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Antioxidant, phytochemical, and therapeutic properties of medicinal plants

Sagar Appasaheb Sangle[1*], Dr. Anuj Bhadauriya[2]

[1] Research Scholar, Shri Krishna University,Chhatarpur M.P.

[2] Professor, Shri Krishna University,Chhatarpur M.P.

ABSTRACT

Oxidation is an integral part of aerobic processes of life. It involves the transfer of electrons or hydrogen via a chemical reaction from a substance to an oxidizing agent leading to the production of free radicals. These free radicals which are highly reactive in turn initiate a chain of reactions that lead to cellular damage. The etiology of plethora diseases has been linked to the generation of free radicals beyond the body's antioxidant capacity, leading to oxidative stress. Consequently, the focus of research has tilted toward plants which provide natural products rich in antioxidants capable of scavenging and distrupting the harmful effects of these free radicals. A large group of compounds produced by plants referred to as phytochemicals possessing high antioxidant properties have been seen to be helpful in tackling numerous diseases. This review covered the antioxidant potential of some plants with medicinal properties beneficial to people, industries, and health institutions who desire their potential benefits. A total of two hundred and fifty plants from the following families; Asteraceae, Combretaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Moraceae and Malvaceae were reviewed. These plants exert important biological properties, such as anti-inflammatory, antioxidant, immunomodulatory, anticancer, and antimicrobial properties, among others.

KEYWORDS: Antioxidant activity ,phytochemicals medicinal plants ,free radicals antioxidant mechanisams

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Introduction

Over the years, humans have been faced with various diseases, discomfort and struggles to antagonize it with various approaches Amongst the numerous approaches employed in combatting ailments is the use of medicinal plants for the treatment of various diseases. Despite the development of various major therapies, the tilt toward herbal medicine is gaining momentum due to the rising concerns of the increasing toxicities associated with main line therapies. In recent times, the use of medicinal plants is considered as a complementary and alternative therapies in combination with other treatments.

These diseases are mostly linked to the production of free radicals. Free radicals are an essential part of aerobic life and metabolism. They are highly indispensable to any biochemical process and are implicated in the etiology of many diseases such as cancer, Alzheimer's disease, Parkinson's disease, inflammatory disease, lipid peroxidation, DNA damage, celiac disease,stroke,[Citation16] cardiovascular disease, protein oxidation, and diabetes.

Antioxidants protect cells from damage caused by free radicals. Antioxidants have been shown to slow down or prevent the oxidation of other molecules. They possess the ability to terminate chain reactions and inhibit oxidation reactions via the removal of radical intermediates and by becoming oxidized themselves, The body system is rich with substances that have the ability stop free radicals formation or limit their damage. These antioxidants can be sourced internally and externally. Internally made antioxidants are generated via the activity of body enzymes which includes superoxide dismutase (SOD), catalase (Cat) and Glutathione peroxidize. In contrast, they are sourced externally from foods

containing vitamins A, E (alpha tocopherol), C (ascorbic acid), minerals and polyphenols which are predominantly plant based.

Plants contain numerous antioxidants which help to confer protection against free radicals associated diseases. The antioxidant compounds are mostly produced in plants in the form of secondary metabolites. Phytochemicals can be literally referred to as 'plant-chemicals.' They are the non-nutritive chemical components of plants that possess numerous health benefits and disease prevention properties. The nutrients they contain are non-essential, i.e, they are not required by the body for sustaining life. These chemicals are produced by plants to sustain life which in turn confer health benefits to humans upon consumption. There are over a thousand known phytochemicals classified as primary or secondary constituents based on their role in plant metabolism.

Phytochemicals classified as primary constituents includes the common sugars, amino acids, chlorophyll's, purines and pyrimidines of nucleic acids and proteins etc. Others classified as the secondary constituents are the chemicals consisting of alkaloids, flavonoids, terpenes, phenolics, lignans, plant steroids, curcumines, saponins, glucosides.Of these secondary constituents, phenolics are seen to be the most numerous consisting of 45% of the secondary phytochemical constituents of plants, terpenoids and steroids 27%, alkaloids 18% and others 10%.Phytochemicals possess nutraceutical importance. They are the bioactive constituents that maintain health and serve as a bridge between the food and pharmaceutical industries. Phytochemicals perform numerous functions. They possess unique pharmacological effects such as anti-inflammatory, antiplasmodic, anti-allergic, antioxidants, antibacterial, antifungals, chemopreventive, neuroprotective, hypotensive, antiaging, etc.They stimulate the immune system, block the formation of carcinogens, reduce oxidation, slow the growth rate of cancer cells, reduce inflammation, trigger apoptosis, prevent DNA damage, regulate hormones such as estrogen and inulin which excess levels are linked with increased risk of breast and colon cancer.

Polyphenols are major dietary phenolics comprising the polyphenols (hydrolysable and condensed tannins), phenolic acids (hydroxybenzoic and hydroxycinnamic acids) and flavonoids. Flavonoids are the most extensively studied group of polyphenols. The major dietary sources of polyphenols are legumes (pulses and beans), cereals (corn, barley, oats, sorghum, rice and wheat), nuts, oilseeds (rapseed, flaxseed, olive seeds and canola) beverages (fruit juices, tea, coffee, beer, wine and cocoa), fruits and vegetables. The subclasses of phenols include flavones, flavanols and minor flavonoids (flavanones and dihydroflavonols). They exhibit their antioxidant potentials by preventing the decomposition of hydroperoxide into free radicals and by inactivating free radicals. Flavonoids play important roles in preventing diseases associated with oxidative stress. It has the capacity to transport electrons to free radicals, inhibit oxidases, reduce radicals of alpha tocopherol, activate antioxidant enzymes and chelate metals.[Citation45] They help to block angiotensin converting enzyme (ACE) that raises blood pressure. They have also been found to block enzymens that produce estrogen implicated in breast cancer and inhibit cyclooxygenase which has been known to form prostaglandins.

Numerous methods can be applied in determining the antioxidant activities and capacities of various plants. These methods are broadly divided into two major categories; invitro and invivo.[Citation43] The invitro methods involves all assays carried out outside the living organism. They spectrophotometrically measure the reaction of antioxidants with chromogenic radicals such as 2,2′-azino-bis-3-ethylbenzotiazolin-6-sulfonic acid (ABTS+), 2,2′-diphenyl-1-picrylhydrazyl (DPPH) or its ability to reduce iron from +3 to +2 oxidations states (FRAP).[Citation46] In addition, scientific literature has witnessed a growing number of publications on the evaluation of the efficacy of medicinal plants which have made important contribution to the maintenance of health via numerous mechanisms. Despite this applaudible advancement, there still exist a paucity of information on the updated comprehensive compilation of promising medicinal plants from different flora.[Citation46,Citation47]

The overall aim of this study was to comprehensively highlight the importance, uses, phytochemical content, isolated antioxidant compounds, antioxidant content (total phenol and total flavonoid contents) and the antioxidant activities (DPPH, FRAP) of selected medicinal plants with the aim of their short term or long-term development into future phytopharmaceuticals for the treatment or management of a wide range of diseases. Many medicinal plants Amaranthus hybridus L., Anarcadium occidentale L., Allium sativum, Vernonia amygdalina, Mangifera indica, Mondora myristica, Uvaria chamae, Xylopia aethiopica, Newbouldia laevia, Garcinia kola, Telifaira occidentalis, Carica papaya, Mucuna

puriens, Ocimum gratissium, Thymus vulgaris, Rhizophora mangle, Zingiber officinale, Solanium aethiopicum L., Mentha arvensis, Anisopus mannii, were considered.

Medicinal plants with antioxidant potential

provide information on medicinal plants with antioxidant potential. Several reports have linked free radicals to the occurrence of several ailments like diabetes, cancer, cardiovascular and neurological diseases. Antioxidants, on the other hand, have the capacity to quench these free radicals sourced both exogenously and endogenously. Plants are naturally endowed with antioxidant and radical scavenging properties.There are several plant constituents that protect the cells from damage caused by free radicals. Plants with medicinal importance and antioxidants properties mainly have phenols and flavonoids as their main constituents. These constituents have the ability to scavenge these free radicals due to their structures

Amaranthus hybridus (Linn.)

Amaranthus hybridus (Linn.) is commonly known as spinach which is used majorly as a part of diet which could be consumed raw or cooked. It contains diverse medicinal and nutritional properties. These properties includes antidiabetic, anti-microbial, gastroprotective, anti-inflammatory, anti-malarial, antinoceceptive, cardioprotective, hepatoprotective and antioxidant effects. The antioxidant profile of this plant showed that the whole plant, leaf and seed parts of Amaranthus hybridus possesses high antioxidant activities. The total flavonoid content of the methanol extract of the leaf is 18.40 mg QE. The total phenol content of the methanol extract of the leaf (40.01 mg GAE/g DM) is higher than the seed (31.20 mg GAE/g DM). The aqueous extract of the whole plant exhibits highest DPPH scavenging activity, followed by the methanol extract of the leaf (83.45 µg/ml), hydroacetone extract (56.02 µg/ml) and Aqueous extract (42.31 µg/ml). The Ferric reducing power activity of the various leaf extracts is highest in the hydroacetone extract (257.31 µg/ml) followed by the aqueous extract (245.16 µg/ml) then the methanol extract (232.01 µg/ml). Its high DPPH and FRAP activities could be as a result of its flavonoid and phenol contents amongst other phytochemicals such as phlobatannins, saponins, tannins, terpenoids, triterpernoids, courmarins, resins and balsam. Other antioxidants present include quercetin (flavonol), rutin, myricetin, betalains in the plant

Anarcadium occidentale

Anarcadium occidentale L.is a member of the Anacardiaceae. This medicinal plant has a wide variety of biological activities ranging from anti-viral, anti-bacterial, anti-fungal and anti-inflammatory activities. The antioxidant profile of this plant showed that the leaf and stem bark possess antioxidant properties. The total phenol content is highest in its methanol extract of the stem bark (660.52 mg GAE/g DM), the cashew nut (611.13 mg GAE/g DM) and the leaf (604.85 mg GAE/g DM) followed by the other extracts of the leaves; ethanol (402.61 mg GAE/g DM) and aqueous (374.11 mg GAE/g DM) extracts, respectively.[Citation94] The total flavonoid content in the methanol extract of the leaf (76.31 mg QE), stem bark (76.86 mg QE) and cashew nut (70.39 mg QE) are similar. The antioxidant activities of the ethyl acetate extract of the stem bark and different extracts of the leaves varied extensively. The ethylacetate extract of the stem bark exhibit the highest DPPH scavenging activity of 358.18 µg/ml followed by the various extracts of the leaf. The hexane leaf extract exhibited the highest DPPH scavenging activity of 157.49 µg/ml followed by the ethanol (89.80 µg/ml), dichloromethane (85.13 µg/ml), aqueous (71.80 µg/ml), methanol (9.94 µg/ml), butanol (7.77 µg/ml) and ethyl acetate (5.66 µg/ml) respectively.[Citation94] This showed that hexane is the best extracting solvent compared to other solvents in determining the DPPH activity of this plant. The FRAP assay revealed that the methanol extract had the highest activity of (471.21 µg/ml) compared to other extracts; ethyl acetate (402.12 µg/ml), butanol (305.61 µg/ml), methanol (303.82 µg/ml), dichloromethane (281.30 µg/ml) and hexane (163.91 µg/ml).

The antioxidant activities of this plant parts could be as a result of the presence of various antioxidant compounds and phytochemical contents (Table 2). Particularly, the methanol extract maintained an overall high antioxidant property due to the presence of Quercetin 3-O – α-D-glucopyranoside and Kaempferol −3-O-β-D-glucopyranoside compounds of high antioxidant properties in its fraction.[Citation134] Also, the ethyl acetate fraction was found to contain

Agathisflavone (bliflavonoid), Quercetin 3-O- rutinoside and Quercetin 3-O-rhamnoside antioxidant compounds.[Citation94]

Allium sativum L

Allium sativum L. belongs to the family of Amaryllidaceae. Its medicinal uses includes the treatment of atheroclerosis, hyperlipidemia, hypertension, diabetes mellitus, bacterial infections, cancer, fever, dyspepsia, intestinal worms and tuberculosis.[Citation38,Citation135] The antioxidant profile (Table 1) showed that the whole plant and its bulb possesses significant antioxidant properties. The total phenol content was highest in the ethanol extract of the whole plant (73.20 mg GAE/g DM), followed by the methanol extract of the whole plant (70.18 mg GAE/g DM), methanol extract of the bulb (67.02 mg GAE/g DM), Acetone extract of the whole plant (59.59 mg GAE/g DM) and lastly the aqueous extracts of the whole plant (49.81 mg GAE/g DM) and bulb (25.70 mg GAE/g DM) respectively. The high phenol content of the methanol and ethanol extract shows that they are the most suitable solvents for extracting the phenols compounds present in the plant. The total flavonoid content of the bulb was shown to range from 44.13 (mg QE), 34.10 (mg QE) to 12.67 (mg QE) of the methanol, ethanol and aqueous extracts respectively. The DPPH scavenging activity of the bulb was highest in the methanol extract (51.02 µg/ml) followed by the ethanol extract (45.23 µg/ml) and least in the aqueous extract (24.02 µg/ml). The FRAP activity of the aqueous extract was seen to be very significant (198.67 µg/ml).

The antioxidant activities of this plant parts could be as a result of the presence of various antioxidant compounds and phytochemical contents . This plant was found to contain allicin, diallyl sulfide (DAS), diallyl disulfide (DADS), diallyl trisulfide (DATS), S-allyl-cysteine, phytocidin, acrolein, alliin, E-ajoene, Z-ajoene, β-resorcyclic acid, pyrogallol, scordinin,[Citation95] gallic acid, rutin, protocatechuic acid, quercetin, B1-rhamnose, sativoside, voghieroside D1 compounds, all of which have high antioxidant properties.[Citation137,Citation138] This further justifies its wide medicinal use and pharmacological importance as an anti-hypercholestrolemic, antihypertensive, antiviral, carminative, stimulant, cholagogue, tonic, blood purifier, febrifuge, rubifacient, antibiotic, anti-allergic, aphrodisiac, antifungal, diuretic, antiplasmodic, anticoagulant, antirheumatic, and immunostimulatory effects by enhancing mitogemic activity toward human peripheral blood lymphocytes, thymocytes and murine spenocytes.

Vernonia amygdalina

Vernonia amygdalina belongs to the Asteraceae family. It is commonly called bitterleaf due to its bitter taste. Its therapeutic uses include the treatment of dysentery, gastrointestinal tract disorders, diabetes, loss of appetite-induced ambrosia amongst others.The total phenol content of various extracts of the leaf of Vernonia amygdalina (Table 1) ranged from 681.70 mg GAE/g DM (Acetone extract) to 38.33 mg GAE/g DM (ethyl acetate extract). The polar solvents ethanol and aqueous extracts exhibited moderate total phenol content of 96.25 mg GAE/g DM and 70.64 mg GAE/g DM, respectively.[Citation58] The total flavonoid content of the acetone extract was 23.70 mg QE. The DPPH scavenging activity of the plant was highest in the ethyl acetate extract 658.28 (µg/ml) followed by the ethanol extract (636.01 µg/ml) and the aqueous extract (340.22 µg/ml).[Citation61] The FRAP assay revealed acetone to be a better extract (91.60 µg/ml) compared to chloroform (54.10 µg/ml).[Citation60] Overall, acetone exhibited a better extracting capacity when compared to other solvents used such as ethanol, chloroform, ethylacetate and aqueous extracts.[Citation59] The high antioxidant capacity of the leaves of Vernonia amygdalina can be greatly attributed to the presence of isolated antioxidant compounds which includessesquiterpene lactones, flavonoids (luteolin, luteolin 7-O-glucosides and luteolin 7-O glucuronide), steroid glycosides, vernonioside A, B, A1, A2, A3, B2, B3 and A4, edotides as reported by Farombi and Owoeye.[Citation97] The plant contains complex active components such as essential oils, flavonoids, phenols, phlobatannins, saponins, tannins, terpenoids, triterpenoids, coumarins, resins and balsam etc.[Citation156] with antioxidant potentials.

Mangifera indica

Mangifera indica is a nutritional and medicinal important plant. It contains biomolecules from different plant parts such as stem bark, leaves, fruits and its seed kernels. It is used in the treatment of numerous diseases and has been found to possess antimicrobial properties.[Citation62] The total phenol content of the leaves of Mangifera indica was highest in the crude extract (230.00 mg GAE/g DM) followed by the ethanol extract (186.00 mg GAE/g DM) and methanol extract (99.01 mg GAE/g DM). The total flavonoid content was highest in the ethanol extract (191.02 mg QE), followed by the crude extract (131.01 mg QE) and least in the methanol extract (46.10 mg QE).[Citation40] The DPPH scavenging activity of the aqueous seed extract was 41.20 µg/ml, its FRAP activity was higher, 59.68 µg/ml.[Citation62] The overall high antioxidant activity could be accounted for as a result of the presence of a vast number of isolated antioxidant compounds which includes Phenolic compounds (Protacatechic, Gallic acid, Methyl gallate, 2,5-Di-tert-butylphenol, Sodium gallate, Tetrahydroxy sodium benzoate, Derivatives of gallic acid, Derivatives of theogallin with one OH missing, theogallin); Xanthones (Mangiferin, Isomangiferin, Mangiferin-3-methly ether, Mangiferin-6′-O-gallate); Flavonoids (Quercetin, Kaemferol, Rhamnetin, Quercetin carboxylic acid, Quercetin pentoside, Quercetin 3-O-rhamnoside, Quercetin 3-O- glucoside Epicatechin gallate hexamalonate, Rhamnetin hexoside); Benzophenones (Maclurin, Iriflophenone glucoside derivative, Iriflophenone 3-C-β-D-glucopyranoside, Maclurin 3-C-(6”-O-p-hydroxybenzoyl)β-D-glucoside, Iriflophenone tri-O-galloyl-glucoside); Terpenoids (Lupeol, Mangieronic acid, Manglanostenoic acid, Cycloart-25-ene-3,24,27-triol, Cycloartane-3,24,25-triol); Gallotannins (Digalloyl glucoside, Tri-O-galloyl glucoside, Tetra-O-galloyl glucoside, Penta-O-gallose-glucose) and Ferulic acid Hexoside as shown in Table 2. It contains some phytochemical constituents such as phenols, flavonoids, saponins, steroids, tannins, anthraquinones and glucosides.

Monodora myristica

Monodora myristica belongs to the family of Annonaceae. It is commonly called Orchid flower tree (English), ‘Ehuru’ (Igbo), ‘Abo lakoshe’ (Yoruba), ‘Ehinawosin’ (Ikale), ‘Uyengben’ (Bini), ‘Fausse noix de muscade’ (French).[Citation142,Citation143] Every part of the tree was economically and medicinally important. The seeds of Monodora myristica are used as spices or condiments.[Citation144] They are used in the treatment of sores, constipation[Citation145] and as a stimulant with palm oil. The total phenol content, flavonoid content, DPPH scavenging activity and FRAP activity can be found in Table 1. The total phenol content of the seeds (Table 1) is highest in the aqueous extract (27.60 mg GAE/g DM) and lower in the crude extract (14.78 mg GAE/g DM). The total flavonoid content was highest in the crude extract (41.20 mg QE) and lower in the aqueous extract (37.03 mg QE).[Citation63] The DPPH scavenging and FRAP activity of the aqueous seed extract was 62.05 µg/ml and 15.01 µg/ml respectively.[Citation3] The phytoconstituents of the seed includes essential oils, phenols, flavonoids, tannins, alkaloids, phlobatannins, terpenoids, steroids and saponins.[Citation146] Table 2 also shows the profile of isolated antioxidant compounds from the seed extract of Monodora myristica. The content includes Catechin, phenol, Phenylacetic acid, Salicyclic acid, myrcene, cinnamic acid, Protocatechuic acid, carvacrol, gentisic acid, p-coumaric acid, vanillic acid, safole, eugenol, isoeugenol, gallic acid, methyl isoeugenol, methyly eugenol, elemicin, myristicin, caffeic acid, ferulic acid, syringic acid, piperic acid, sinapinic acid, daidzein, coumestrol, genistein, apigenin, naringenin chalcone, naringenin, shogaol, glycitein, kaempferol, luteolin, capsaicin, epicatechin, epigallocatechin, gingerol, myricetin, isorhamnetin, quercetin, 3-o-caffeoylquinic, chlorogenic acid, rosmarinic acid, curcumin, miquellanin, eriocitrin, rutin, papain, phenyl-6-o-malonyl-beta-D-glucoside, 4-o-methyl-epi-gallocatechin, Epi-gallocatechin-3O-gallate, lupeol and Eriocitrin.[Citation108] These numerous bioactive compounds which accounts for its antiemetic, aperients, stimulant, stomachic, tonic functions.[Citation147] They impart stimulating properties when added to medicines. It also possesses the potential of reducing coronary heart disease when consumed due to its high unsaturated fatty acid content.

Methods for the extraction of bioactive compounds from plants

Many conventional and non-conventional methods have been employed to extract important phytochemicals from plants. Their efficiency mostly depends on factors such as nature of plant matrix, critical input parameters, scientific expertise, chemistry of bioactive compounds, etc. Solvent extraction is mostly used. The extraction can progress in four stages via: penetration of solvent into the matrix; dissolving of solute dissolves in the solvent; diffusion of solute is out of the matrix; and, collection and purification of extracted solutes.[Citation167,Citation168] Factors that improve the

solubility and diffusivity in these stages will facilitate the extraction process. The solvent properties, the ratio of solvent to solid, materials particle size, extraction duration, and extraction temperature also affect the efficieny of extraction. Many methods have been employed to improve the yield of bioactive compounds from plant materials, including enzyme digestion, marceration, ultrasound, pulsed electric field, ohmic heating, accelerated solvents, extrusion, microwave heating, supercritical fluids, etc.Solid-phase extraction, liquid-liquid extraction, and solid-phase micro-extraction are considered conventional/traditional methods, while microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), pulsed electric field (PEF), instant controlled pressure drop (DIC), supercritical fluid extraction (SFE), etc., have been employed as cost effective and environmentally friendly alternatives.Hydrodistillation has also been employed as a traditional method for extracting essential oils and bioactive compounds from plant materials. Hydrodistillation does not make use of organic solvents and can be done before dehydrating plant materials.

Conclusion

The study evaluated the major biological properties of many medicinal plants with the aim of understanding their therapeutic uses and potential antioxidant properties. The overall biological properties, especially antioxidant strengths, of the plants were extensively studies. The medically significant plants were shown to possess high antioxidant capacity when compared to synthetic antioxidants. These plants have high phenolic and flavonoid contents alongside high DPPH and FRAP activities. They were also shown to possess some active compounds with high antioxidant and other biological activities. Systematic investigations of these antioxidant plants in vitro and in vivo studies using same experimental methods of analysis and solvents are needed to enable an overall ranking of the plants in order of their antioxidant capacities.

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