest for novel antioxidants from plant origin, well-known and conventionally utilized natural antioxidants from tea, wine, fruits, vegetables, spices, and many other plant species have been examined (Koleva *et al.,*2002). Using the 2, 2, diphenyl picryl hydrazyl radical, 22 medicinal herbs from Nigeria were isolated and tested for antioxidant activity (Oke and Hamburger, 2002). Popular chemicals linked to antioxidant activity in plants include flavones, flavonols, and pro anthocyanidins (Skerget *et al.,*2005). Phenolics can be split into two classes viz. Phenolic acids present in polyphenolics and simple phenols. According to Marinova *et al.,* (2005), polyphenol, phenolic acid, flavonoid, and vitamin C all contribute to the antioxidant capabilities of plants.

The pigmentary properties of flavonoids are what give flowers, fruits, and even leaves their color. In addition to their roles in regulating plant development and disease resistance, flavonoids also have antioxidant and antimutagenic properties. Flavonoids also shield plants from UV ray damage (Gurib-Fakim, 2006).The leaves and stems of the Rubiaceae plant *Gallium aparine*has tannins, phenolic acids, flavonoids, and iridoid glycosides (Vanwyk and Wink, 2004). The antioxidant properties of plants are attributed to flavonoids, phenols, tannins, and terpenoids (Rice Evans, 2004; Aderogba *et al.,*2005; Basile *et al.,*2005). Fruits, vegetables, wine, tea, chocolate, and other goods made from cocoa all include natural chemicals called flavonoids (Sies *et al.,*2005).The epidemiologic data on the health effects of polyphenols, which focused on the flavonoids subclasses of flavonols, flavones, and catechins and on lignans, revealed that both flavonoids and lignans have beneficial effects on cardiovascular diseases. *Chrysanthemum morifolium* has a novel substance called Dicaffeoylquinic acid that Kim and Lee (2005) discovered to have antioxidant properties. According to Aqil *et al.,* (2006)'s investigation on 12 traditionally used Indian medicinal herbs, they have antioxidant properties since they contain phytochemicals.

Polyphenols are one of the most diverse classes of compounds found in plants, ranging from basic molecules like phenolic acids to complex compounds like tannins(Li et al., 2006). Additionally, because of their antioxidant capabilities, it has the ability to trap and scavenge free radicals. When albino rats were under restraint stress, Thangaraj *et al.,* (2007) investigated the antioxidant properties of *Emblica officinalis*. Implementation of *E. officinalis* (500 mg kg-1 body weight for 30 days) considerably reduces the rise in LPO and corticosterone levels and the stress-related oxidative stress, which may be attributed to the plant's potent antioxidant properties.

According to studies (Maisuthisakul *et al.,*2007), phenolic chemicals and their derivatives have a strong correlation with antioxidant activity, and plants with high antioxidant activity also have high total phenolic and flavonoid contents. Vaijanathappa *et al.*(2008) reported in vitro antioxidant activity in *Enicostemmaaxillare* with IC_{50} values ranging from 13.26 to 24.36 g ml-1. Using the deoxyribose and lipid peroxidation techniques, the chloroform extract has demonstrated strong antioxidant activity against H_2O_2, nitric oxide, and hydroxyl radical, with IC_{50} values of 16.99 0.38, 60.66 0.30, 25.06 0.12, and 94.66 2.40 g/ml, respectively.

Psidium guajava, *Mangifera indica*, *Carica papaya*, *Vernonia amygdalina*, and vitamin C were found to have IC_{50} values of 0.04 mg ml-1, 0.313 mg ml-1, 0.58 mg ml-1, 2.30 mg ml-1, and 0.054 mg ml-1, respectively, for 50% inhibition of DPPH radical scavenging effect. By using a technique to inhibit lipid peroxidation, Kumar *et al.,* (2008) reported the antioxidant activity of five medicinal plants: *Albizia amara, Achyranthes aspera, Cassia fistula, Cassia auriculata*, and *Datura stramonium*. The antioxidant activity of *A. amara* was nearly four times stronger than that of the synthetic antioxidant BHT. *A. amara* could be used to create pharmaceutical formulations. Four Indian medicinal plants' methanolic extracts have been tested for their capacity to scavenge free radicals. *Hemidesmus indicus* (Stem), *Acorus calamus* (Rhizome), *Plumbago zeylanica* (Root), and *Holarrhenaantidysenterica* (Bark) all showed drop in 1, 1-diphenyl-2-picryl hydrazyl radical (DPPH) standard solution (Zahin, 2009).

Patil *et al.,* (2009) studied the antioxidant activity of methanolic extract of stem bark of *Gmelina arbora* and discovered that it has strong free radical scavenging activities and a close association between the antioxidant activity and phenolic content. Erasto and Mbwambo (2009) assessed the antioxidant effects of fresh and dried fruits from *Lagenaria siceraria*, and the findings showed that the fresh fruit's ethyl acetate extract had stronger DPPH radical scavenging activities than other samples. Different *Ficus religiosa* extracts showed free radical scavenging activity (Kirana et al., 2009; Pandit *et al.,*2010; Krishanti *et al.,*2010). By using the DPPH technique to assess antioxidant activity, *Vitex negundo* leaves revealed a 23.21 mg/100 g Ascorbic acid Equivalent Antioxidant Capacity (AEAC) (Praveenkumar *et al.,*2010). According to comparative research by Upadhyay (2008), Kigelia stem extract had the highest level of radical scavenging activity, followed by Gemelia and Hibiscus leaf extracts. All of the cultivars and fruit tissues of *Malus domestica* that were examined showed a strong association between total phenolic content and antioxidant capacity, with the exception of the pulp (Henriquez *et al.,*2010).

Senthilkumar and Vijayakumari (2012) observed that the ethanolic extract of *Cassia auriculata* leaves had IC_{50} values for DPPH, nitric oxide, superoxide, and hydroxyl radical scavenging activities of 49.45, 125.31, 247.52, and 142.04g ml^{-1}. respectively. According to Rupeshkumar *et al.,* (2012), measurements of the antioxidant levels in rat liver tissues revealed that *Cardiospermum halicacabum*flavonone (5 and 10 mg kg^{-1}p.o) demonstrated a great antioxidant activity.

In vitro assays using DPPH, nitric oxide, and hydroxyl radicals revealed considerable antioxidant activity in stem bark from *Tamarindus indica* and *Cassia fistula* (Agnihotri and Singh, 2013). Soni and Sosa (2013) investigated the antioxidant activity of methanolic extract of dried leaves of*Ocimum sanctum, Mentha spicata, Trigonella foenum-graecum*, and *Spinacia oleracea*. The study found that the *Mentha spicata* crude extract's IC_{50} value for DPPH activity was 170 g ml^{-1}, and its reducing power was maximal (1.92) at 1 mg ml-1 concentration. The findings suggested that *Mentha spicata* has promising antioxidant activity and might be used as a

natural antioxidant source. Thus, the studies reveal plants as a strong source of antioxidants that may be beneficial to humans to protect from diseases.

Conclusion

The rising prevalence of oxidative stress-related disorders has intensified the search for effective and safe antioxidants. Medicinal plants, rich in naturally occurring phytochemicals such as flavonoids, phenolics, tannins, and tocopherols, offer a promising alternative to synthetic antioxidants, which are often associated with adverse health effects. Extensive evidence supports the antioxidant, anti-inflammatory, antimicrobial, and therapeutic potential of these plant-derived compounds in combating free radical-induced cellular damage. The growing recognition of the health benefits and safety of natural antioxidants emphasizes the importance of continued research into phytochemical-rich medicinal plants. This not only aids in understanding their mechanisms of action but also paves the way for the development of novel plant-based antioxidant therapies that are both biologically effective and environmentally sustainable.

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