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Nutraceutical, pharmaceuticals and industrial bioactive compounds of gasteroid fungi: A review

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ABSTRACT

The gasteroid fungi are the group of macro-fungi within the division *Basidiomycota* which produces spores inside the basidium unlike the other members of basidiomycetous mushroom. The gasteroid fungi are well recognized for their nutritional as well as therapeutic values throughout the world. Their fruiting bodies have been evaluated to be a magnificent source of digestible carbohydrates, proteins and fats with essential amino acids, dietary fibers, vitamins and minerals. Therapeutic significance of this group of fungi includes anti-cancerous activity either by suppressing the tumor cell lines or due to their immuno-modulatory properties through the production of bioactive compounds. The metabolites from them have also been proved to be a natural anti-inflammatory, antibiotics and antifungal agents that may substitute the drugs to provide a healthy food supplement without any adverse effects. The bioactive substances from these macrofungi are also known to lower the blood glucose level by regulating level of alpha amylases and aldolase reductase. The gasteroid fungi also known for potential antioxidant properties and aphrodisiac activity. The present study aims to review the diversity of gasteroid fungi and their role in production of potential bioactive metabolites especially of nutraceutical and therapeutic importance.

Keywords: Bioactive compound, Gasteroid fungi, Nutritional value, Medicinal properties

INTRODUCTION

The fungi as potential nutrient recycler and decomposer play a significant role in ecosystem practices and also have their impact on humans and their activities (Mueller and Schmit, 2007). Among fungi, the macrofungi not only provides a diverse range of food and nutrition to mankind but also make available, innumerable raw material for industries, agriculture and pharmacy (Chang and Miles, 2004). A large number of wild mushrooms are edible but some are toxic too. Therefore, the identification and sensible utilization of these macrofungi is an important exercise. The edible mushrooms with medicinal properties have long been known by humans and were also been used by ancient civilizations as the source of valuable food and medicines as they known to have of high and low-molecular-weight bioactive compounds (Badalyan *et al.,* 2019)

The gasteroid (literally "stomach fungi") are the cluster of macro-fungi within the division *Basidiomycota*. This cluster was formerly placed in the obsolete class *Gasteromycetes* of the order *Gasteromycetales*. The cluster is, moreover, informally positioned in the taxonomic hierarchy as it includes an unnatural heterogeneous assemblage (puff balls, earth stars, stink horn and birds nest fungi) of *Basidiomycetes* having endogenous (within the basidiocarp) production of basidiospores instead of exogenous that occurs in other basidiomycetous fungi (Gogoi and Vipin, 2015). The cluster is polyphyletic displaying morphological variation as their species are not closely related to each other. The gasteroid fungi are the most evolved and display a significant morphological diversity at a glance from other groups of macrofungi. They are cosmopolitan and are more prevalent in dry and warmer parts of the world where soil temperature is high and soil fertility is minimal suggesting a hymeno-mycetous origin for adaptation to xerophytic condition (Smith and Weber, 1980), in contrast to some species of stinkhorns and their allies found in the wet tropic and also on temperate sand dunes. Nutritionally, most of the species are saprobic in soil and some are growing on dung (coprophillus) and rooten wood (lignicolous), tree stumps, on decaying logs, or on the ground in the woods, hidden under leaf litter (Geastrum), city lawns, grassy open field and also hot desert (Gehlot *et al.,* 2020) while, a few have ectomycorrhizal association (Scleroderma) forming a mutually beneficial relationship with the roots of living trees (Gehlot and Singh, 2015). Further, there are two aquatic gasteroid fungi, *Niavibrissa* is marine and grows on the drift wood in the sea that is also called a marine white rot gasteroid fungus (Julich, 1981) and *Limnoperdon*, grows in marshy places (Escobar *et al.,* 1976; Hibbett and Binder, 2001). The fruiting bodies of most of gasteroid fungi are epigean (Blackwell and Spatafora, 2004), although some forms do produce their basidiocarp beneath the surface of soil are called hypogean (*Rhizopogon*).

The gastroid have characteristic angiocarpic (basidiocarp) fruit bodies together with aseptate halo-basidia and passive release of basidiospores (statismospores) as the basidia are not involved in the release of spore. These basidiocarp ranges from a few mm (2 mm in *Sphaerobolus*) to over one meter in diameter (*Calvatia*). The fruit bodies are stalked either with true (consists of parallel hyphae) or pseudo stem (made of spongy tissue). The inner fertile portion of basidiocarps known as gleba remain covered with sterile jacket called peridium that further consists of exoperidium, mesoperidium and endoperidium. Additionally, gleba comprises basidia and trama (sterile tissues) that may or may not include columella and capillitium. Columella are involved in conduction of nutrients whereas, capillitium helps in efficient dispersal of spores. The gleba at maturity may be dry and powdery or fleshy and slimy. The peridium may be firm and hard or thin and papery. The basidiocarp of gasteroid fungi generally remain permanently closed and the dispersal of spores takes place either through the disintegration of peridium through external agents or through inbuilt mechanism occurs once the spores get matured. Only a few species have been cultured in laboratory, and in most cases even the spore germination fails on synthetic media (Phutela *et al.,* 1998; Doshi *et al.,* 1999).

A wide range of basidiomata structure occurs among the gastroid fungi and these characteristic life-forms results in the designation of many genera monotypic or having limited number of species. Trierveiler-Pereira and Baseia (2009) have recorded about 232 gasteroid species from Brazil which are distributed among the 54 genera and 16 families with few prevailing species as *Morganella fuliginea, Calvatia cyathiformis, Geastrum saccatum, Scleroderma albidum* and *S. verrucosumas*.

The gasteroid genus like *Scleroderma* that contains both epigeous and hypogeous components were discussed imposing the molecular techniques regarding secondary metabolites, development, spore morphology, and anatomy (Watling, 2006). The mushrooms, like higher plants, have ability of bioaccumulation of phytochemicals with potential medicinal properties (Akgul *et al.,* 2017). The synthetic drugs although provide a rapid relief but they are also toxic in many ways. Therefore, there is a need for adapting the natural pharmaceutical products with few or none adverse effects. The mushrooms exhibit antimicrobial, antibacterial, anti-carcinogenic, antioxidant, antiviral, anti-inflammatory, anticoagulant, cytotoxic, cytostatic, antiatherogenic, antioxidant, anti-allergic, hypoglycemic and immuno-suppressive properties (Lam *et al.,* 2001; Sano *et al.,* 2002; Barros *et al.,* 2007; Olennikov *et al.,* 2011). In mushrooms both the fruiting bodies and mycelial mass constitutes diverse forms of compounds including flavonoids, alkaloids, polysaccharides, polyglucans, polyphenol, steroids, terpenoids, polyketides and dietary fibers with numerous pharmacological activities (Thatoi and Singdevsachan, 2014). The basidiomycetous-mushrooms are also efficient in degradation of lignin as they utilize all major cell wall components (Jasalavich *et al.,* 2000).

Determination of biological activities of mushrooms is significant to reveal new pharmacological agents. Decisively the gasteroid-mushrooms have ability for diverse therapeutic metabolites having potential biological activities and thus make it important to characterize not only their compounds but also taxonomic positions so that the researchers can screen their taxa for future biotechnological applications. The gasteroid fungi although has been exploited well for their potential use in biocontrol, bioremediation and novel bioactive compounds but extensive research is required to ensure the role these fungus for potential biotechnological and pharmacological applications. Further, out of 83 genera known of gasteroid fungi only few have been explored potentially for their bioactive compound and further, among the explored once there is not any concise report available that undertakes the nutraceutical bioactive compounds, pharmaceuticals compounds with therapeutic use like anticancerous, antibiotic, antioxidants, antidiabetic, immunomodulatory, antibacterial and antifungal properties including the industrial and ethnomycological uses and application of gasteroid bioactive compound. Therefore, this review tried the compile the scattered literature available for majority of gasteroid genera known for significant bioactive compounds under diverse categories that likely to be beneficial for research communities.

NUTRITIONAL AND NUTRACEUTICAL BIO-ACTIVE COMPOUNDS

The edible mushrooms flourishing in their natural habitats were always conventionally valued for their health promoting attributes (Crisan and Sands, 1978) and were exploited as a prevailing nutraceutical source having great aroma and flavor (Kalač, 2016). The great amount of energy with low amount of fats makes them an important food supplement and natural endowments. The fruit bodies gasteroid mushrooms are found to be magnificent source of digestible carbohydrates and protein with essential amino acids, dietary fibers, vitamins and minerals (Yin and Zhou, 2008; Liu *et al.,* 2012; Vishwakarma *et al.,* 2017). The mushrooms in the current world are also regarded as therapeutic foods or nutraceuticals due to the presence of compound in their fruit bodies having great pharmacological properties (Barros *et al.,* 2008).

Astraeus hygrometricus is known to have too hard fruiting bodies to be consumed in North American regions (Miller and Miller, 2006). In contrast to this its collected and sold in the markets of India and Nepal as one of the delicious foods (Maiti *et al.,* 2008). In southeast Asia the species of *Astraeus* were reported to have an abundance of volatile compound of eight carbon including furfural, benzaldehyde, cyclo-hexenone, and furanyl (Kakumyan and Matsui, 2009). Similarly, the *Battarrea phalloides* and *B. stevenii* are also described as unknown edibility. However, in Cyprus, the immature egg-form of the fruit body is eaten (Miller and Miller, 2006; Roberts and Evans, 2011). The young fruiting bodies or the puffballs of the genus *Bovista* are edible till they are white inside as they can be jumbled with immature Amanitas which are potentially deadly harmful (McKnight and McKnight, 1998). Additionally, the immature fruit bodies of *Geastrum triplex* having white and firm gleba are also edible although it's very much uphill task to obtain the fruiting bodies in this condition (Rinaldi and Tyndalo, 1985). Similarly, the immature puffballs of *Calvatia craniiformis* with a firm, white gleba and mild odor prior to formation of spores are also edible (Meuninck, 2017). The gasteroid *Calvatia gigantea* is also known to have polyunsaturated fatty acids, proteins, carbohydrates, gentisic acid (a phenolic compound) and hexanal (an aroma compound) that make it a capable source of healthy food supplements (Kıvrak *et al.,* 2014).

Dictyophora indusiata (bamboo mushroom) is consumed in China due to its nutritive bioactive compounds that benefits eyes and cardiovascular system and for its moderate medicinal values. The fungus consists around twelve vital metal ions, seven essential amino acids, carotenes, water soluble vitamins (thiamine, riboflavin, nicotinic acid and vitamin C) and minerals like calcium and phosphate (Ker *et al.,* 2011). Likewise, the edible mushroom *Lycoperdon perlatum*, also known as "poor man's sweetbread" (due to their flavor and texture), is considered to be a great source of food till the gleba is homogeneous and white and become inedible when gleba becomes yellow-tinged (Dickinson and Lucas, 1982). The fungus is well known to contains an unusual and exclusive amino acid lycoperdic acid. The study of Colak *et al.* (2009) revealed that the 100 g dried mass of puffballs contains 42 g carbohydrates, 10.6 g of fats and 44.9g of proteins together with trace number of micronutrients including copper, iron, manganese and zinc. The predominant fatty acids in fruit bodies are mainly the unsaturated one including palmitic, linoleic, oleic and stearic acid (Nedelcheva *et al.,* 2007).

The fruit bodies of *Mutinus caninus, Phallus ravenelli* and *P. impudicus* are known to edible in north America (McIlvaine and Macadam, 1900). At immature egg stage, the crisp and crunchy receptaculum of *P. impudicus* with radishy taste ts eaten either raw or as pickle and sausages in France and Germany (Zeitlmayr, 1968; Bon *et al.,* 1987). Similarly, the eggs of gasteroid *Clathrus dbarius* were are eaten by the Maori trible peoples of New Zealand with an inappropriate name "thunder dirt". Additionally, some members of the order *Hymenogastrales* are also being consumed as substitute of truffles (Berkeley, 1867). The fungus *Hymenogaster citrinus*, *Rhizopogon luteolus* and *R. rubescens* are considered edible by mycophagists of England and are being eaten by the local population (Ramsbottom, 1953). The order *Lycoperdales* constitutes the majority of edible species including *Calvatia, Lycoperdon* and *Bovista* in north America (McIlvaine and Macadam, 1900).

Fruit bodies of *Phallus indusiatus* particularly in eastern part of Asia is well known for its delicacy and are kept reserved for the special occasions. The mushroom has an attractive shape, tender texture and it remain crisp which make them a decent source of food within the localists. The mushroom in its dehydrated forms is sold in the local markets and can be used in verity of ways as they can be rehydrated by soaking and can be used in stir-fry's (cooked in small amount of oil), in chicken soups, stuffed etc. (Newman, 1999; Halpern, 2007). The nutritional composition of *P. indusiatus* at egg stage per 100 g of dry fungus weight contains 1:30 ratio of fats and proteins respectively with 20.9 g dietary fiber and mineral composition as calcium (61.0 mg), copper (1 mg), iron (36.6 mg), magnesium (156 mg), manganese (5.1 mg), potassium (153 mg), sodium (5.1 mg) and zinc (133 mg) (Jonathan et al., 2008).

Phellorinia inquinans is well known for edibility and considered to be a source of high nutraceutical compounds (Gehlot *et al.,* 2016). The sporophore contains around 23 % crude proteins, 9% carbohydrates, 13% fibers and trace amount of lipids along with vital minerals like potassium, phosphorus, calcium, and magnesium (Jandaik, 1977; Doshi and Bohra, 2000). The mushroom also contains a good amount of essential and non-essential amino acids (Sharma *et al.,* 2015). Correspondingly, *Podaxis pistillaris* is utilized in India and Arab countries as a culinary and gourmet sustenance (Singh *et al.,* 2006; Gehlot and Singh, 2016). The fruiting body of *P. pistillaris* contains high values of protein and carbohydrates and at the same time have low fat values that makes them an important supplement to food. The 100 g of the dry weight comprises 14.5 g protein, 1.97 g fats and 77.79 g carbohydrates. Further it also contains phenols, flavonoids, steroids and β-carotene (Mridu and Atri, 2017) and minerals like Na, P, K, Ca and Mg (Abdalla *et al.,* 2016).

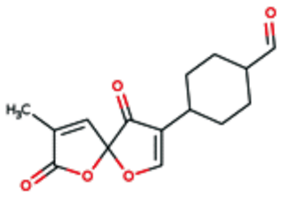
The *Rhizopogon roseolus* is also known to be edible in East-Asia particularly in Japan and the commercial cultivation of the mushroom is also been successfully established in Japan and New Zealand (Yun and Hall, 2004). Chittaragi *et al.* (2014) were tried to evaluate the macro nutrient profiles of *Scleroderma bermudense* and observed that wild mushrooms contain dry matter (9.49), protein (36.32%), ash (4.45-10.29%), lipid (2.79%), fiber (11.44%) and carbohydrate (42.55%) while *Geastrum triplex* contain carbohydrates (40.83%), lipid (2.06 %), protein (27.41%) and fiber (3.77%). Abdalla *et al.* (2016) studied proximate composition of *Calvatia cyathiformis* and estimated 40.47% crude protein 3.05% crude fat, 24.83% carbohydrate, 16.25% crude fiber with mineral constituents of sodium, potassium, phosphorous, calcium and magnesium. Agrahar-Murugkar and Subbulakshmi (2005) estimated 27.3% protein, 1.0% lipid/fat and 22.0% fiber with minerals nutrients (Ca, P, Fe, Mn, Cu, Zn, Na, K, Mg and Se) in *Calvatia gigantea*. Pavithra *et al.* (2018) attributed nutritional quality of edible gasteroid wild fungus *Astraeus hygrometricus* and quantified crude protein 16.80%, total lipids 3.55%, crude fibre 14.58% and total carbohydrates 46.17% with adequate quantity of some important minerals and six essential amino acids. Therefore, the mushroom is a low energy healthy food that can be utilized as a protein supplements which have adequate amount of carbohydrates, essential amino acids, fibers, important vitamins and minerals.

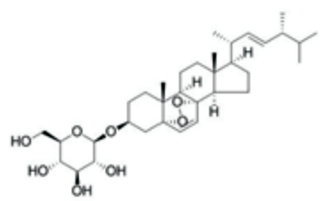
PHARMACEUTICAL COMPOUNDS/ THERAPEUTIC SIGNIFICANCE

Anti-cancerous and anti-tumor compounds

The extract of *Astraeus hygrometricus* with a chief polysaccharide AE2 was reported to have profound inhibitory ability against several tumor line *in-vivo* (Mallick *et al.,* 2010). The AE2 is composed of mannose, glucose and fucose in a 1:2:1 ratio and it is known to be activated by a signal transduction pathway mediated by mitogen-activated protein kinase pathway (Mallick *et al.,* 2011). Additionally, the extract was also reported to stimulate the growth of splenocytes, thymocytes, and bone marrow cells in mice (Mallick *et al.,* 2011). The puffballs of *Calvatia* are the chief source of calvacin (an anti-tumor mucoprotein), although found in very small quantities but the compound is known to stimulate the immune cells (Coetze and Wyk, 2009).

Mannan having the molecular weight of 620 kDa have been extracted from the liquid cultures of *Dictyophora indusiata* exhibited strong anticancer bioactivity (Hara *et al.,* 1982). Similarly, the polysaccharides from fruiting body showed immuno-suppressive effect on prostate-cancer-associated fibroblasts (Habtemariam, 2019). Erkel *et al.* (1996) reported two vital cytotoxic sesquiterpene compounds nidulal and niduloic acid from *Nidula candida* having significant role in the upregulation of human promyelocytic leukemia cells differentiation. Moreover, fungus is also known as a potent scavenger of superoxide anions that shields the lipoproteins of plasma membrane from peroxidation predicting its anti-cancerous and immuno-stimulatory effects (Wei, 2005).

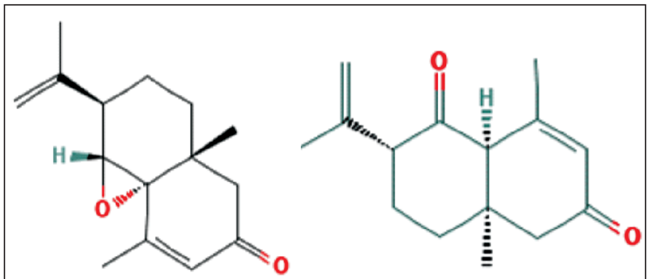

Nidulal C15H16O5


Ergosterol peroxide 3-glucoside

Gasteroid mushroom *Phallus indusiatus* is known to have a bioactive polysaccharide that have a structure constituted chiefly with D-mannopyranosyl residues linked with α-1→3 linkages together with traces of 1→6 linked D-mannopyrosyl residues (Ukai *et al.,* 1980). The polysaccharide was found to have a potent tumour-suppressing ability against subcutaneously implanted sarcoma (Ukai *et al.,* 1983). Kovacs *et al.,* (2018) has isolated and characterized an antiproliferative secondary metabolites from the potato earthball mushroom, *Scleroderma bovista*. He observed that the lanostane-type derivatives and ergosterol peroxide 3-glucoside exerted significant antiproliferative property on one or more human cancer cell lines on MTT assay.

Immuno-modulatory properties

The extract of *Astraeus hygrometricus* was found to encourage cell of immune system in mouse where it stimulated the activity of natural killer cells, macrophages to produce nitric oxide and enhanced production of cytokines (Chakraborty *et al.,* 2004). Under in-vitro conditions the polysaccharides extracted from the fruiting bodies of *Dictyophora indusiata* showed a significant immuno-stimulatory effect as these were found to induced a proliferative response whereas, the cytokines, No synthase and nuclear factor k-light-chain-enhancer of B-cells as the markers of macrophages were also upregulated (Deng *et al.,* 2016). In same context the study of Han *et al.,* (2017) on prostate cancer fibroblasts showed that the fungal polysaccharides not only induced the proliferation of lymphocytes but also upgraded the growth of suppressed CD4+/CD8+ T cells.


Dictyophorine-A and Dictyophorine-B ($C_{15}H_{20}O_2$)

Dictyophorine-A and Dictyophorine-B are the two novel sesquiterpenes that have been isolated from the fruit bodies of fungus *Phallus indusiatus* (Kawagishi *et al.,* 1997). The compounds are characterized as the pioneer eudesmane derivatives with potential to induce the nerve-growth-factors (NGF) in astrocytes, the cells which forms the blood brain barriers (Kawagishi *et al.,* 1997). Additionally, Liu (2005) reported the quinazoline derivatives (Dictyoquinazol A, B, and C) isolated from the fungus have a shielding effect on neurotoxins exposed mouse neurons.

Anti-inflammatory activity

Inflammation in general is defined as a complex biological process, induced by natural microbial infection or by accidental damage of tissues (García-Lafuente *et al.,* 2009). The inflammation may leads to various rheumatic disorders such as fever, arthritis, ankylosing spondylitis (Anilkumar, 2010). In other word the Inflammation can be defined as body defense activities in order to limit or eliminate the spread of injurious agent; oedema, leukocyte infiltration, and granuloma formation etc. can be observes as a byproduct of the process (Amdekar *et al.,* 2012). There are many of the drugs which available to counter the inflammatory responses but these are toxic too that have a severe side effect including various gastrointestinal problems (Bisht *et al.,* 2014). Therefore, there is need of natural anti-inflammatory drug with significant functionality and without imparting any side effects.

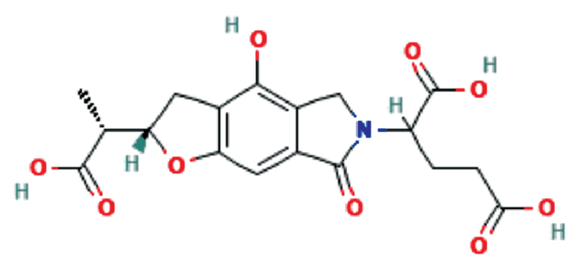
The ethanolic extract of *Astraeus hygrometricus* fruit bodies showed anti-inflammatory activity comparable to the drug diclofenac in laboratory experiments (Biswas *et al.,* 2010). Furthermore, the two water soluble glucans, having β −1 →6 branches linked to β-(1→3)-D glucose main frames, isolated from the liquid cultures of *Dictyophora indusiata* showed significant anti-inflammatory responses (Hara *et al.,* 1982).

A β-glucan protein complex isolated and characterized from *Geastrum saccatum* found to inhibit the inflammatory enzymes like nitric oxide synthase and cyclooxygenase and thus proved to be a substantial anti-inflammation agent (Dore *et al.,* 2007). The lipoxygenase (LOX) enzymes are responsible for the development of leukotrienes (LTs) that increases under rheumatic conditions and plays a vital role in pathophysiology of various inflammatory diseases. The inhibition of LOX pathway directly prevents the formation of LTs (Yahaya and Don, 2012). The methanolic extract from *Geastrum fimbriatum* has been tested for lipoxygenase inhibition essay and observed to have 12.92% inhibition (Sarac *et al.,* 2019). Similar, reports were also obtained from the study of Dore *et al.* (2007) on *Geastrum saccatum* extract that found to be a potential inhibitor of enzyme cyclo-oxygenase.

The puffballs of *Mycenastrum corium* are although very thick due to their outer periderm but these puffballs are also used for their alleged anti-inflammatory properties in Mexico (Pérez-Silva *et al.,* 2015). A bioactive polysaccharide β-D-glucan, named as T-5-N isolated in alkaline extracts from the fruit bodies of *Phallus indusiatus* contains significant anti-inflammatory properties (Ukai *et al.,* 1983).

Anti-diabetic activity

The species of genus *Bovista* are suggested to improve diabetes mellitus (Jain, 1997). The whole fruiting body extract of Calvatia gigantea showed a significant in-vitro alpha amylase inhibitory activities and *in-vivo* antidiabetic activity that underlined the facts that the gasteroid fungi could be used potentially as a functional antidiabetic (Ogbole *et al.,* 2019). Matsumoto *et al.* (1995) extracted new bioactive compounds designated as salfredins from the liquid cultures of the fungus *Crucibulum laeve*. salfredins have structural resemblance with benzofuran and chromene containing cyclic amide or lactone ring structures. These salfredins have therapeutic use as it inhibits the enzyme aldose reductases responsible for the formation cataracts during the advanced stages of diabetes mellitus (Kyselova *et al.,* 2004; Srivastava *et al.,* 2005).



Salfredins (C18H19NO9)

The alkali extracted polysaccharides from *Dictyophora indusiata* was proved to have a direct glucose lowering effect and also regularized the serum adiponectin level, insulin and leptin (Wang *et al.,* 2019).

Antioxidant properties

The reactive oxygen species in form of free radicals including superoxides, hydroxyl ions are produced as a byproduct of human physiological processes that causes oxidative stress by reacting with different biomolecules such as proteins, lipids, DNA etc. (Gülçin *et al.,* 2002). Although the living organism itself possesses variety of endogenous defense system to counter the oxidative damages but the supportive exogenous supply of antioxidants is always essential that scavenge the free radicals and maintains the normal physiology of the cells (Halliwell and Gutteridge, 2015). Not only in the living systems but also the preservative foods require these antioxidants to counter the peroxidation and therefore synthetic antioxidants like propylgallate, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and tertabutylhydroquinone are used as preservative. These artificial scavengers cause variety of damages such as liver-cirrhosis and carcinogenesis and affects the normal physiology (Hettiarachchy *et al.,* 1996). Therefore, there is need of antioxidants from natural compounds without any adverse effects and none is more important than mushrooms that produce variety of bioactive compounds with a known and potential antioxidant properties (Caleja *et al.,* 2017).

The ethanolic extract of *Astraeus hygrometricus* fruit body have shown significant antioxidant activity. Clinical studies have revealed the hepatoprotective properties in mouse as the extract found to restore the diminished levels of superoxide dismutase and catalase (antioxidant enzymes) in mouse exposed with carbon tetrachloride (Biswas *et al.,* 2011). Likewise, the polyketide-antioxidants such as cyathusals, pulvinatal and cyathuscavin was identified in the liquid cultures of *Cyathus stercoreus* which showed antioxidant and nucleic acid protection activities (Kang *et al.,* 2007). Polysaccharides from *Dictyophora indusiata* showed a potent antioxidant activity in *Caenorhabditis elegans* under the oxidative stress conditions induced with parquet where it decreased the level of reactive oxygen species (ROS) and malondialdehyde (MDA) and showed increased levels of SOD (Zhang *et al.,* 2016).

Sevindik *et al.* (2017) determined the total antioxidant status (TAS), total oxidant status (TOS), oxidative stress index (OSI) of *Geastrum pectinatum* mushroom and found that the methanolic extract of the mushroom showed a significant TAS value and could be consumed as an alternative antioxidant source. In the same context, chemical constituents and antioxidant activity of the Arctic mushroom *Lycoperdon molle* has been exploited in the study of Singh *et al.* (2012) where, in order to determine the in-vitro antioxidant potential, fungal fruiting bodies were extracted in 20 ml of methanol, ethanol, acetone and DMSO using a soxhlet extractor. The extracts were tested for free-radical scavenging (FRS) activity, inhibition of lipid peroxidation (ILP) and Trolox equivalent antioxidant capacity (TEAC) and concluded to have more than 50% potential for FRS, ILP and TEAC with maximum FRS in methanolic extract (89%). The strong correlation between the antioxidative potential and higher polysaccharide concentration has also been established that also corroborate the findings of Liu *et al.* (1997), who also reported that the polysaccharides have the ability to scavenge free radicals.

The extracts of the fruit body of *P. indusiatus* contains antioxidant properties due to the presence of polyphenols, known to counter the cellular damage due to the formation of ROS (Mau *et al.,* 2002). Similarly, the extracts of mushroom *Phellorinia herculeana* was analyzed for radical scavenging effect by the DPPH assay. The extracts showed inhibition values greater than 90% (concentration of 500 mg) comparable with the activity of the reference compound ascorbic acid (Al-Fatimi *et al.,* 2005). Furthermore, the gasteroid mushroom *Podaxis pistillaris* is also considered as an important antioxidant source due to presence of secondary metabolites such as phenols, flavonoids, steroids, β-carotene and lycopene in its fruit bodies (Mao, 2000; Mridu and Atri, 2017).

Antibiotics compounds

The macro-fungi are also rich sources of natural antibiotics. The glucans as a component of their cell wall along with several secondary metabolites showed antibacterial, antifungal and anti-viral activities and are known to be potential immuno-modulators (Cohen *et al.,* 2002). Although the medicinal values of these wild mushrooms have been exploited nowadays but they have a history of traditional medicine for curing various types of diseases (Iwalokun *et al.,* 2007).

Gasteroid Cyathus striatus in 1971 was first time reported to have ability for the production of compounds with an indole ring collectively known as indolic-substances in addition to a complex of diterpenoid antibiotic compounds known as cyathins (Allbutt *et al.,* 1971). These indolic substance were later on named as striatins with potential antibiotic activity against imperfect fungi, gram positive and negative bacteria (Anke *et al.,* 1977).

Akpi *et al.* (2017) studied the antimicrobial activity and phytochemical characteristics of the crude extract of *Lycoperdon perlatum*. The phytochemicals analysis using the ethanol, methanol and water extracts of puffballs suggested the presence of diverse bioactive compound including flavonoids, saponins, protein, carbohydrate and glycosides. The agar gel diffusion methods were applied in order to evaluate the antimicrobial activity. The aqueous extract showed retardation in growth of all the tested microbes including *Staphylococcus aureus, Bacillus cereus, Candida albicans* except *Pseudomonas aeruginosa* while the methanol and ethanol extracts was found to be most effective as they inhibited all the tested organisms. The outcome suggests the gasteroid as a broad-spectrum antimicrobial agent. Moderate antibiotic activity were also reported from *Nidula candida* due to two bioactive fifteen-carbon sesquiterpene compounds, nidulal and niduloic acid (Erkel *et al.,* 1996).

Addition of fungal extract of *Phallus indusiatus* in the liquid broths prevent it from spoiling for many days. The extracts were also tested against numerous human pathogens and reported to be a decent substitute for the antibiotic's ampicillin, tetracycline, and nystatin (Habtemariam, 2019). An antibiotic albaflavenone was later on isolated from the fungus that's chemically a sesquiterepene already known from *Streptomyces albidoflavus* (Huang *et al.,* 2011).

Antibacterial activity

An increase in the resistance to existing antibiotics put an enormous load on pan-scientific community for innovation and discoveries of the new emerging antibiotics and for this none have more potential than the herbs, plants and mushrooms (Iftekhar *et al.,* 2011). The production of antimicrobial metabolites from the mycelial or spore culture of wild mushroom has been reported substantially throughout the world (Hasan *et al.,* 2015). *Cyathus helenae* has been shown to produce a complex of metabolites so called cyathin complex that has antimicrobial properties and showed to inhibit the growth of actinomycetes, bacteria and some fungi (Allbutt *et al.,* 1971; Ayer and Taube, 1972). In 2008, five lanostane-type triterpenes were isolated and identified from the fruit bodies of *Astraeus pteridis*; two of these compounds had an inhibitory effect on the growth of the pathogen *Mycobacterium tuberculosis* with antituberculosis activity (Stanikunaite *et al.,* 2008).

The liquid extract of *Dictyophora indusiata* exhibited a weaker activity against microzymes and molds but found to have immensely potential anti-bacterial activity (Hao *et al.,* 2008). The well-known antibiotic albaflavenone has also been isolated from *D. indusiata* which is a module of streptomyces and its biosynthesis pathway and activities have been the subject of many microbial studies. Chittaragi *et al.* (2013) demonstrated the antibacterial activities of petroleum ether, chloroform and methanol extract of mushroom *Geastrum triplex* using agar well diffusion method on three plants and six human pathogenic bacteria. They observed maximum antibacterial activity of chloroform extracts against *Xanthomonas campestris* and of methanol extract against *Agrobacterium tumefaciens*. Further concluded that chloroform extracts showed promising antibacterial activity against plant pathogens then other two whereas, the petroleum ether extract were found more effective against human pathogenic bacteria.

Methanolic extracts of *Lycoperdon umbrinum* with terpenoids as key component has showed a significant anti-bacterial activity against numerous human pathogens including *Bacillus subtilis, Escherichia coli, Salmonella typhimurium, Staphylococcus aureus, Streptococcus pyogenes,* and *Mycobacterium smegmatis* (Dulger, 2005) and found moderately effective against *Enterococcus faecium* and *Staphylococcus aureus* (Suay *et al.,* 2000). Similarly, the extract from species *L. perlatum* showed antibacterial activity analogous to the antibiotic ampicillin and inhibits the growth of numerous human pathogens including *Bacillus subtilis, Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa* (Ramesh and Pattar, 2010). Additionally, the study of Dulger (2005) found similar antagonistic activity against *Mycobacterium smegmatis, Salmonella enterica* and *Streptococcus pyogenes*.

The extracts from the fruit bodies of fungus *Mutinus elegans* showed an antibacterial activity against the five human pathogenic bacteria *Salmonella typhimurium, Bacillus cereus, B. subtilis, Escherichia coli,* and *Staphylococcus aureus* (Coletto and Lelli, 1998). Likewise, dichloromethane, methanol and water extracts of mushroom *Phellorinia herculeana* showed a potential antagonistic activity against *Streptomyces aureus* and *Bacillus subtilis* in agar diffusion assay whereas, the bacteria *Mariniluteicoccus flavus* and *Candida maltosa* found to be resistant against all three extracts. Additionally, the dichloromethane and methanol extract of fungus found to be effective against E. coli and P. aeruginosa but both showed resistance against water extracts (Al-Fatimi *et al.,* 2005). In the same context, Gehlot *et al.* (2018) tested the ethyl acetate extract of *P. herculeana* fruiting bodies for their efficacy against five human pathogenic bacteria *E. coli, Vibrio cholera, Salmonella enteric typhimurium, S. aureus* and *Enterococcus faecalis* using the agar gel diffusion method and observed that crude extract checked the growth of all the five pathogenic bacteria, further, gas chromatography mass spectroscopy analysis of crude suggested the presence of decane, 1-chloro- and dodecane, 1-chloro responsible for this activity.

Antagonistic activity of *Podaxis* sp. was determined against the number of pathogenic gram negative and positive bacteria like *P. aeruginosa, Proteus mirabilis* (Panwar and Purohit, 2002), *S. aureus, Micrococcus flavus, B subtilis, Proteus mirabilis, Serratia marcescens* and *E. coli* (Al-Fatimi *et al.,* 2006). Al-Fatimi *et al.* (2006) identified three possible antibacterial compounds as epidi-thio-diketo-piperazines *viz.,* epicorazine A, epicorazine B and epicorazine C.

Antifungal activity

A number of *Cyathus* species are reported to be effective against some of the human pathogens like *Cryptococcus neoformans* (infects lungs and central nervous system), *Aspergillus fumigatus* (causes chronic pulmonary infections) and *Candida albicans* (causes genital yeast infections) (Liu and Zhang, 2004). Liquid broth cultures of *Geastrum* species were found to have effective anti-microbial activities against pathogenic fungi *Candida krusie, C. albicans,* and *Trichophyton mentagrophytes in-vitro* in agar cup diffusion method on potato dextrose broth medium (Panda *et al.,* 2017).

A number of fungal species including *C. albicans, Aspergillus fumigatus, Botrytis cinerea* and *Verticillium dahliae* showed a significant retardation in their growth when subjected to the puffballs extract from the mushroom *Lycoperdon perlatum* (Pujol *et al.,* 1990). The extract from *Mutinus elegans* showed a potential anti-fungal activity against the yeast *C. albicans* (Coletto, 2006). In the same context, the ectomycorrhizal fungi *Scleroderma citrinum, Lycoperdon perlatum* and *Pisolithus albus* was found to have antifungal potential against *Alternaria solani, Botrytis* sp., *Fusarium oxysporum, Phytophthora* sp., *Pythium* sp. and *Rhizoctonia solani* in various capacity in *in-vitro* conditions (Mohan *et al.,* 2015). These species were further quantitatively assessed for the production of enzyme chitinase and found to have around 38.99 µg/ml in *S. citrinum* and 32.38 µg/ml of chitinase in *P. albus* (Mohan *et al.,* 2015). Similarly, Soytong *et al.* (2014) isolated two bioactive lanostane-type steroid compounds named 4,4-dimethoxy-methyl vulpinate (DMV) and 4,4-dimethoxyvulpinic acid (DMVA) from fruiting body of *S. citrinum* which were found significantly inhibiting the growth of *Phytophthora palmivora* and *Colletotrichum gloeosporioides*.

Two important antibiotic compounds named pisolithin-A (p-hydroxy benzoyl formic acid 2-(4'-hydroxyphenyl) 2-oxoethanoic acid) and pisolithin-B (p-hydroxymandelic acid (R)-(-)-2-(4'-hydroxyphenyI)-2-hydroxyethanoic acid) has been extracted from the cultures of *Pisolithus tinctorius*. These compounds are well characterized for their inhibitory potential towards the germination of spores of many plant pathogenic fungal species like *Phytophora* sp., *Rhizoctonia solani, Fusarium solani, Pythium ultimum* (Tsantrizos *et al.,* 1991). These gasteroid fungi not only act as biocontrol agent against phytopathogens but also can contributes in plant growth promotion by production of various phytohormones including indole acetic acid, cytokinin and gibberellin (Ek *et al.,* 1983).

Other therapeutic uses

The cyathane-diterpenoids isolated from the *Cyathus* spp. has been reported to stimulates nerve growth factor (NGR) synthesis that ensures their therapeutic potential for treatment of Alzheimer's disease (Krzyczkowski *et al.,* 2008). The patients with recurring breast cancer have tendency to develop the blood clots in vein (venous thrombosis) that contributes majority of the death incidence in cancer survivors, therefore, they have to kept lifelong on the anticoagulants. The extract from the fruit bodies of fungus Phallus impudicus have potential to reduce the clumping of platelets and thus can be utilize as supportive preventive nutrition (Kuznecov *et al.,* 2007).

Fruit bodies of *Scleroderma polyrhizum* comprise steroids ergosta-4,6,8(14) 22-tetraen-3-one and 5α,8α-epidoxyergosta-6,22-dien-3β-ol along with unsaturated fatty acids palmitic and oleic acids and are used as a conventional Chinese medicine for the treatment of detumescence and hemostasis (Xianling *et al.,* 2005).

The spore mass of *Podaxis pistilaris* and *Geastrum triplex* are used in skin disease and skin burns (Kumar *et al.,* 2017). The spore mass of *Astraeus hygrometricus* mixed with mustard seed oil is used as an ointment for burn cases (Rai *et al.,* 1993). The spores of *Pisolithus arrhizus* are used as medicine for treatment of wounds (Manna *et al.,* 2014). *Calvatia gigantea* is used in stomach upset and to cure stomach pains in women during menstruation (Thangaraj *et al.,* 2017). The spore of *Lycoperdon perlatum* is used to dress wounds for quick healing of wound and also to stop bleeding (Pala *et al.,* 2013). *Bovista plumbea* is used for the treatment of sores, ulcers and skin infection (Devi *et al.,* 2016). *Rhizopogon villosulus* is used against kidney stone, urinary tract infections and also to cure fatty liver and asthma (Malik *et al.,* 2017).

Gasteroid fungi are not only responsible for the production of substance that humans can use directly as medicines but also these are the versatile tools in the vast field of medical research. The utilization of *Bovista stevenii* spores as substance responsible for promoting the process of healing through the re-formation of scar tissues (Scarpa, 2004). Similarly, *Mycenastrum corium* can be used remedially in Mexico as a hemostatic and also as a tonic for throat and lungs (Pérez-Silva *et al.,* 2015).

The gasteroid fungi are also known to have products which were previously not known from the biological origins. Three exclusive triterpene derivatives of 3-hydroxy-lanostane having δ-lactone (a six-membered ring) in the side chain have been isolated from *Astraeus hygrometricus* fruit bodies that represents a novel chemical feature which is not previously known from the mushrooms of *Basidiomycotina*. In addition to this, another different steryl ester (3β, 5α-dihydroxy-(22E, 24R)-ergosta-7,22-dien-6α-yl palmitate) also known to be present in the liquid cultures of gasteroid (Hong-Jun *et al.,* 2007). The *Bovista* has proven to be a significant curative in head affection characterized by sensation as if the head were enormously increased in size. The spores of *Bovista* is also known to restrict blood circulation through the capillaries and found accompanying with menstrual irregularity or trauma. It also known for causing suffocation and might be beneficial in remedying asphyxiation resulting from inhalation of charcoal fumes (Farrington, 1999). Other benefits of *Bovista* includes improvement of awkwardness in speech and action, stuttering or stammering in children, palpitation after a meal, diabetes mellitus, ovarian cysts, and acne due to cosmetics (Jain, 1997).

Kakumyan *et al.* (2020) collected the volatile organic compound emitted from different stage of fruit bodies of the stinkhorn fungus *Pseudocolus fusiformis* and analyzed using the gas chromatography-mass spectrometry (GC-MS). They observed 3-methyl-butanol, 4-methyl-phenol, and dimethyl tetra-sulfide in addition to dimethyl disulfide, trisulfide and tetra-sulfide as the major organic volatiles in mature fruit bodies. *Cavatia gigantean* and *C. caelata* possess, when burnt, anaesthetic properties similar to those of chloroform (Berkeley, 1867).

APHRODISIAC PROPERTIES

The two *Cyathus* species named *C. limbatus* and *C. microsporus* are used as a source of vitality (aphrodisiac) by the local tribes of Colombia and Guadeloupe respectively. Although the actual effect of these fungus on physiology is not clearly known (Brodie, 1975). Likewise, fruit bodies of *Phallus impudicus* is fed to the young bulls in Northern Montenegro due to its potent aphrodisiac property whereas, it is gently rubbed on the necks of bulls prior to their combat in order to make them strong (Davis *et al.,* 2012). Similarly, The unopened stinkhorns, known as “ghost's or daemon's eggs" among local population of Thuringia, is used as dried powder in drinks as an aphrodisiac (Lightfoot, 1789). In the same context, Holliday and Soule (2001) claimed that some species of *Phallus* found in Hawaii is aphrodisiac to women and just inhaling the mushroom can cause spontaneous orgasm. Although, the study never reproduced and proved by any other study.

DYE/ PIGMENT COMPOUNDS

Red colour of *Calostoma cinnabarinum* is ascribed to the presence of pigment 'calostomal' with IUPAC nomenclature of all-trans-16-oxohexadeca-2,4,6,8,10,12,14-heptaenoic acid (Gruber and Steglich, 2007). Similarly, the fruit bodies of *Lycoperdon perlatum* contain the pigment melanin (Almendros *et al.,* 1987).

The major pigments responsible for the conversion of fruits from orange to red are carotenes, predominantly lycopene and beta-carotene. The lycopene is identified as a chief pigment in fungus *Clathrus archeri*, while beta-carotene is the predominant pigment in the family *Phallaceae* (Fiasson and Petersen 1973). Aulingeret *et al.,* (2001) isolated a poly-unsaturated organic compounds (polyene pigment) named melanocrocin from the fruit body and mycelial cultures of subterranean fungus *Melanogaster broomeianus*. Melanocrocin is a N-acyl derivative of L-phenylalanine methyl ester.

Genus *Scleroderma* is mainly consisting of gasteroid ectomycorrhizal (ECM) species having spores which are characteristically reticulate to echinulate globose and named as earthballs (Sims *et al.,* 1995). The alkaline extraction method was applied for the isolation of melanin pigments from the moist gleba of *S. citrinum* fruiting bodies further refined by acid hydrolysis and washing with organic solvents. The pigment also showed ROS scavenging and antimicrobial activity (Łopusiewicz *et al.,* 2018). Melanin is generally known as brown and black pigments derived from oxidation of monophenols (Solano, 2014). Therefore, melanin's from *S. citrinum* possess notable therapeutic action and could be applied in the food, cosmetics and pharmaceutical industries. The pigment found in the fruiting body of *S. citrinum* are sclerocitrin, norbadione A, xerocomic acid and badione A (Winner *et al.,* 2004).

Furthermore, gasteroid fungus *Pisolithus arrhizus* is also being used as a natural dye for coloring of clothes (Roberts and Evans, 2011). *P. tinctorius* is locally referred as 'Dye Ball' due to the presence of purple and yellow dyes in the fruiting bodies and is utilized extensively for dyeing cotton and wool, in the Canary Islands and parts of Italy (Rolfe and Rolfe, 1925). Tan *et al.* (1978) first reported the production of dark-colored pigments, phenolic, p-hydroxybenzoic and humic acid from the fruit bodies of *P. tinctorius* and similarly the study of Gill and lally (1985) firstly evaluated the presence of pigment norbadione-A from the sporophores of fungus accountable for the intense pigmentation of fruit bodies.

AGRICULTURAL PRODUCTS

Cyathus stercoreus has been reported to have ligninolytic and cellulolytic activities which selectively degrade lignin in agricultural byproducts such as wheat straws, leaving great part of cellulose intact. It results in increase in digestible carbohydrates for ruminants which improves the quality of food source (Wicklow *et al.,* 1980; Akin *et al.,* 1995).

The extract of *Podaxis pistillaris* harbors a significant fibrolitic activity and thus make them a probiotic, a food supplement having living bacteria (Vasquez-Davila, 2017). The exogenous fibrolytic enzymes are the bio-catalyst used for the eradication of non-nutritive products from the foods of monogastric and ruminant species (Bedford, 2000). Squeezing the spore sac of *Geastrum saccatum* and *G. triplex* released spores into bee hives which anesthetize bees for about 30 min facilitating harvest of honey (Tibuhwa, 2012).

INDUSTRIAL PRODUCTS

The enzymes such as laccase and manganese peroxidase extracted from the liquid cultures of *Cyathus stercoreus* are well known to have potential applications in pulp and paper industries. The ligninolytic potential of these enzymes are used for removal of lignin from paper pulp (Sethuraman *et al.,* 1999). In addition to this, the species *C. bulleri* contains three enzymes (lignin peroxidase, manganese peroxidase, and laccase) that not only contributes in the paper and pulp industries but also have abilities to enhance the digestibility and protein contents in forage (Vasdev *et al.,* 1995). Further the enzyme laccase also has potential of breaking down the phenolics that might be useful in excavating toxic materials from the effluents of dyes and textile industries thus making it a good environmentally friendly practice (Chhabra *et al.,* 2008). The liquid cultures of *C. stercoreus* and *C. pallidus* was reported to have biodegradable activity to degrade explosive 2,4,6-trinitrotoluene (TNT) and RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) by Bayman *et al.* (1995).

The commercial pesticides manufacturers utilize the bioactive compounds from the species of the genus *Nidula*. These compounds in their acetate form include raspberry ketone with chemical name 4-(p-hydroxyphenyl)-2-butanone as a major component of raspberry flavor and insect attractor. It also shows structural resemblance with sex pheromones of female melon fly that attracts male insects (Ayer and Singer, 1980). Furthermore, fruit bodies of mushroom *Lycoperdon perlatum* contains 14 mg/kg cinnamic acid of fungal dry weight (Barros *et al.,* 2009) that can be utilized in various industries as flavorings, synthetic indigo, perfume industries and also as a precursor of sweetener aspartame (Garbe, 2000).

Hydroxy methyl furfural is a chemical, extracted from the fruit bodies of fungus *Phallus indusiatus*, having the tyrosinase inhibitor activity (Sharma *et al.,* 2004). The enzyme responsible for catalyzing the pioneer step in the process of melanogenesis particularly in mammals and unwanted browning reactions in harvested fruits that make this inhibitor a vital component for cosmetic and food industries (Chang, 2009). The starches from the fruiting bodies of fungus with various physicochemical and functional properties plays a vital role in food and other industries. These physiochemical properties can be influenced by the ratio of amylose and amylopectin. These contribute as thickeners in food processing and also have applications in cosmetics, paper coatings, laundry and biofilms (Kong *et al.,* 2009). *Scleroderma citrinum* is known to grow vigorously on dead and decaying woods as they are lignocellulolytic fungi. The total starch content from the fruit bodies was evaluated to have high amylose and comparatively low amylopectin. The gelatinization temperature was found to be in optimum range and the sample showed stable dextrin production which suggests the potential applicability of these starches in non-food industries (Aniekemabasi *et al.,* 2018).

ETHNOMYCOLOGICAL KNOWLEDGE OF ETHNIC TRIBE

Astraeus hygrometricus is traditionally used as a hemostatic agent in China. The powdered dust prepared from spore is applied directly on cuts and wounds to stop bleeding (Hobbs, 1995). The tribes Biga and Bharia in the forests of Madhya Pradesh (India) are also very much acquainted to medicinal properties of the fungus. The blend of spores in mustard oil is used by them against the burns (Rai *et al.,* 1993). Similarly, decoction (boiled extract) of fungus *Cyathus stercoreusis* is used as a Chinese medicine to reduce the symptoms of gastralgia (Liu and Bau, 1980).

Indigenous people of the South-Eastern woodlands of the United States utilize the fruiting body of *Geastrum triplex* as prophylactic on the umbilici of newborns after birth until the fell off of umbilical cord. Further, it is also used to reduce inflammation and swelling of respiratory tracts (Ying, 1987). Likewise, stinkhorns of *Phallus indusiatus*, due to their unique shapes, are consumed during the divinatory ceremonies in Mexico (Læssøe and Spooner, 1994). The mushroom is designated as Akufodewa by theYo-ruba tribes of Nigeria which means “die-for-hunter-search” because the unusual odor of fruit bodies attracts hunter who mistakes them for dead animals (Oso, 1975). From the Chinese Tang Dynasty, the fungus is utilized for the treatment of inflammations and neural diseases as mentioned in pharmacopoeia. Similarly, it has been used by Miao people in China for the treatment of various conditions including cough, dysentery, leukemia, laryngitis and leucorrhea, oliguria, diarrhea, hypertension and hyperlipidemia (Ker *et al.,* 2011).

The mushroom Phellorinia herculeana is known to have numerous medicinal properties and exploited throughout the globe for their health benefits (Gehlot *et al.,* 2018). The basidiospores upon their maturity are traditionally applied on the fresh wounds, on cracked bone and also contributes in management of diabetes and cardiac conditions (Sharma and Doshi, 1996; Gehlot and Gehlot, 2020). The traditional pharmacological literature of many countries comprises the name of *Podaxis pistillaris* (Muhsin *et al.,* 2012) with numerous health benefits such as treatment of skin disease, wound healing, sunburn, inflammation and their antibacterial effects (Diallo *et al.,* 2002; Al-Fatimi *et al.,* 2006). Therefore, both *P. herculeana* and *P. pistilaris* are being sold out in market by ethnic communities with high price (Gehlot, 2016).

Four gasteroid fungi (*Lycoperdon echinatum, Bovista nigrescens, Pisolithus arrhizus* and *Scleroderma citrinum*) are known traditionally for the treatment of skin diseases and wound healing (Chang and Miles, 2004). The fumes of burning fruit bodies of puffball *Calvatia gigantea* was believed to have tranquilizing properties and used by the tribal people to calm the bees to facilitate the collection of the honey (Dickinson and Lucas, 1979). This sedative property is not due to the presence of any anesthetic compound rather due to an excess of carbon dioxide. According to Rolfe and Rolfe (1925), the hygroscopic nature of mushroom *Astraeus hygrometricus* leads to the use of the species as a hygrometer. Similarly, in some parts of China, the boiled extract of *Phallus* and *Dictyophora* are used as a preservative to preserve the food for shorter durations (Ying, 1987).

CONCLUSION

Although the much literature available on the bioactive compound of mushrooms but the information about the gasteroid bioactives is either not available or if available it is in a very discreet form therefore, the present review aims to compile a concise report on bioactive compounds of gasteroid fungi. In this study not only the nutritive but also pharmaceutical activities of gasteroid fungi have been explored along with their industrial and ethnomycological applications. The bioactive compounds extracted from the fruiting bodies of these fungi are potential anticancerous, antifungal, antimicrobial, antioxidant and antifungal agents. As far as the industrial applications are concern a number of dyes, ligninolytic and cellulolytic compounds, exchangers of toxic materials from the effluents of dyes and textile industries have also known to be extracted from these fungi.

FUTURE PROSPECTS

The macrofungi (mushrooms) are well known for the production of wide range of natural products as a part of their secondary metabolism like polyketides, glucans, peptides terpenes/terpenoids etc. The interest in these bioactive compounds has been considerably increased nowadays, as most of these fungal metabolites have their medicinal, industrial and agricultural applications. Although plenty of synthetic drugs are available today in the form of antibiotics, antimycotics, nematocidal, etc. but at same time their continuous application also increasing resistance of microorganisms towards these drugs. Therefore, there is need for the exploration of new antimicrobial drugs from the natural resources. In this review, we aim to provide a report on the potential of gasteroid fungi in the food, pharmaceuticals, agricultural industries which otherwise unavailable for the researchers. The study will help to understand the significance of the gasteroid macrofungi and will call the attention of researcher to further explored bioactive compounds from these gasteroid.

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