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NUTRIONAL VALUES, ETHNO-MEDICINAL USES AND ANTIOXIDANT ACTIVITY OF MUSHROOM: A REVIEW

Lena Ahmed Saleh Al-Faqeeh*[1], Rafiuddin Naser[2], Kagne S. R.[3] and Subur W. Khan[4]

[1]Research Scholar in Microbiology, Department of Botany, Maulana Azad Collage of Arts, Science and Commerce, Dr. Rafiq Zakaria Campus, Rauza Bagh, Aurangabad, M.S., India.
[2]Head Department of Botany, Maulana Azad Collage of Arts, Science and Commerce, Dr. Rafiq Zakaria Campus, Rauza Bagh, Aurangabad, M.S., India.
[3]Associate Professor of Microbiology, Department of Microbiology, Badrinarayan Barwale Mahavidyalaya College, Jalna, India.
[4]Department of Pharmacognosy, Y.B. Chavan College of Pharmacy, Dr. Rafiq Zakaria Campus, Aurangabad, India.

***Corresponding Author: Lena Ahmed Saleh Al-Faqeeh**
Research Scholar in Microbiology, Department of Botany, Maulana Azad Collage of Arts, Science and Commerce, Dr. Rafiq Zakaria Campus, Rauza Bagh, Aurangabad, M.S., India. **DOI: https://doi.org/10.17605/OSF.IO/H9VY6**

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ABSTRACT
Consume of mushrooms by human are maily due to their nutritional value and flavors. Traditional use of mushrooms in different countries has been reported by many researcher. During years, Many of mushrooms were reported to possess antioxidant activity due to the prescence of many active compounds like polysaccharides, lipids, proteins, phenolic compounds and flavonoids. The following review will summarize the nutritional values, Ethno-medicinal uses and antioxidant activity of mushroom.

KEYWORDS: Mushrooms, Ethno-medicinal, Free radicals, Active compounds, Antioxidant.

INTRODUCTION
Mushrooms are macrofungi and commonly belonging to Basidiomycotina and rarely to Ascomycotina. Mushrooms can be either hypogeous or epigeous and large enough to be seen with naked eye and to be picked by hand.[1] They obtain their nutrition through being symbiotic, saprotrophs and parasites as mycorrhiza. Mushrooms have a vegetative phase (mycelia) and reproductive phase (fruiting bodies).[2] Numerous mushrooms are considered not only as nutritionally rich food but also have medicinal properties. Present study reviews nutritional values, ethno-medicinal and traditional uses of mushroom, medicinal properties of mushroom as antioxidant and antimicrobial.

MUSHROOMS AND THEIR NUTRITIONAL VALUES
Mushrooms are filamentous fungi with both sexual and asexual reproduction cycle. The characteristic of basidiomycetes is a spore-producing structure or fruiting body (cap) called basidium. The morphological unit of the basidium is the hyphae, and a mass of hyphae is called mycelium. The spores produced inside the basidium are called basidiospore and are responsible for its reproduction and its dissemination. Sexual reproduction begins when the basidiospore germinates and grown as a haploid mycelium in optimal environmental conditions.[3,4] Mushrooms are well-known as edible and nonedible macro-fungi. The edible and non-edible mushroom can differentiate based on morphological characteristics like color, appearance, and shape of the cap.[5]

Mushrooms are considered as a functional food and can be used for medicinal purposes for humans. Mushrooms nutritionally contain carbohydrate, protein, several vitamins (B, C, D, K), essential oil, fibers, unsaturated fatty acid, enzymes, minerals (potassium, phosphorus) and trace elements (selenium).[6-8] Mushrooms in general contain 90% water and 10% dry matter and due to their high water content, they have low caloric value.[9] Carbohydrates constitute about one-half of mushroom dry matter (DM) and have a significant role in medicinal properties of mushrooms through their immune-stimulating glucans, along with other polysaccharides.[10] Protein content in dry mushrooms was 228 and 249 g/kg DM.[11] Mushrooms crude fat are low, ranging from 20 to 30 g/kg DM. Also, ascorbic acid content is 150–300 mg/kg DM, vitamin D_2 content was 16.88 µg/g, vitamin B_2 content was 12.68 µg/g but certain species contain detectable amount of vitamin D when exposed to UV light. Also, B-group vitamin contents of riboflavin (2.6–9.0 mg/kg), thiamine (1.7–6.3 mg/kg), niacin (63.8–83.7 mg/kg) and pyridoxine (1.4–5.6 mg/kg), were determined in different mushrooms species.[12] Also, sodium content in mushroom is very low, which made them useful in low salt content diets.[13]

ETHNO-MEDICINAL AND TRADITIONAL USES OF MUSHROOMS

Mushrooms have been used and consumed by ancient people. Traditional knowledge about mushroom benefits have been transferred from one generation to another orally. It has been mentioned in ancient texts like Vedas. Roman and Chines, think that mushroom have a power for life, energy and strength and its the God Osiris gift for them. In ancient days, people in India, China and Iran used mushrooms in their religion activities.[14-18] Also, in the past thousands years ago various types of mushrooms were recognized by human beings edible and non-edible. They are also identified as a source of food and medical treatment purpose. It is used in traditional treatments in many countries such as Mexico, Japan, China, Africa, Korea and in Central and North American countries. They used them as anti- inflammatory, blood coagulant, wound healing, analgesic agents.[19-22]

Ethnomedical and traditional applications of mushrooms have been reported in many countries. Sitotaw et al[23] clarified in his study that only few people in Menge District, Ethiopia, recognized the medicinal properties of wild mushrooms in their community. *Termitomyces clypeatus, Termitomyces microcarpus, Laetiporus sulphureus* and *Ganoderma* sp. were recognized as a medicinal mushroom. *T. clypeatus* was usually given to underweight children and *T. microcarpus* used for gastritis and constipation in adults while powders of dried *Ganoderma* sp. and *L. sulphureus* were used to accelerate wound healing process and to treat common cold. Also, Woldegiorgis et al[24,25], demonstrated medicinal contribution of *L. sulphureus* from the southwest part of Ethiopia (Kaffa Zone). People of this area used it to relieve stomachache and to expel a woman's retained placenta following delivery.

Also, Haro-Luna et al[26] ,shed light on traditional and medicinal uses of mushrooms among the Wixaritari and mestizos of Villa Guerrero, Jalisco, Mexico. The mestizos people identified eleven species of edible mushrooms and Wixaritari people recognized twenty-one species. Both groups preferred certain species, but in general mushrooms were valued as a food source and more appreciated than meat. Only Wixaritari use medicinal mushrooms for particular conditions. They ground *Ganoderma oerstediin* and *Pycnoporus sanguineus*, mixed with water, boiled and seasoned with salt. They used this remedy to treat heart and joint problems. Also, A drink made from *Ganoderma oerstedii* was used for stomach pain, intestinal diseases, and kidney problems. It can be applied with wet clothes on the stomach. *Pycnoporus sanguineus* was used to treat skin conditions and fever; the liquid obtained from cooking this mushroom was applied to affected areas or used as a body wash in the case of fever.

In Anambra State, Nigeria, people used six different species of mushrooms for various traditional medical purposes.[27] In which *Auricularia auricular-judae* and *Lentinus squarrosulus* used to treat infertility and anaemia, *Volvariella volvacea* used for anaemia cure, *Daldinia concentrica* used in cure of stomach upset, *Termitomyces* spp. for curing high blood pressure, weakness and anaemia and *Trichobatrachus robustus* used in remedies of high blood pressure and anaemia.

Debnath et al[28], documented the traditional medicinal uses of different wild mushroom species in different states of India. 136 mushroom species were reported to have different activities such as treatment of urinary disorders, boils, asthma, blisters on skin, eczema, athlete's foot disease, chicken pox, wound, skin infections, pneumonia, constipation, rheumatism, diarrhea, lowering high blood pressure, abdominal discomfort, cough and whooping cough. Also, used for reduce high fever, cure fatty liver, diabetes, jaundice, arthritis, releases intestinal inflammation and mouth ulceration, an anti-inflammatory agent, etc.

Also, in West Bengal, India, tribal peoples used five mushroom species as traditional medicine.[29] Both *Pisolithus arhizus* and *Daldinia concentrica* fruiting bodies powders is mixed with coconut oil and used to relief from itching, healing minor burning and skin infections, fruiting bodies paste of *Termitomyces clypeatus* used in the treatment of pox, *Schizophyllum commune* fruiting bodies pasted is mixed with water to make soup and used as a tonic and *Clonorchis sinensis* fruiting bodies powdered is taken in tea or soups to use as a invigorative, aphrodisiac, revitaliser and anti‑aging.

Ethnomedicinal knowledge of wild mushrooms from the vicinities of Lumle and Kathmandu valley of Nepal was also documented.[30] Eight species, viz. *Coriolus hirsutus, Pycnoporus cinnabarinus, Daldinia concentrica*, *Schizophyllum commune* and *Lycoperdon pyriforme* were found to be used for wounds treatment. Also, wise used of *Laetiporus sulphureus* as a vegetable for cancer treatment, *Grifola frondosa* and *Ramaria botrytis* were used to relief from muscles pain.

ANTIOXIDANT ACTIVITY

Free radicals

Free radicals are atom or molecules fragments containing one or more unpaired electrons in atomic or molecular orbitals.[31] Generally, they are unstable and attack quickly the nearest stable molecule to capture the needed electron for gaining stability. Usually, free radicals derived from molecular oxygen are known as reactive oxygen species (ROS). ROS are the most important class of radical species generated in living systems and includes not only free radicals superoxide radical, hydroxyl radical but also molecules such as singlet oxygen, hydrogen peroxide and ozone.[32-35]

Sources of free radicals

There are multiple exogenous and endogenous sources that induce ROS generation (Fig.1). Smoking cigarette, drugs, environmental pollution, radiation and certain foods are the major exogenous sources of ROS. Many xenobiotics, especially different homo- and heterocyclic compounds, are clearly related as ROS generators in autooxidation reactions.[32,33] Also, inadequate nutrition may result in oxidative stress which impairs the cellular defense mechanisms indirectly.

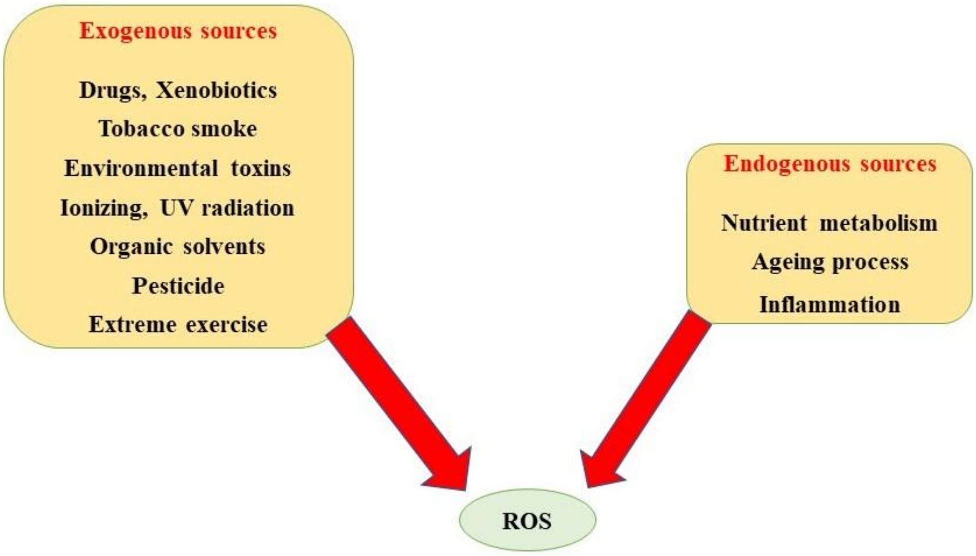

Fig.1. Major sources of free radicals.

Oxidative stress and human diseases

Oxidative stress results from overproduction of ROS. When generation of these species overtake the system`s ability to neutralise and eliminate them, such stresses occur. ROS can damage nucleic acid, proteins, cell structure and lipids at high concentration.[33,36] Un-controlled formation of these free radicals leads to the initiation and progression of many diseases (Fig.2) such as heart diseases, lung diseases, liver diseases, Parkinson`s disease, diabetes, cirrhosis, atherosclerosis, premature aging, neurological disorders (Alzheimer`s disease), several types of cancers, rheumatoid arthritis, etc.[37-40]

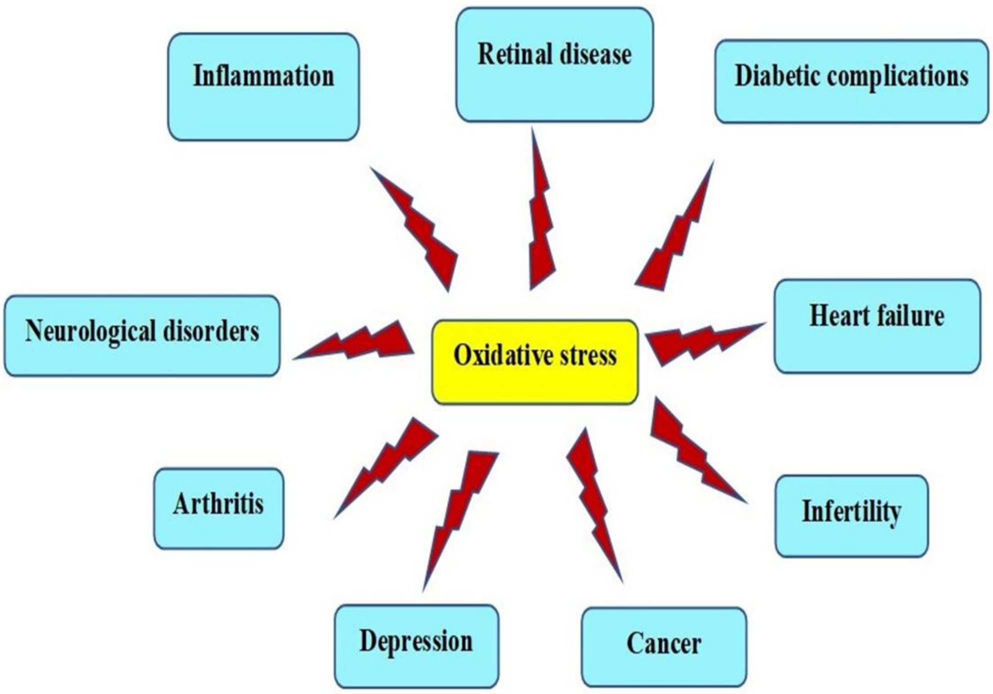

Fig.2. Oxidative stress and human diseases.

ANTIOXIDANT

Antioxidants are the compounds that present at low concentration, compared to those of oxidisable substrate, which delay or inhibit oxidation of that substrate significantly by scavenging the unpaired electron, preventing the production of free radicals, terminating chain reaction and quenching the energy of executed molecule.[35] They are the first-time defense in human body against free radical damage and are important to maintaining optimum health. The need for antioxidants becomes with increased exposure to free radicals. So, to keep healthy lifestyle and well balanced, wholesome diet, antioxidant supplement is now being recognized as an important means of improving free radical protection.[41]

Antioxidants sources

Antioxidants are broadly classified in to two groups which are enzymatic antioxidants and non-enzymatic antioxidants (low molecular weight). The enzymatic antioxidants are superoxide dismutase peroxidases and catalases while non-enzymatic antioxidants include glutathione, vitamins and several plant pigments.[35]

Antioxidant can be divided in to two types they may be natural antioxidants and synthetic antioxidants. Natural antioxidants are classified in to plant and fungal extracts, spices (Oregano, Clove, Rosemary, Thyme, Cinnamon, Marjoram, Nutmeg, Sage, Basil, and Pepper), vitamin C, vitamin A (including carotenoids), vitamin E (including tocopherols and tocotrienols), glutathione, flavonoids, ubiquinol, zinc (Zn) and selenium (Se).[42]

Plant cells normally contain different antioxidant compounds. Antioxidant complement often changes as organs grow and develop and is markedly affected by environmental stresses. 1120 food samples from United States Department of Agriculture (USDA) were evaluated and ranked for total antioxidant activity. Among 1120 food samples only 50 food were found to be a rich in antioxidant which occupied by vegetables, chocolate, spices, fruits, berries and nuts.[43] Along with vitamins, fats, proteins, carbohydrates and trace elements, natural antioxidants are considered as an important component of a healthy diet. Also, several phytochemical compounds which present in plant, fungi and herbs possess a strong antioxidant activity. Flavonoids which widely found in fruit, vegetables, red wine, cocoas, and tea play an important role in the protection against oxidative stress.[44,45]

In a study conducted by Azab et al[46], consumption of Fenugreek, Garlic, Peppermint, Propolis, Curcumin, Pomegranate, Parsley, Rosemary and Sesame showed that these medicinal plants and herbs have protective effect against nephrotoxic agents and renal diseases induced renal dysfunctions in experimental animals and human. The nephroprotective effect may be due to the inhibition of tissue lipid peroxidation and enhancement of antioxidant activity. This study suggested that these antioxidants may be useful for the persons who expose to nephrotoxic agents and patients suffer from renal diseases. Also, protective effects may be due to the presence of flavonoids, benzoquinones, glycosides, flavonol glycosides, alkaloids, steroid glycosides, carotenoids, catechols, mono, di, and triterpenes, saponins, terpenoids, sterols, glycoalkaloids and polyphenols in these medicinal plants and herbs.[46-48] Epidemiological studies show that consumption of vegetables and fruits with high phenolic content related to reduced cancer deaths, cardio and cerebrovascular diseases.[49]

Synthetic phenolic antioxidants include butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) and others e.g. propyl gallate, tert-butylhydroquinone (TBHQ), ethoxyquin (EQ), that all inhibit oxidation effectively.[50] However, some synthetic antioxidants are suspected to cause adverse toxic effects like carcinogenic and liver damage under certain conditions.[51,33] BHA, which is very often used as an additive in food industry, can have negative effects on the regulation of the activity of mitogen-activated protein kinase (MAPK) depending on the dosage.[51,52] Several synthetic antioxidants are authorized for use as feed additives in the European Union.[53]

So, the restriction on the use of synthetic antioxidants, such as BHA and BHT, lead to increased interest towards natural antioxidant substances. Recently, edible mushrooms have attracted attention as a commercial source of antioxidants.[51,54] They Can be used directly in enhancement of antioxidant defenses through dietary supplementation to minimize the level of oxidative stress.

Mushrooms as antioxidant

Many of wild and edible mushrooms were reported to possess antioxidant activity (Table 1). Extracts of fungi fruiting bodies, mycelium and broth confirmed the presence of many components which has its own specific biological effects.[55] Many of edible mushrooms represent a good source of carbohydrates such as β-glucans; phenolics such as tocopherols; B-vitamins such as niacin, flavin and pyridoxine; organic acids such as ascorbate, shikimate, malate and fumarate; monoterpenoid and diterpenoid; lipids; proteins such as hydrophobins and trace elements such as selenium.[56-57] These compounds are responsible for mushroom medicinal properties including antioxidant, antimicrobial and antitumor potentials.[59]

Table (1): Some studies of antioxidative activity of wild and edible mushrooms.

Mushrooms	Type of extract	Tests	References
Plerotus ostreatus, Volvariella sp., *Termitomyces* sp., *Termitomyces shimperi, Auricularis auricular* and *Volvariella volvaceae*	Aqueous and ethanolic	DPPH scavenging activity	[60]
Lactarius deliciosus	Ethanol and aqueous	DPPH Scavenging Activity, ABTS Radical Scavenging Activity and Ferric Ion Reducing Activity Assay	[61]
Macrocybe crassa	Methanol	DPPH radical scavenging, Superoxide anion scavenging activity, Lipid peroxidation scavenging activity and Nitric Oxide scavenging activity	[62]
Ganoderma lucidum	Diethyl ether, 75% of diethyl ether, Ethanol, 75% of ethanol, Butanol, 75% of butanol, Chloroform, 75% of chloroform, Acetone and 75% of acetone.	DPPH radical scavenging	[63]
Agaricus bisporus	Hot water and ethanol	DPPH radical scavenging, Superoxide anion scavenging activity, Hydroxyl radical scavenging and Reducing power	[64]
Plerotus ostreatus, Plerotus floridanus, T. versicolor, Mycrocybe sp. Agrocybe aegerita and *Calocybe indica*	Aqueous	DPPH radical scavenging	[65]
Calocybe indica	Ethanol	ABTS radical scavenging activity, DPPH radical scavenging, Hydroxyl Radical Scavenging Activity, Superoxide Anion Radical Scavenging Activity, Reducing Power and Nitric oxide radical scavenging,	[66]
Pleurotus florida and *Hypsizygus ulmarius*	95% Chilled ethanol	Total antioxidant capacity (TAC) by phosphomolybdnum method	[67]
Lentinula. edodes, Hericium erinaceus and *Agrocybe aegerita*	50% Ethanol	DPPH assay and Reducing power	[68]
Lentinula edodes, Volvariella. volvacea, Plerotus eous, Plerotus sajor-caju and *Auricularis auricula*	Water, 50 % ethanol and diethyl ether	DPPH assay, reducing power, Superoxide anion radical-scavenging activity and Chelating effect on ferrous ions	[69]
Plureotus florida, Calocybe indica and *Tricholoma gigantum*	Aqueous	DPPH assay	[70]
Pleurotus ostreatus, Lentinula edodes and *Hypsizigus tessulatus*	Methanol	DPPH assay	[71]

Important antioxidant components of mushroom

Phenolic compounds are one of the most important antioxidant components of mushrooms. They are aromatic hydroxylated compounds, possessing aromatic rings with one or more hydroxyl groups. Polyphenols can act as antioxidant as they can donate an electron or hydrogen to stabilize chain breaking reaction and terminate Fenton reaction.[72,73]

Another large group of phenolic compounds with antioxidant activity is flavonoids. Flavonoids have been shown to be highly effective scavengers for most types of oxidizing molecules, including singlet oxygen and various free radicals.[33] Flavonoids can alter peroxidation kinetics and decrease fluidity of membranes.[74]

Also, Polysaccharides, including polysaccharide-protein complexes, are a class of major bioactive constituents of edible and medicinal mushrooms.[55] They act primarily as immunostimulators and adaptogens. Mushroom polysaccharides have been reported to have antioxidant activity based on various *in vitro* and *in vivo* assays.[75-77, 51] Their antioxidative activity is due to the ability of RSO scavenging, their reduction property and ability to chelate Fe^{2+}, lipid peroxidation inhibition, erythrocyte hemolysis and the increase of enzymes activities in eukaryotic as well as in prokaryotic cells as well as in taking part in antioxidative processes, such as Superoxide Dismutase(SOD), Catalase (CAT) and Glutathione Peroxidase (GPx).[78-81, 51]

Vitamin E is a family of chemically related compounds, namely tocopherols and tocotrienols, which share a common structure with a chromanol ring and isoprenic side chain.[82] Tocopherols and tocotrienols are essential components of biological membrane.[83] There are four tocopherols and tocotrienol isomers such as α-, β-, γ-, δ-. α- tocopherol has the highest antioxidant activity of all tocopherols.[84] α and β- tocopherols are equally effective in quenching singlet oxygen physically.[85] In membrane, α- tocotrienol is found to be better antioxidant than α-tocopherol.[86]

CONCLUSION

This review study revealed the importance of mushroom as a functional food and also as a medicinal source for many active compounds which can be used as antioxidants.

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