Environment and Ecology 39 (2) : 358—369, April—June 2021
ISSN 0970-0420

Biochemical Composition, Nutritional Values and Medicinal Properties of Some Edible Mushrooms : A Review

Robin Rijal, Meenakshi Rana, Seweta Srivastava

Received 27 April 2021, Accepted 27 May 2021, Published on 11 June 2021

ABSTRACT

Cultivation of mushrooms becoming more popular all over the world because different cultivated and wild edible mushrooms possess valuable bio-chemical properties essential for the human health. Mushrooms have incomparable health benefits, which are considered as erich source of nutrition, vitamins, minerals, dietary fibers, essential fatty acids, polysaccharides, enzymes, essential elements and antioxidants. Therefore, edible mushrooms are popular for antimicrobial, anti-diabetic, anticoagulant, anti-ageing, immunological, hepatoprotective and hypolipidemic activities that made them to appropriate for use in healthy foods, biomedicines, cosmetics and widely accepted as admirable source of Immune-modulatory agent that have Immune-Stimulation activities. Nowadays, farmers are attracted towards the mushroom cultivation because it is considered as more profit-oriented enterprise that have more potential to earn attractive returns compared to field and horticultural crops per unit area. Besides, mushroom's cultivation also assists to reduce the environmental pollution raised by burning of agricultural residues such as sugarcane trashes, crops stubbles and paddy straw because its cultivation requires these raw materials, which acts as alternative way to manage such by-products and transforming agricultural waste into food of high healthy nutritional benefits, therefore considered as a naturally feasible alternative.

Keywords Antioxidants, Polysaccharides, Enzymes, Anticoagulant, Hepatoprotective.

Robin Rijal, Meenakshi Rana, Seweta Srivastava*
Department of Plant Pathology, School of Agriculture, Lovely Professional University, Phagwara 144411, Punjab, India
Email : seweta.21896@lpu.co.in
*Corresponding author

INTRODUCTION

Mushroom is an asexual fruiting body of edible fungi, which belongs to the sub-division of fungi Ascomycotina or Basidiomycotina. Mushrooms are heterotrophic and achlorophyllous, eukaryotic decomposers that mainly grow on dead and decaying organic matters, therefore termed as "Saprophytes" (Thongnaitham 2012, Brajesh *et al.* 2018, Kumar *et al.* 2018). Nowadays, cultivation of mushrooms become trendy in different countries because this enterprise requires less area, time and investment, but potential to earn attractive returns compared to field and horticultural crops. Therefore, farmers from different countries are interested to grow different type of edible mushrooms, due to which its production is continuously increases. The cultivation of mushrooms assists to manage and transform the agricultural and agro-industrial waste in to food of high healthy nutritional benefits, which prevents the air pollution caused by residual burning of harvested crops and considered as a naturally feasible alternative (Pontes *et al.* 2018). Across the world, China becomes the leading producer of mushrooms (Figs.1-5),which alone produce more than 30% of mushrooms (Miles and Chang 2004, Fletcher and Gaze 2007, Aida *et al.* 2009, Koushki *et al.* 2011, Patel and Goyal 2012, Mishra and Mishra 2013).

Among 14000 known species of mushrooms, 2000 are considered as safer for human consumption in which 650 species possess medicinal properties (Rai *et al.* 2005). There are many species of edible mushrooms are either harvested wild or cultivated in farm (Kozarski *et al.* 2015). Till date, numerous domestic and wild edible mushroom species are growing in several suitable ecological conditions. The most common edible mushroom species that are cultivated in favorable ecological conditions are *Agaricus* spp., *Pleurotus* spp. (oyster), *Volvariella volvacea* (straw), *Lentinula edodes* (shiitake), *Ganoderma lucidum* (Reishi)*, Hericiumerinaceus* (Lion's head), *Tremella fuciformis, Grifola frondosa* (maitake), *Pholiotanameko, Lepista nuda* (blewit), *Auricularia auricula-judae* (ear), *Coprinus comatus* (shaggy mane) and *Flammulina velutipes.* Among these, some valuable mushrooms, such as *Agaricus bisporus*, *Pleurotus* spp., *Flammulina velutipes* and *Lentinula edodes* are grown under full climatization on a well-defined substrate because these mushrooms have high economic values (Caglarirmak 2011,Kozarski *et al.* 2015).

The evaluation of bio-chemical composition and properties of mushrooms contain very useful phytochemicals such as ascorbic acid, carotenoids, phenolics, ergosterol and tocopherols that have antioxidant activity and rich in nutritional status, which includes good source of non-starchy carbohydrates, proteins, vitamins (B1, B2, B12, C, D, and E), minerals, dietary fibers, polysaccharides, folates, essential elements (sufficient level of K and P, very low Na contents and substantial amount of some microelements), several bioactive components and low fat content with unsaturated fatty acids, but absence of trans fatty acids (Barros *et al*. 2008,Yamanaka 1997, Mattila *et al.* 2000, Adejumo *et al.* 2015, Kozarski *et al*. 2015, Vetter 2019). Mushrooms generally contain 20-40% proteins on dry weight basis, and have zero cholesterol content (Nour *et al.* 2011). It has been reported that protein content of mushroomsis twice than that of vegetables and four times more than oranges (Bano 1993), which is significantly higher than those of wheat (Aletor 1991). It has higher nutritional contents compared to eggs, meat and milk (Thatoi and Singdevsachan 2014). Therefore, mushrooms are used as conventional source of animal proteins, which becomes relatively much cheaper than pork, beef and chicken (Adejumo and Awosanya 2005).

In recent years, synthetic antioxidants, such as

Fig.1. Global map that represents the different edible mushroom species grown commercially all over the world (Kozarski *et al*. 2015).

BHA (Butylated Hydroxyanisole) and BHT (Butylated Hydroxytoluene) was restricted to use in food industry, has caused interest towards natural (organic) antioxidant substances. Due to which, mushrooms are getting more attention as a commercial source of antioxidant, which helps to reduce the level of oxidative stress in body through dietary supplementation (Ferreira *et al*. 2009, Khatua *et al.* 2013, Kozarski *et al.* 2014).

Nutritional compositions of edible mushrooms

Edible mushrooms are rich in nutritional value, particularly in carbohydrates and proteins. Along with these, edible mushrooms are also acting as excellent source of vitamins and minerals (Kayode *et al.* 2015, Han *et al.* 2016). The mean nutritional values of different types of edible mushrooms are presented in Tables 1, 2. Edible mushrooms are not only the significant food sources of our age (healthy and functional foods) but also contain certain valuable bio-chemical substances. Some medicinal mushrooms have anti-oxidant, anti-carcinogenic, anti-microbial effects and reducing hypercholesterolemia activities (Chirinang and Intarapichet 2009, Jose and Janardhanan 2000). For instance, Triterpenoides (ganodericacids: *Ganoderma lucidum*) hasanti-carcinogenic potential; unsaturated fatty acids (polyunsaturated and/or monounsaturated) in mushroom (*Coprinuscomatus, Ganoderma lucidum, Agaricus bisporus*) has anti-diabetic property, which has positive effects on insulin sensitivity that can enhance the sugar metabolism in body (Risérus *et al.* 2009, Phan *et al.* 2019). Moreover, Kozarski *et al*.(2015) reported that mushrooms have high mannitol and low glycemic index, which is most beneficial for diabetic patients. Similarly, Polysaccharides (Lentinan: Lentinula edo-

Table 1. Mean nutrients content in different species of raw mushrooms per 100 g edible portion. Source: USDA 2019; nd: no data.

Nutrients	White mushroom	Oyster mushroom	Shiitake mushroom	Chanterelle mushrooms	Enoki mushrooms
Moisture (g/100 g)	92.45	89.18	89.74	89.85	88.34
Energy (kcal/100g)	22	33	34	32	37
Protein (g/100 g)	3.09	3.31	2.24	1.49	2.66
Fat (g/100 g)	0.34	0.41	0.49	0.53	0.29
Fatty acids, total monounsaturated	0.00	0.031	nd	nd	0.00
Total polyunsaturated fatty acids (g/100 g)	0.16	0.123	nd	nd	0.124
Dextrose (g/100 g)	1.48	1.11	2.38	1.16	0.22
Carbohydrate (g/100 g)	3.26	6.09	6.79	6.86	7.81
Ash (g/100 g)	0.85	1.01	0.73	1.26	0.91
Total dietary fiber (g/100 g)	1.0	2.3	2.5	3.80	2.7
Sodium (mg/100 g)	5	18	9	9	3
Magnesium (mg/100 g)	9	18	20	13	16
Calcium (mg/100 g)	3	3	2	15	0
Iron (mg/100 g)	0.5	1.33	0.41	3.47	1.15
Copper (mg/100 g)	0.318	0.244	0.142	0.353	0.107
Manganese (mg/100 g)	0.047	0.113	0.23	0.286	0.075
Phosphorus (mg/100 g)	86	120	112	57	105
Potassium (mg/100 g)	318	420	304	506	359
Zinc (mg/100 g)	0.52	0.77	1.03	0.71	0.65
Selenium (μg/100 g)	9.3	2.6	5.7	2.2	2.2
Niacin (mg/100 g)	3.607	4.956	3.877	4.085	7.032
Thiamin (mg/100 g)	0.081	0.125	0.015	0.015	0.225
Riboflavin (mg/100 g)	0.402	0.349	0.217	0.215	0.2
Pantothenic acid (mg/100 g)	1.497	1.294	1.5	1.075	1.35
Ergosterol (mg/100 g)	56	64	85	61	36
Pyridoxine (B-6) (mg/100 g)	0.104	0.11	0.293	0.044	0.10

Table 2. Enzymatic activities found in different types of edible mushrooms.

Mushroom species	Enzymes	References
Agaricus arvensis	Cellulose, Endoglucanase, Cellobiohydrolase, Beta-glucosidase	Jeya *et al.* 2010
Agaricus bisporus	Manganese Perioxidase, Lignin Peroxidases, Laccase, Tyrosinase	Bonnen *et al*. 1994, Ismaya *et al.* 2011
Boletus edulis	Antioxidant enzymes, Superoxide Dismutase, Catalase	Collin-Hansen *et al*. 2005
Calocybe indica	Mannitol dehydrogenase, Laccase, Xylanase, Tyrosinase and Lipoxygenase	Bhupathi *et al.* 2017
Cantharellus cibarius	Tyrosinase, Amylase, Laccase, Cellulase Protease	Khaund and Joshi 2014
Clavulina sp.	Tyrosinase, Laccase, Amylase, Cellulase Protease	Khaund and Joshi 2014
Ganoderma lucidum	Cellulose, Hemicellulose, Laccases, Cellobiohydrolase, Haem peroxidases, Mn-dependent peroxidase, Versatile peroxidase	Zhou *et al*. 2018
Gomphus floccosus	Cellulase, Tyrosinase, Laccase, Amylase, Protease	Khaund and Joshi 2014
Lactarius deliciosus	Laccase, Tyrosinase, Amylase, Protease, Cellulase	Khaund and Joshi 2014
Lentinus edodes	Catalase, Superoxide Dismutase, Ascorbate Peroxidase and Glutathione Reductase	Jiang *et al*. 2010
Pleurotus eryngii	Ligninolytic enzyme, Laccase, Mn-oxidizing Peroxidases, Aryl-alcohol oxidase	Stajic *et al*. 2009
Pleurotus ostreatus	Lignin Peroxidases, Manganese Perioxidase, Cellulases, Laccase	Adebayo and Martinez-Carrera 2015
Pleurotus ostreatus *P. citrinopileatus*	Laccase, Mn-peroxidase, Cellulase and Xylanase	Carabajal *et al.* 2012
Pleurotus sajor-caju	Cellulase, Xylanase, Endoglycanase, B-glucosidase, Laccase, Lignolytic enzyme	Madan and Bisaris1984, Khan *et al*. 2016
Ramaria botrytis	Laccase, α-amylase, Xylanase, β-glucosidase, exo-β-1,4-glucanase, Chitinase, Lipase, Protease	Lee and Han 2001
Ramaria sp.	Cellulase, Tyrosinase, Laccase, Protease, Amylase	Khaund and Joshi 2014
Tricholoma saponaceum	Tyrosinase, Cellulase, Protease, Amylase, Laccase	Khaund and Joshi 2014
Volvariella volvacea	Cellulase, Endoglucanase, β-glucosidase, Laccase	Chang and Steinkraus 1982, Chen *et al*. 2003

des) of mushrooms is widely accepted as excellent immune-modulatory agent (Phan *et al.* 2019). In the past few years, mushrooms are also known as "Mycoremediation tools" in view of their utilization in remediation of various types of pollutants (Kulshreshtha *et al.* 2014).

The fruiting bodies of mushrooms have well assimilated mineral elements among which Ca, Mg, Na, P, K and S are the major minerals constituents and elements such as Zn, Fe, Cu, Mn, As, Cd, Co, Cr, Ni, Mo, Se, Pb form miner constituents (Bano *et al*. 1981, Bano and Rajarathanum 1982). According to Mattila *et al.* (2001), mineral contents are lower in cultivated mushrooms compared to wild edible mushrooms. Kaul (1978) advocate that *Morchella esculenta* contains 3.31 mg/g of P, 3.83 mg/g of K, 0.57 mg/g of Ca and 1.21 mg/g of Fe. According to Oluwafemi *et al*. (2016), different parts of mushroom such as the cap, stalk and the mixture (cap + stalk) of Oyster mushroom (*Pleurotus ostreatus*) have different proximate composition. The outcomes of the experiment showed that highest moisture content was found in stalk followed by cap in dry weight basis, which was 6.33 % and 3.48 % respectively. Also, there was a noticeable difference was observed in protein content in different parts of mushrooms, which was 20.96%, 34.19 % and 30.48 % in stalk, cap and cap + stalk, respectively. Similarly, the crude fiber content was highest in stalk+cap, followed by stalk and cap which was 8.12%, 7.53% and 3.14% respectively. Sometimes, edible mushrooms are also used as a thickener and flavor enhancer food in some food production.

Mattila *et al.* (2001) analyzed and determined

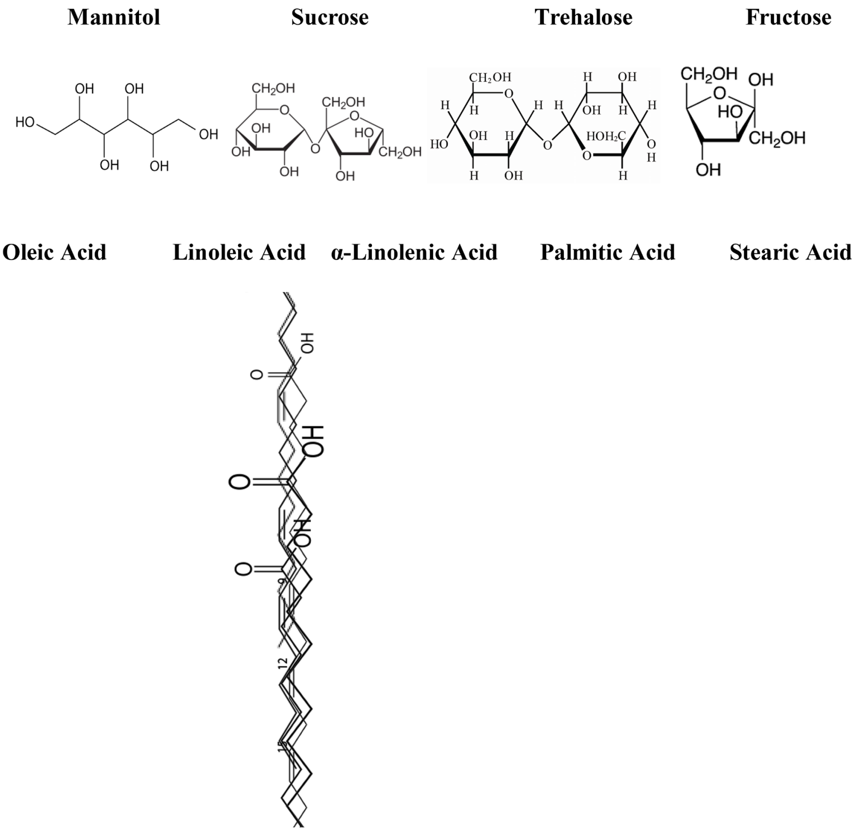

Fig. 2. Chemical structure of different sugars and fatty acids.

the contents of several minerals (Na, Mg, P, K, Ca, Cu, Fe, Mn, Pb, Cd and Se), Vitamins (B1, B2, B12, C, D, niacin and folates), and some phenolic compounds such as phenolic acids, lignans and flavonoids in different edible cultivated mushrooms *(Agaricus bisporus/*white*, Agaricus bisporus/*brown, *Lentinusedodes* and *Pleurotusostreatus*). It was found that these mushroom species were rich in Vitamin B2, folates and niacin in the range of 1.8-5.1, 0.30-0.64 and 31-65 mg/100 g respectively in dry weight basis. Similarly, the contents K, P, Cu and Zn contents in edible mushrooms are found in the range of 26.7–47.3 g/kg, 8.7–13.9 g/kg, 5.2-35 mg/kg in dry weight, respectively. Along with these, large amount of Se (1.2 mg/kg dw) and Cd (1.2 mg/kg dw) levels were quite high in *A. bisporus* (brown) and *L. edodes,* respectively. Whereas, the phenolic acid was very low in content. According to Agrahar-murugkar and (Subbulakshmi 2005), macronutrients in seven wild edible mushrooms from Meghalaya were found to be rich in protein, minerals (including trace minerals) and had low fat contents. It was found that vitamin C content (mg/g) in *Calvatia gigantean*, *Cantharel-luscibarius, Coprinopsis cinerea, Gomphus floccosus,* Lactariusquieticolor, *Ramariabrevispora* and *Russula integra* was 14.9, 41.9, 41.8, 25.8, 18.1, 28.0 and 19.6 mg/g, respectively. Furthermore, Singdevsachan *et al.* (2013) analyzed the vitamin contents (Ascorbic acid, riboflavin and thiamine) in *Lentinus sajor-caju* and *Lentinus torulosus* from Odisha and reported that highest and lowest content of thiamine was found in *Lentinus torulosus* (0.19 mg/g) and *Lentinus sajor-caju* (0.13 mg/g),respectively. Besides, higher ascorbic acid was found in *L. torulosus* (52.91 mg/g) and least in *L. sajor-caju* (17.75 mg/g), but riboflavin was not detected (Thatoi and Singdevsachan 2014).

Gruen and Wong (1982) advocate that edible mushrooms were superior in nutritional compositions compared with eggs, dairy products and meat. According to Bano (1993), food value of edible mushrooms lies between vegetables and meat. Bano *et al.* (1963) reported that *Pleurotus flabellatus* has 90.95% of moisture, 1.084% crude fiber, 0.974% ash, 0.105% fat, 2.75% protein and 0.14% non-protein nitrogen. Jha and Tripathi (2012) collected 3 different edible mushroom species (*Ramaria botrytis, Lycoperdon pyriforme* and *Laccaria laccata*) from parts of Kathmandu valley and analyzed the bio-chemical composition. The biochemical study of these fungi species includes 72.88%, 49.88%, 58.50% carbohydrates, 13.55%, 38.00%, 25.71% protein, 4.22%, 9.60%, 3.30% lipid, 7.25%, 5.25%, 11.75% ash, and 5.00%, 8.00%, 11.00% crude fiber, respectively. Similarly, the pH of *R. botrytis, L. pyriforme* and *L. laccata* was 7.0, 6.5 and 7.0 sequentially.

Antioxidant properties addressed from different edible mushrooms

From the ancient time, mushrooms have been using as a source of nutrition and medicinal values. Edible mushrooms have antioxidants activity, which might be the potential natural source of antioxidants to reduce oxidative stress. The major important antioxidants found in edible mushrooms are Phenolic compounds, Flavonoids, Tocopherols, Tocotrienols, Glycosides, Polysaccharides, Ergothioneine, Carotenoids and Ascorbic acid (Khatua *et al.* 2013, Kozarski *et al.* 2015). Beside the antioxidant properties, edible mushrooms are also popular for anti-diabetic, antimicrobial, anti-ageing, anticoagulant, antiviral, antitumor, anti-complementary, hepatoprotective, hypolipidemic and immunological activities, which made them appropriate for use in healthy food, biomedicine, cosmetics, waste water management and environmental protection (Van Griensven 2009, Khatua *et al*. 2013, Kozarski *et al*. 2014, Loria-Kohen *et al.* 2014). Therefore, edible mushrooms are most popular to enhance the antioxidant defence mecha-

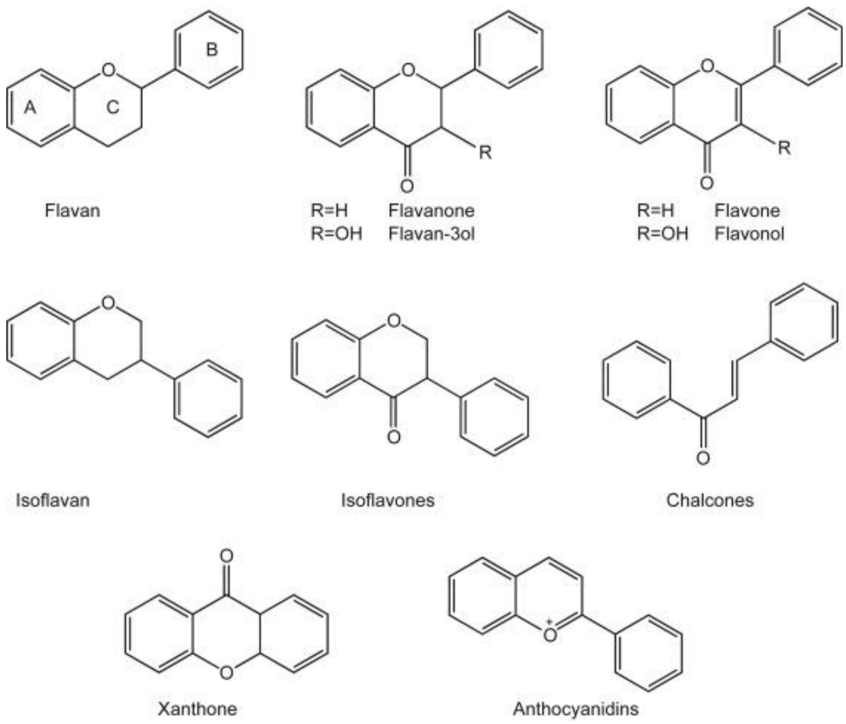

Fig. 3. Classification of flavonoids (Hernández-Rodríguez *et al.* 2019).

nisms in human body that reduces the oxidative stress level in body. This depicts that the consumption of different edible mushrooms acts as a powerful tool to maintain good health, longevity and quality life (Kozarski *et al.* 2015).

Phenolics compounds

Phenolic compounds are important constituent of plants because of their scavenging property, which is due to the presence of hydroxyl (OH-) group in its structural composition. Phenolic compounds play a crucial role in stabilizing the peroxidation of lipids and directly contribute to the antioxidative action (Hatano *et al.* 1989, Duh *et al.* 1999, Keleş *et al.* 2011). Keleş *et al.* (2011) determined the total phenolic content in different types of edible mushrooms by using Folin-Ciocalteu reagent and reported that *Boletus edulis* has higher amount of total phenolics compounds, followed by *Polyporus squamosus, Lepista nuda, Agaricusbisporus, Lactarius deliciosus*, *Pleurotousostreatus* and least was in Hydnumrepandum in the quantity of 12775.56, 4531.11, 4175.56, 4020, 2708.89, 2686.67 and 420.00 mg/kg, respectively. Similarly, Alispahić *et al.*(2015) determined the phenolic compounds in *Boletus edulis*, *Agaricus bisporus, Agaricus bisporus* var *Avellaneus, Pleurotus ostreatus* and *Lentinula edodes* from Bosnia and reported that highest total phenolic content was noted in *B. edulis* (35.56 mg GAE/g) and lowest in *L. edodes* (4.94 mg GAE/g). In between, *A. bisporus* var *Avellaneus, A. bisporus* and *P. ostreatus* has 7.66, 6.43 and 6.27 mg GAE/g of total phenolic compounds were noted sequentially.

Flavonoids

Flavonoids are group of natural substances that have variable phenolic structures and has antioxidant activity. Flavonoids commonly found in flowers, fruits, vegetables, mushrooms, stems, roots, tea and wine. Due to the beneficial effects on human health,

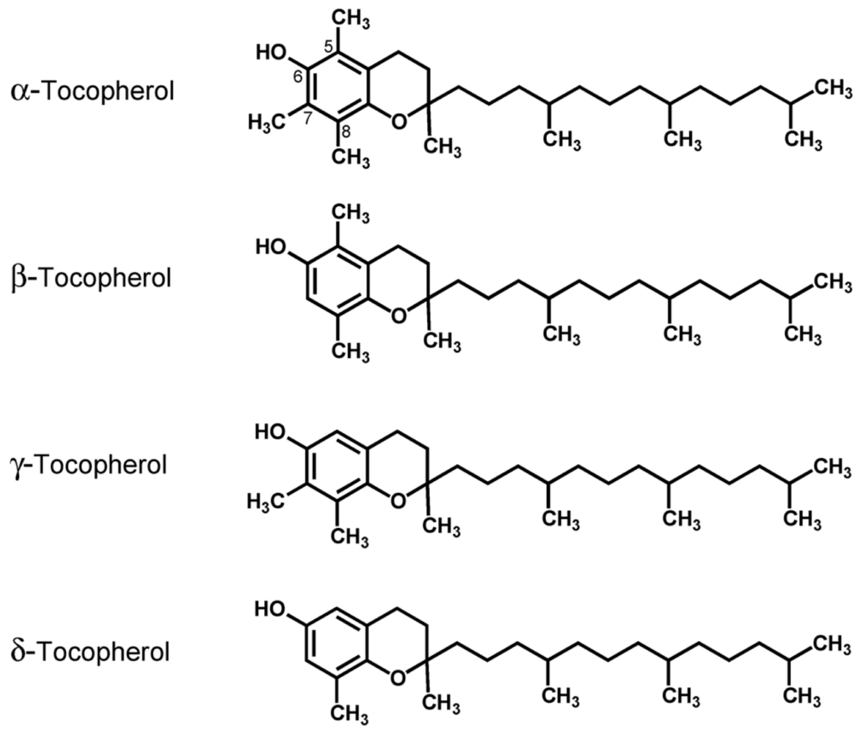

Fig. 4. Chemical structures of α-, β-, γ- and δ-Tocopherols (Smolarek and Suh 2011).

flavonoids are considered as an essential-components in cosmetic, pharmaceutical, medicinal and nutraceutical applications. It was reported that flavonoids are highly effective scavengers, which prevents the generation of free radicles in the body by promoting their decomposition or scavenging them. Besides, it has also anti-carcinogenic, anti-mutagenic, anti-oxidative and anti-inflammatory properties. Therefore, prevents from tissue damage (Ferreira *et al.* 2009, Lobo *et al.* 2010, Khatua *et al.* 2013, Panche *et al.* 2016). Mujić *et al.* (2010) collected three edible mushrooms species (*Lentinula edodes, Hericium erinaceus, Agrocybe aegerita*) from Istra region of Crotia and analyzed the flavonoids compound in Laboratory. They found that highest total flavonoids extraction was present in *A. aegerita,* followed by *L. edodes* and *H. erinaceus* in the quantity of 5.04, 1.98 and 1.61 mg CE/g. Similarly, highest percentage of extraction yield was achieved in *L. edodes* (20.82%), whereas lowest in *H. erinaceus* (11.34%).

Tocopherols

Tocopherols are fat soluble antioxidants/organic compounds/phenolic compounds that are the major forms of vitamin *E. Tocopherols* and tocotrienols are essential components of biological membranes. There are 4 isomers of tocopherol and tocotrienol (α, β, γ and δ). The nomenclature of different types of tocopherols depending on the number and position of methyl groups (-CH3) present on the chromanol ring, which are designed as α, β, γ and δ (Kagan 1989, Constantinou *et al.* 2008, Das Gupta and Suh 2016). Among all, α-tocopherol has highest antioxidant activity than other forms of tocopherols. In biological membrane, it was found that α-tocotrienol was much better than that of α-tocopherols (Kamal-Eldin and Appelqvist 1996, Packer *et al.* 2001). As an antioxidant, tocopherols intercept the dispersion of harmful free radicle reactions in the body and also show pro-oxidant activity. When bio-chemical reaction happens between free radicles and α-tocopheryl radicles, non- radicle oxidation products will form and that will be conjugated to glucuronic acid and escaped out from the body through the bile or urine (Herrera and Barbas 2001). It was revealed that tocopherols are mostly found in *Agrocybe cylindracea, Boletus badius, Boletus edulis, Clitocybe alexandri, Cortinariusglaucopus, Hydnumrepandum, Hygrophorop sisaurantiaca, Laccaria laccata, Laccaria amethystine, Lactariusaurantiacus, Lentinula edodes, Lepista nuda, Pleurotus ostreatus, Polyporus squamosus, Ramaria botrytis* and *Russuladelica* (Sánchez 2017).

Carotenoids

In mushrooms fruiting bodies, carotenoids are found in abundant quantity, which have antioxidant property essential for biological systems (Barros *et al.* 2008c). Beside pro-vitamin A properties, carotenoids also act as a lipid peroxidation chain breaker, lipid radical scavenger and singlet oxygen quenchers (Frei- 1994, Grune *et al.* 2010, Robaszkiewicz *et al.* 2010). All-*trans*-β-carotenes are most important precursor for vitamin A, which is structurally and functionally identical from other carotenoids, therefore considered as the most important member of carotenoid groups. Furthermore, medical studies showed that β-carotenes have moderate UV protective effects in the skin (Köpcke and Krutmanna 2008, Grune *et al*. 2010).

Robaszkiewicz *et al.* (2010) analyzed the carotene concentration in different species of edible mushrooms extract through spectrophotometrically method and found in the range of 0.233 to 18.649 µg/g of carotene in dried edible mushrooms with Methanolic extract. They reported that highest β-carotene was noted in *Tricholomaequestre* cap (18.649 µg/g of

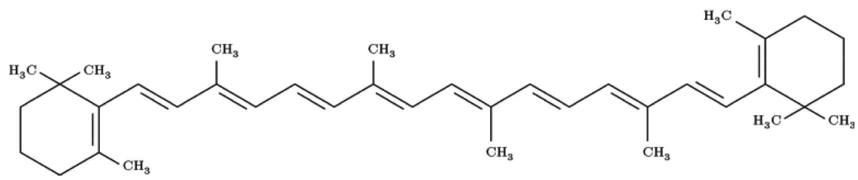

Fig. 5. Chemical structure of -carotene.

dried mushrooms) and lowest in Tuber mesentericum (0.233 649 µg/g of dried mushrooms). In between, β-carotene content was 0.317, 0.426, 0.467, 0.511, 0.729, 3.275 and 15.256 µg/g in *Pleurotusostreatus, Agaricus bisporus* cap with peel, *Boletus edulis* white stalk, *Agaricus bisporus* cap without peel, *Boletus edulis white* cap, *Cantharellus cibarius* and *Suillus bovinus* cap, respectively. Similarly, Barros *et al.* (2007b) also assayed the β-carotene content in 3 edible mushroom species from Portugal and reported that 2.97, 2.53 and 1.88 µg/g of β-carotene was found in *A. arvensis, S. imbricatus* and *L. giganteus,* sequentially.

Extracellular enzymes produced by the cultivated mushroom

Edible macrofungus contain wide range of bio-active metabolites and beneficial enzymes. Enzymes are globular proteins (tertiary structure) that seems like rounded or squashed ball structure. Biological enzymes are biological catalysts that are considered as vital components of any living organisms because they govern many metabolic and physiological functions, such as digestion and absorption of nutrients from foods, energy conversion and maintain all internal organ functions including metabolic efficiency, generate energy, cell repair, promote blood circulation, improve immunity and anti-inflammatory detoxification (Roland 2019, Colter 2020). Leatham (1985) explained the activities of extracellular enzymes (over the 150 days incubation period) produced by *L. edodes* during degradation of lignocellulosic medium, which includes hemicellulases, acid phosphatase, cellulolytic system enzymes, acid protease, laccase, (gluco-)amylase, pectinase and cell wall lytic enzymes (laminarinase, 1,4-β-d-glucosidase, β-N-acetyl-d-glucosaminidase, α-d-galactosidase, β-d-mannosidase).

Khaund and Joshi (2014) collected 10 different edible mushroom species from mycophillic ethnic-tribes of India and assayed enzymatic profiling. They select *Cantharelluscibarius, Gomphus floccosus, Lactarius deliciosus, Lactariusvolemus, Laccaria lateritia Malençon, Tricholomasaponaceum, Inocybe* sp., *Albatrellus* sp., *Ramaria* sp. and *Clavulina* sp. to determine enzymatic activities (Amylase, Laccase, Protease, Cellulase, Tyrosinase) present in these mushrooms. They found that higher activities of Amylase enzymes, Protease enzymes,Tyrosinase enzymes, Cellulase enzymes and Laccase enzymes was noticed in *Inocybe* sp. (40.29 U/mL), *Tricholomasaponaceum* (50.03 U/mL)*, Laccarialateritia-Malençon* (77.66 U/mL), *Inocybe* sp.(20.26 U/mL) and *Lactarius deliciosus* (99.38 U/mL), respectively. According to Mohapatra *et al.* (2008), post-harvest browning of mushrooms is mainly due to the presence of endogenous activities of peroxidase (POD) and polyphenol oxidase (PPO). It depicts that enzymatic activities of POD and PPO was highest at harvesting stage of mushrooms.

CONCLUSION

Mushrooms are gaining popularity and are widely consumed across the globe by all age groups. Mushrooms are considered to be one of the superfoods due to its high nutrient content, especially protein, dietary fiber, vitamins and minerals. In addition, mushrooms are also well-known to contain bioactive compounds, such as ergosterol, β-glucans, lentinan and peroxidase, which possess health functionalities. Knowledge advancement in biochemistry, biotechnology and molecular biology boosts application of mushrooms in medical sciences. From a holistic consideration, the edible mushrooms and its by-products may offer highly palatable, nutritious and healthy food besides its pharmacological benefits.The increasing awareness about high nutritional value accompanied by medicinal properties means that mushrooms are going to be important food item in coming days and at places may emerge as an alternate to non-vegetarian foods. Growing mushroom is economically and ecologically beneficial. Consuming mushroom is beneficial in every respect.

REFERENCES

Adebayo EA, Martinez-Carrera D (2015) Oyster mushrooms (*Pleurotus*) are useful for utilizing lignocellulosic biomass. *Afr J Biotechnol* 14 (1) : 52—67.

Adejumo TO, Awosanya OB (2005) Proximate and mineral composition of four edible mushroom species from South Western Nigeria. *Afr J Biotechnol* 4(10) : 1084—1088.

Adejumo TO, Coker ME, Akinmoladun VO (2015) Identification and evaluation of nutritional status of some edible and medicinal mushrooms in Akoko Area, Ondo State, Nigeria. *Int J Cur Microbiol Appl Sci* 4 : 1011—1028.

Agrahar-Murugkar D, Subbulakshmi GJFC (2005) Nutritional value of edible wild mushrooms collected from the Khasi hills of Meghalaya. *Food Chem* 89 (4) : 599—603.

Aida FMNA, Shuhaimi M, Yazid M, Maaruf AG (2009) Mushroom as a potential source of prebiotics: A review. *Trends Food Sci Technol* 20 (11-12) : 567—575.

Aletor VA (1991) Anti-nutritional factors in some Nigerian feedstuffs, herbage byproducts, crop residues and browse plants. A monograph prepared for the Presidential task force on alternative formulation of livestock feeds.

Alispahić A, Šapčanin A, Salihović M, Ramić E, Dedić A, Pazalja M (2015) Phenolic content and antioxidant activity of mushroom extracts from Bosnian market. *Bull Chem Technol Bosnia Herzegovina* 44 : 5—8.

Bano Z (1993) Food value of mushrooms. *Gram Prandyogiki* 3 : 224—225.

Bano Z, Rajarathnam S (1982) Pleurotus mushroom as a nutritious food. Tropical mushrooms–Biological Nature and cultivation methods (Chang ST, Quimio TH (eds). The Chinese University press, Hongkong.

Bano Z, Bhagya S, Srinivasan KS (1981) Essential amino acid composition and proximate analysis of the mushrooms *Pleurotus eous* and *Pleurotusflorida. Mushroom Newsletter from Tropics* 1(3) : 6—10.

Bano Z, Srinivasan KS, Srivastava HC (1963) Amino acid composition of the protein from a mushroom (*Pleurotus* sp.). *Appl Microbial* 11(3) : 184—187.

Barros L, Baptista P, Correia DM, Casal S, Oliveira B, Ferreira IC (2007a) Fatty acid and sugar compositions, and nutritional value of five wild edible mushrooms from Northeast Portugal. *Food Chem* 105(1) : 140—145.

Barros L, Ferreira MJ, Queiros B, Ferreira IC, Baptista P (2007b) Total phenols, ascorbic acid, β-carotene and lycopene in Portuguese wild edible mushrooms and their antioxidant activities. *Food Chem* 103 (2) : 413—419.

Barros L, Venturini BA, Baptista P, Estevinho LM, Ferreira IC (2008) Chemical composition and biological properties of Portuguese wild mushrooms: A comprehensive study. *J Agric Food Chem* 56 (10): 3856—3862.

Bhupathi P, Krishnamoorthy AS, Uthandi S (2017) Profiling of morphogenesis related enzymes of milky mushroom Calocybeindica (P & C). *J Pharmacog Phytochem* 6 (5) : 2537-2543.

Bonnen AM, Anton LH Orth AB (1994) Lignin-degrading enzymes. *Environm Microbiol* 60 (3) : 960—965.

Brajesh K, Gopal S, Singh VP, Jaydeep P, Prashant M, Debjani C, Seweta S (2018) Effect of commercial button mush room, *Agaricus bisporus.* Appldifferent inorganic additives on spawn run, cropping period and yield performance of oyster mushroom (*Pleurotus* species). *Pl Pathol J (Faisala bad)* 17(1) :19—24.

Carabajal M, Levin L, Albertó E, Lechner B (2012) Effect of co-cultivation of two *Pleurotus* species on lignocellulolytic enzyme production and mushroom fructification. *Int Biodeteriorat Biodegrad* 66 (1) : 71—76.

Carneiro AA, Ferreira IC, Dueñas M, Barros L, Da Silva R, Gomes E, Santos-Buelga C (2013) Chemical composition and antioxidant activity of dried powder formulations of *Agaricus blazei* and *Lentinus edodes. Food Chem* 138 (4) : 2168—2173.

Chen S, Ma D, GeW, Buswell JA (2003) Induction of laccase activity in the edible straw mushroom,*Volvariella volvacea. FEMS Microbiol Letters* 218 : 143—148.

Chang SC, Steinkraus KH (1982) Lignocellulolytic enzymes produced by *Volvariella volvacea,* the edible straw mushroom. *Appl Environ Microbiol* 43 (2) : 440—446.

Chirinang P, Intarapichet KO (2009) Amino acids and antioxidant properties of the oyster mushrooms, *Pleurotus ostreatus* and *Pleurotus sajor-caju. Sci Asia* 35 (2009) :326—331.

Colter I (2020) Detailed Introduction to the Functions and Roles of Enzymes. https://www.pharmiweb.com/article/detailed-introduction-to-the-functions-and-roles-of-enzymes. Accessed: February 12, 2021.

Collin-Hansen C, Andersen RA, Steinnes E (2005) Molecular defense systems are expressed in the king bolete (*Boletus-edulis*) growing near metal smelters. *Mycologia* 97 (5) : 973—983.

Constantinou C, Papas A, Constantinou AI (2008) Vitamin E and cancer: An insight into the anticancer activities of vitamin E isomers and analogs. *Int J cancer* 123 (4) : 739—752.

Das Gupta S, Suh N (2016) Tocopherols in cancer: An update. *Mol Nutr Food Res* 60 (6) : 1354—1363.

Dıez VA, Alvarez A (2001) Compositional and nutritional studies on two wild edible mushrooms from northwest Spain. *Food Chem* 75(4) : 417—422.

Duh PD, Tu YY, Yen GC (1999) Antioxidant activity of water extract of HarngJyur (*Chrysanthemum morifolium* Ramat). *LWT-Food Sci Technol* 32 (5) : 269—277.

Ferreira IC, Barros L, Abreu R (2009) Antioxidants in wild mushrooms. *Curr Med Chem* 16(12) : 1543—1560.

Fletcher JT, Gaze RH(2007) Mushroom pest and disease control: A color handbook (1st edn). CRC Press : 5—16.

Frei B (1994) Reactive oxygen species and antioxidant vitamins: Mechanisms of action. *The Am J Med* 97(3) : S5—S13.

Gruen VEC, Wong HX (1982) Immunodulatory and Antitumour activities of a polysaccharide-peptide complex from a mycelial culture of *Trichoderma* sp. *Sciences* 57: 269—281.

Grune T, Lietz G, Palou A, Ross AC, Stahl W, Tang G,Thurn ham D, Yin S, Biesalski HK (2010) β-Carotene is an important vitamin A source for humans. *The J Nutr* 140(12) : 2268S—2285S.

Guillamón E, García-Lafuente A, Lozano M, Rostagno MA, Villares A, Martínez JA (2010) Edible mushrooms: Role in the prevention of cardiovascular diseases. *Fitoterapia* 81(7) : 715—723.

Han NS, Ahmad WANW, Ishak WRW (2016) Quality charac teristics of *Pleurotussajor-caju* powder: Study on nutritional compositions, functional properties and storage stability. *Sains Malaysiana* 45(11) :1617—1623.

Hatano T, Edamatsu R, Hiramatsu M, Mori A, Fujita Y, Yasu hara T, Yoshida T, Okuda T (1989) Effects of the interaction of tannins with co-existing substances. VI.: Effects of tannins and related polyphenols on superoxide anion radical and on 1, 1-Diphenyl-2-picrylhydrazyl radical. *Chem Pharmaceut Bull* 37(8) : 2016—2021.

Hernández-Rodríguez P, Baquero LP, Larrota HR (2019) Flavonoids: Potential therapeutic agents by their antioxidant capacity. In Bioactive compounds. Woodhead Publishing: 265—288.

Herrera E, Barbas C (2001) Vitamin E: Action, metabolism and perspectives. *J Physiol Biochem* 57 (1) : 43—56.

Ismaya WT, Rozeboom HJ, Weijn A, Mes JJ, Fusetti F, Wichers HJ, Dijkstra BW (2011) Crystal structure of *Agaricus bisporus* mushroom tyrosinase: Identity of the tetramer subunits and interaction with tropolone. *Biochemistry* 50 (24) : 5477—5486.

Jayakumar T, Thomas PA, Geraldine P (2009) *In-vitro* antioxidant activities of an ethanolic extract of the oyster mushroom, *Pleurotus ostreatus*. *Innov Food Sci Emerging Technol* 10(2) : 228—234.

Jeya M, Moon HJ, Kim SH, Lee JK (2010) Conversion of woody biomass into fermentable sugars by cellulase from *Agaricus arvensis. Biores Technol* 101(22) : 8742—8749.

Jha SK, Tripathi NN (2012) Comparative nutritional potential of three dominant edible and medicinal macrofungi of Kathmandu valley, Nepal. *Am J Pharm Tech Res* 2(3) : 1036-1042.

Jiang T, Jahangir MM, Jiang Z, Lu X, Ying T (2010) Influence of UV-C treatment on antioxidant capacity, antioxidant enzyme activity and texture of postharvest shiitake (*Lentinus edodes*) mushrooms during storage. *Post-harvest Biol Technol* 56 (3) : 209—215.

Jose N, Janardhanan KK (2000) Antioxidant and antitumour activity of *Pleurotus florida. Curr Sci* 9 (7) : 941—943.

Kagan VE (1989) Tocopherol stabilizes membrane against phospholipase A, free fatty acids and *Lysophospholipids* a. *Ann New York Acad Sci* 570 (1) : 121—135.

Kalač P (2013) A review of chemical composition and nutrition al value of wild-growing and cultivated mushrooms. *J Sci Food Agric* 93(2) : 209—218.

Kamal-Eldin A, Appelqvist LÅ (1996) The chemistry and antioxidant properties of tocopherols and tocotrienols. *Lipids* 31(7) : 671—701.

Kaul TN (1978) Nutritive value of some edible Morchellaceae. *Ind J Mushroom* 4 : 26—34.

Kayode RMO, Olakulehin TF, Adedeji BS, Ahmed O, Aliyu TH, Badmos AHA (2015) Evaluation of amino acid and fatty acid profiles of commercially cultivated oyster mushroom (*Pleurotussajor-caju*) grown on gmelina wood waste. *Nigerian Food J* 33(1) : 18—21.

Keleş A, Koca I, Gençcelep H (2011) Antioxidant properties of wild edible mushrooms. *J Food Processing Techn*ol 2(6) : 2—6.

Khan M, Motiar R, Ray M, Ray L, Guha AK (2016) Extracellular laccase from *Pleurotus sajor-caju* : Fermentative conditions and influence of nitrogenous. *Sources* 15 : 230—235.

Khatua S, Paul S, Acharya K (2013) Mushroom as the potential source of new generation of antioxidant : A review. *Res J Pharm Technol* 6(5) : 496—505.

Khaund P, Joshi SR (2014) Enzymatic profiling of wild edible mushrooms consumed by the ethnic tribes of India. *J Kore an Soc Appl Biol Chem* 57(2) : 263—271.

Köpcke W, Krutmann J (2008) Protection from Sunburn with β□Carotene—A Meta-analysis. *Photochem Photobiol* 84(2) : 284—288.

Koushki M, Abras SK, Mohammadi M, Hadian Z, Poorfallah NB, Sharayei P, Mortazavian AM (2011) Physico-chemical properties of mushrooms as affected by modified atosphere packaging and CaCl2 dipping. *Afr J Agric Res* (24) : 5414—5421.

Kozarski MS, Klaus A, Nikšić M, Van Griensven LJ, Vrvić M, Jakovljević D (2014) Polysaccharides of higher fungi: Biological role, structure and antioxidative activity. *Hemijska industrija* 68 (3) : 305—320.

Kozarski M, Klaus A, Jakovljevic D, Todorovic N, Vunduk J, Petrovi P,Niksic M, Vrvic MM, Van Griensven L (2015) Antioxidants of edible mushrooms. *Molecules* 20(10) : 19489—19525.

Kulshreshtha S, Mathur N, Bhatnagar P (2014) Mushroom as a product and their role in mycoremediation. *AMB Express* 4(1) : 29.

Kumar B, Kumari C, Kumar M (2018) Effect of Bio-Fertilizers on Mycelial Growth and Physical Properties of White Button Mushroom [*Agaricus bisporus* (Lange) Imbach]. Int *J Curr Microbiol Appl Sc*i 7(2) : 2216—2222.

Leatham GF (1985) Extracellular enzymes produced by the cultivated mushroom *Lentinus edode*s during degradation of a lignocellulosic medium. *Appl Environm Microbiol* 50 (4) : 859—867.

Lee TH, Han YH (2001) Enzyme activities of the fruit body of *Ramaria botrytis* DGUM 29001. *Mycobiol* 29(3): 173—175.

Lobo V, Patil A, Phatak A, Chandra N (2010) Free radicals, antioxidants and functional foods: Impact on human health. *Pharmacog Rev* 4(8) : 118.

Loria-Kohen V, Lourenço-Nogueira T, Espinosa-Salinas I, Marín FR, Soler-Rivas C, Ramirez de Molina A (2014) Nutritional and functional properties of edible mushrooms: A food with promising health claims. *J Pharm Nutr Sci* 4 : 187—198.

Madan M, Bisaria R (1984) Cellulolytic enzymes produced by the edible mushroom, *Pleurotus sajor-caju. Appl Bbiochem Bbiotechnol* 9(4) : 397—398.

Mattila P, Könkö K, Eurola M, Pihlava JM, Astola J, Vahteristo L, Hietaniemi V, Kumpulainen J, Valtonen M, Piironen, V. (2001). Contents of vitamins, mineral elements, and some phenolic compounds in cultivated mushrooms. *J Agric Food Chem* 49(5) : 2343—2348.

Mattila P, Suonpää K, Piironen V (2000) Functional properties of edible mushrooms. *Nutrition* (Burbank, Los Angeles County, Calif) 16 (7-8) : 694—696.

Miles PG, Chang ST (2004) Mushrooms : Cultivation, nutritional value, medicinal effect and environmental impact. CRC press : 1—37.

Mishra AD, Mishra M (2013) Nutritional Value of Some Local Mushroom Species of Nepalanapriya. *J Interdis Studies* 2 : 1—11.

Mohapatra D, Frias JM, Oliveira FAR, Bira ZM, Kerry J (2008) Development and validation of a model to predict enzymatic activity during storage of cultivated mushrooms (*Agaricus bisporus* spp.). *J Food Engg* 86(1) : 39—48.

Mujić I, Zeković Z, Lepojević Ž, Vidović S, Živković J (2010) Antioxidant properties of selected edible mushroom species. *J Central Europ Agric*1(4) : 387—392.

Necla C (2011) Edible Mushrooms: An Alternative Food Item. In Economical and Societal Features, Proceedings of the 7th International Conference on Mushroom Biology and Mushroom Products (ICMBMP7), Convention Center, Arcachon, France: World Society for Mushroom Biology and Mushroom Products 5 : 548—554.

Nour V, Trandafir I, Ionica ME (2011) Effects of pretreatments and drying temperatures on the quality of dried button mushrooms. South Western *J Hort Biol Environ* 2(1) : 15—24.

Oluwafemi GI, Seidu KT, Fagbemi TN (2016) Chemical composition, functional properties and protein fractionation of edible oyster mushroom (*Pleurotusostreatus*). *Ann Food Sci Technol* 17(1) : 218—223.

Packer L, Weber SU, Rimbach G (2001) Molecular aspects of α-tocotrienol antioxidant action and cell signalling. *The J mNutr* 131(2) : 369S—373S.

Panche AN, Diwan AD, Chandra SR (2016) Flavonoids: An overview. *J Nutr Sci* : 5.

Patel S, Goyal A (2012) Recent developments in mushrooms as anti-cancer therapeutics : A review. *3 Biotech* 2(1) : 1—15.

Phan CW, Tan EYY, Sabaratnam V (2019) Bioactive molecules in edible and medicinal mushrooms for human wellness. Journal: Bioactive Molecules in Food Reference Series in Phytochemistry : 1597—1620.

Pontes MVA, Patyshakuliyeva A, Post H, Jurak E, Hildén K, Altelaar M, Mäkelä MR (2018) The physiology of Agaricus bisporus in semi-commercial compost cultivation appears to be highly conserved among unrelated isolates. *Fungal Genet Biol* 12 : 12—20.

Rai M, Tidke G, Wasser SP (2005) Therapeutic potential of mushrooms 4(4) : 246—257.

Reis FS, Barros L, Martins A, Ferreira IC (2012) Chemical composition and nutritional value of the most widely appreciated cultivated mushrooms: An inter-species comparative study. *Food Chem Toxicol* 50(2) :191—197.

Risérus U, Willett WC, Hu FB (2009) Dietary fats and prevention of type 2 diabetes. *Prog Lipid Res* 48(1) : 44—51.

Robaszkiewicz A, Bartosz G, Ławrynowicz M, Soszyński M (2010) The Role of Polyphenols, ß-Carotene and Lycopene in the Antioxidative Action of the Extracts of Dried, Edible Mushrooms. *J Nutr Metabolism* 2010 : 1—9.

Roland J (2019) Why Are Enzymes Important? https://www.healthline.com/health/why-are-enzymes-important. Last Accessed: February 22, 2021.

Sánchez C (2017) Reactive oxygen species and antioxidant properties from mushrooms. *Synth Syst Biotechnol* 2(1) : 13—22.

Singdevsachan SK, Patra JK, Thatoi H (2013) Nutritional and bioactive potential of two wild edible mushrooms (*Lentinus sajor-caju* and *Lentinus torulosus*) from Similipal Biosphere Reserve, India. *Food Sci Biotechno*l 22(1): 137—145.

Smolarek AK, Suh N (2011) Chemopreventive activity of vitamin E in breast cancer: A focus on γ-and δ-tocopherol. *Nutrients* 3(11) : 962—986.

Stajic M, Vukojevic J, Duletic´-Lauševic´ S (2009) Biology of Pleurotus eryngii and role in biotechnological processees A review. *Critical Rev in Biotechnol* 29(1) : 55—66.

Thatoi H, Singdevsachan SK (2014) Diversity, nutritional composition and medicinal potential of Indian mushrooms: A review. *Afr J Biotechnol* 13(4) : 523—545.

Thongnaitham M (2012) Organic Mushroom Cultivation Manual. Freeland Foundation 591 : 56.

USDA (2019) Food Data Central. https://fdc.nal.usda.gov. Accessed : August 12, 2019.

Valverde ME, Hernández-Pérez T, Paredes-López O (2015) Edible mushrooms: Improving human health and promoting quality life. *Int J Microbiol* 2015 : 1—14.

Van Griensven LJ (2009) Culinary-medicinal mushrooms: Must action be taken? *Int J Med Mush* 11(3) : 281.

Vetter J (2019) Biological values of cultivated mushrooms—A review. *Acta Alimentaria* 48(2) : 229—240.

Yamanaka K (1997) I. Production of cultivated edible mushrooms. *Food Rev Int* 13(3) : 327—333.

Zhou S, Zhang J, Ma F, Tang C, Tang Q, Zhang X (2018) In vestigation of lignocellulolytic enzymes during different growth phases of *Ganoderma lucidum* strain G0119 using genomic, transcriptomic and secretomic analyses. *PloS One* 13(5) : e0198404.