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THERAPEUTIC APPLICATIONS OF MUSHROOMS AND ITS COMPOSITIONAL ANALYSIS BY HIGH THROUGHPUT SCREENING TECHNIQUES

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ABSTRACT: Mushrooms can be considered as a prolific resource for drugs as per previous literature surveys. Their constituent bioactive components are broadly classified such as phenols, flavonoids, triterpenoids, saponins. Whole mushrooms or mainly fruiting bodies extracts and compounds isolated from their mycelium are of immense pharmacological importance. Extraction employing suitable solvents leads to the isolation of various principle compounds. Pure compounds can also be isolated from natural material or can be synthesized chemically. 80-85% of all medicinal mushroom products are isolated from fruiting bodies. 15% of all products are obtained from mycelia. Cultivation of mushrooms requires minimal resources; therefore the development of cultivation farm helps for creating employment for various people in many parts of the country. Many kinds of literature have already reported the detailed chemical bioactive constituents of the extracts prepared from mushrooms *via* various extraction methods. These compounds are of immense therapeutic importance, and some of them have already become a part of clinical trials as an adjuvant therapy along with the conservative therapy applied for patients suffering from cancer in various countries like China, Japan. The next most crucial part is the development of suitable galenic formulations in the form of capsules, tea or tablets which depends on the isolated material. Mixing of several mushroom components is also becoming common and will be of course beneficial to mankind shortly.

INTRODUCTION: Chang and Miles described mushrooms as fruiting body of macrofungi visible by naked eye and can be easily picked up by hands. Literature revealed that its fleshy fruiting body had been used as food and food supplement for many years [1].

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They are found all over the world, and their body is made up of an extensively branched network of a thread called hyphae. The structure that we recognize as mushrooms are referred to as organized hyphae specialized for reproduction. After incubating the substrate bed inoculated with spores of mushroom under favorable growth under conditions, the mycelium gives rise to fruiting bodies called "mushrooms" [2]. They are considered as a delicious and nutritious food all over the world. "The aromas of these beautiful creatures are used to charm the luxury-loving Roman aristocrats as it charms people all over the world today. People

hunt mushrooms as they consider it as curious life forms or as spectacular photographic interest subject" [2].

Taxonomical Classification of Mushrooms: Fungi are the class of plants that lack true leaves, stems, and roots. They do not have chlorophyll and undergo asexual mode of reproduction, *i.e*., by spore formation. It has three subclasses - Phycomycetes, Ascomycetes, Basidiomycetes. Here the hyphae are septate, and spores are located within in a specialized cell called 'ascus.'

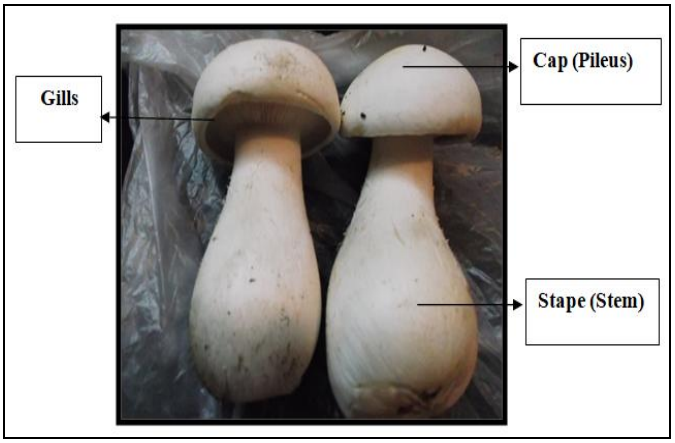

FIG. 1: THE PICTURE REPRESENTS THE FLESHY FRUITING BODY OF MUSHROOM *CALOCYBE INDICA*

Mushrooms belong to the third subclass Basidiomycetes, and the fundamental characteristic of the members of this group is that their spores are produced outside the mother cell. The features of the typical basidium is a club-shaped single cell having four little stalks called 'sterigmata' present at the apex and spores are born on the tips of these stalks. After maturation, the spores get discharged from sterigmata because of surface tension effect and the special features that are found in most of the larger fleshy fungi, such as agarics, boletus, hydnums, clavarians and polypores [3].

Cultivation Process of Mushrooms Adopted by Cultivars in India: Nowadays mushrooms have become an excellent source of nutrition and also acted as a potent reservoir of many pharmacologically active compounds. Cultivation of oyster mushrooms is very popular in India next to button mushrooms [4]. *Pleurotus ostreatus*, *P. sajor-caju*, *Agaricus bisporus*, *P. florida*, *Calocybe indica*, *Volvariella volvaceae* all together forms the entire bulk of edible mushrooms that are produced in this part of the country. Mushrooms can be cultivated using limited resources such as rice straw, wheat straw, ragi straw, hulled maize cab and also the waste paper which are generally used for the preparation of substrate bed [5, 6, 7]. Directorate of mushroom research of Solan executed immense effort via the agricultural foundation ICAR (Indian Council of Agricultural Research) by introducing the "Development of mushroom cultivation in Himachal Pradesh," in 1961. [5]

FIG. 2 AND 3: THE PICTURE REPRESENTS THE CULTIVATION PROCESS OF MUSHROOM AND THE SUBSTRATE BED PREPARED WITH STRAW PIECES (1 INCH LENGTH) SOAKED IN LIME WATER FOR ABOUT 12 h AND THEN SEEDED WITH THE INOCULUMS OF MUSHROOM SPORES FOLLOWED BY INCUBATION. THE MYCELIUM GROWS WITHIN 26-27 DAYS WITH THE APPEARANCE OF FRUIT BODY ROUGHLY WITHIN 27 DAYS

Previous literature records revealed that water hyacinth (*Eicchornia crassipes* Solms.) had been used as raw material for the production of oyster mushrooms in India [8]. The highest yield was obtained from oyster mushroom *Pleurotus florida* (923.7g) having biological efficiency (BE) of

184.7% after three flushes cultivated in the bed of paddy straw and water hyacinth followed by paddy straw (698.1g and 139.6% BE) and water hyacinth (614.1g and 122.8% BE) alone, respectively [8]. Various agricultural lignocellulosic waste materials have been used for the production of mushrooms; hence it is an eco-friendly process. This biotechnological technique converts the enormous amount of organic waste residues for the production of protein-rich mushrooms [9]. Cultivation of mushroom depends on parameters like temperature, time, pH, available C: N ratio, light, carbon dioxide, and oxygen requirements and the pH optima lies in the range of 5.5 to 8.5. [10, 11]

Medicinal Importance of Mushrooms: Among 15000 known species of mushrooms, 2000 can be considered for human consumption and out of these, 650 have been reported to have medicinal properties. These creatures are considered to be an untapped reservoir of new pharmaceutically important products and can be considered as a boon for progress in terms of medicinal aspects, food purpose and also for employing in developing countries like India. Therefore, mushrooms have become a matter of immense interest in the field of alternative medicine. The secondary metabolites are getting explored both as traditional medicines and also as the latest targets in molecular biology. Extracts of many medicinal mushrooms have been used as traditional Chinese medicine and cure many diseases [12].

Mushrooms Showing Antimicrobial Activities: To survive in the natural environment, many antibacterial and antifungal compounds are naturally present in mushrooms. It is a well-known fact, that some compounds from microscopic fungi are marketed as antibiotics till date [13]. A recent upsurge in interest was noticed among various researchers regarding the antimicrobial action of the bioactive compounds showing action against multidrug-resistant bacteria. New sesquiterpenoid hydroquinones extracted from medicinal mushroom *Ganoderma pfeifferi*, named as ganomycin, inhibits the growth of methicillin-resistant *Staphylococcus aureus* (MRSA) and other bacteria [14]. Compound applanoxidic acid A isolated from mushroom *Ganoderma annulare* revealed weak antifungal activity against fungus *T. mentagrophytes* because of the presence of. 5α- ergosta-7, 22- dien-3β-ol or 5,8- epidioxy-5α, 8α-ergosta-6, 22- dien-3β-ol, a steroid compounds that has been isolated from mushroom *G. applanatum* (Pers.) revealed feeble activity against gram negative and gram positive organisms [15].

Active ingredient oxalic acid isolated from *Lentinula edodes* (Berk.) showed activity against *S. aureus* and few other bacteria [16]. Ethanol extracts of mycelium of *L. edodes* showed antiprotozoal activity against *Paramecium caudatum* [17]. The antimicrobial activity of mushroom *Podaxis pistillaris* (L.: Pers) Morse was utilized in the treatment of nappy rash of babies in some parts of Yemen and also against sunburn caused by epicorazins in South Africa and the active substance is epipolythiopiperazine-2, 5-diones which is an important fungal metabolite [18].

Mushroom Extracts Showing Antiviral Activity: As very few antiviral drugs are available, mushrooms have been explored for the presence of bioactive metabolites showing antiviral activity. Not only the whole mushroom extract but also the single compounds isolated from mushrooms showed antiviral activity. The compounds may act via direct inhibition of a viral enzyme or the synthesis of viral nucleic acids, or it may be due to the inhibition of the process of adsorption and its uptake by the mammalian cells. The direct and indirect antiviral effects are due to smaller molecules and immunomodulatory polysaccharides and complex molecules [19].

Several compounds such as ganoderiol F (6a), ganodermanontriol (7a) and ganoderic acid B (8a) belongs to the class of triterpenes extracted from medicinal mushroom *Ganoderma lucidium* revealed antiviral activities against human immunodeficiency virus type 1 (HIV-1). The MIC value of compound ganoderiol F (6a) and ganodermanontriol (7a) responsible for complete inhibition of HIV-1 is 7.8 μg/mL and induced the cytopathic effect in MT-4 cells. Ganoderic acid B (8a) has an IC_{50} value of 0.17mM inhibited HIV-1 protease enzyme [20]. Compounds extracted from *G. pfeiffer* such as ganodermadiol (6b), lucidadiol (9a) and applanoxidic acid G (2c) revealed *in-vitro* antiviral activities against influenza virus type A, having $IC5_0$ value in MDCK cells > 0.22mM/L. Herpes simplex virus type 1, responsible for lip

exanthema and other symptoms is inhibited by ganodermadiol (6b) having an IC_{50} value of 0.068mM/L studied in vero cells [14]. Extract prepared from mycelial of fungus *Kuehneromyces mutabilis* showed antiviral activity against influenza virus type A and B *in-vitro* [21]. Extracts prepared from mushroom *Inonotus hispidus*, have isolated phenolic compounds named ergosterol peroxide (4) also available in various mushrooms showed antiviral activity against influenza virus type A and B [22, 23]. *Collybia maculate* showed antiviral activity mainly due to its purine derivatives [24].

Mushrooms and its Components Responsible for Antitumor Activities: Tumour diseases are considered to be the main cause of concern worldwide. Mushrooms play an important role for the prevention and treatment of cancer, based on evidence from countries of Asian and Eastern Europe. *Piptoporus betulinus* was traditionally used in Bohemia for the treatment of rectal cancer and stomach diseases [25]. Fruiting bodies of mushroom *I. obliquus* was used as folk medicine for the treatment of cancer and stomach diseases [26].

In an animal model study, it was found that several extracts and the isolated compounds of this mushroom have antitumor activity mainly due to the presence of triterpenes and ergosterol peroxide [27, 28]. Therefore, mushrooms are considered to be important for immunomodulation, and therefore they are known as "biological response modifier," "immunopotentiator" and also as "immuno-stimulants." Countries like China, Japan, Korea and in other East Asian countries used mushrooms are used as therapeutic food [29].

Mushrooms Acting as Immunomodulators and its Role in Adjuvant Therapy: Compounds such as polysaccharides or polysaccharide-protein complex from mushrooms stimulate the non – specific immune system and show antitumor activity by stimulating host's defense mechanism [30; 31, 32, 33, 34]. Macrophages, T lymphocytes, and NK cells release cytokines namely TNF-α, IFN-γ, IL-1β, *etc*. responsible for antiproliferative action, stimulates apoptosis and are also used for differentiation in tumor cells. β-D-glucans binds to membrane complement receptor type 3 (CR3, alpha Mβ2 integrin or CD11b/ CD18) on immune effector cells [34] and therefore reveals immunological activity. A recent experimental approach showed that schizophyllan obtained from *S. commune* could bind mRNA poly (A) tail [35]. High molecular weight compounds and having a lower level of branching reveals the better extent of water solubility such as β glucans shows higher antitumor activity [36]. On the other hand, higher branched MD fraction isolated from mushroom *G. frondosa* having MW 1000000 – 1200000 Dalton revealed antitumor activity [37, 38].

Bioactive Components Extracted from Mushrooms Undergoing Clinical Trials of as an Adjuvant Therapy: Bioactive components which are already having clinical application in countries such as Japan and China are lentinan, schizophyllan, MD fraction, PSK and PSP. They are mainly used as an adjuvant tumor therapy along with conventional procedures like a surgical operation, radiotherapy and chemotherapy [39]. Lentinan (0.5 – 1.0 mg per day) along with chemotherapy alters the survival time prolongation, restoration of immunological parameters, quality in the improvement of life of patients suffering from stomach, colon and other carcinomas concerning those patients who had only undergone chemotherapy [40]. A randomized multicentric study consisting of 89 patients suffering from stomach cancer, showed that the median survival time in this group has both chemotherapy and lentinan 2mg per week, intravenous, was found to be 189 days. The control group, for this clinical study getting only that chemotherapy, the median survival time was found to be 109 days [41].

In another study group of patients suffering from advanced colorectal cancer, the median survival time of lentinan was 2 mg per week for 23 patients in the treated group was found to be 200 days whereas it is only 94 days in case of control group [42]. A randomized controlled having 130 patients administered with schizophyllan (dosage: 40mg per week, totally 1134 mg) after undergoing surgical removal of their whole tumor tissue in addition to the application of drugs mitomycin and futraful. The drug schizophyllan was advised from day 14 after the operation. Clinical study shows that the median survival time was 72.2% for the schizophyllan group after 5 years and in case of

control group it is 61.9% consisting of 134 patients who had only undergone chemotherapy.

Unfortunately, schizophyllan didn't show any effect upon the survival time when the tumor tissue was not removed [43]. Compound PSK was administered orally (dosage: intravenous application on the day of surgery and 1 day following) for more than 3 years followed by mitomycin C and 5-fluorouracil (orally for 5 months) in another RC study group consisting of 462 patients who have undergone surgical removal from colorectal cancer patients. After four years, the follow-up study was conducted, and it was observed that an increase in the disease-free survival curve of the PSK concerning the control group was found to be statistically significant [44, 45]. A clinical trial with PSP was done among 485 cancer patients (control patients: 211; cancer of esophagus, stomach, and lung). PSP was administered at a dosage rate of 3g/day oral for 30 days, and it was observed that the side effects from the conventional therapy Co^{60} – gamma radiation, DT 65-70 Gy per 6-7 months were significantly lessened. 11% increase in one-year survival rate of patients with esophagus cancer was also observed [44, 46].

FIG. 4: THE PICTURE REPRESENTS THE EDIBLE SHIITAKE (*LENTINULA EDODES*) FRUITING ON LOGS THAT HAVE BEEN ARTIFICIALLY INOCULATED WITH THE FUNGUS [2]

Mushrooms Responsible for Immuno-suppressive and Antiallergic Activity: Mushroom compounds are responsible for stimulation or modulation of our immune system. Those compounds has become of great interest as it helps in the treatment of allergic diseases which are increasing worldwide.

Mushrooms Responsible for Inhibition of Allergic Reactions: Ethanolic extracts of Japanese edible mushrooms namely *H. marmoreus*, *F. velutipes*, *Pholiota nameko*, and *P. eryngii* show remarkable antiallergic effects in mice by oxazolone-induced type IV allergy after oral application. Inhibition of histamine release from the rat mast cells was done by compounds such as Ganoderic acids C (8d) and D (8e) and cyclooctasulfur (compounds from *G. lucidium*) [47, 48]. Regression of severe allergic symptoms was observed in a patient suffering from thromboangitis obliterans and also in a patient with urticaria. The compound known as ergosterol peroxide confirmed the effects in a study conducted in an animal model [23, 49]. Hispolon and hispidin extracted from fruiting bodies of mushroom *I. hispidus* showed inhibition of chemiluminescence response of human mononuclear blood cells and mitogen-induced proliferation of spleen lymphocytes of mice [50].

Mushrooms Showing Anti-complement Activities: Several isolated triterpenes from mushroom *G. lucidium* such as ganoderiol F, ganodermanontriol 7(a) and ganodermanondiol 7(b) showed potent anti-complement activity having an IC_{50} value in the range of 5-40μM against the classical pathway of complement system [51].

Mushrooms Responsible for Antiatherogenic Activity: Oyster mushroom *P. ostreatus* exhibited hypocholesteremic effect along with inhibition of lipid peroxidation was observed among rats and rabbits.

FIG. 5: THE PICTURE REPRESENTS THE OYSTER MUSHROOM *PLEUROTUS OSTREATUS*

According to the literature survey, 10% of dried fruiting bodies of oyster mushroom consumption

reduced the incidence and size of atherosclerotic plaques in rabbits [52]. The lead compound that has been identified to be responsible for the observed effects is 'lovastatin' [53, 54].

Mushrooms Showing Anti-oxidative Activity and Other Related Biological Activities: Isolated triterpene ganoderic acid C (8d) and its derivatives from mushroom *G. lucidium* can inhibit the biosynthesis of cholesterol [55]. Various other triterpenes of the fungus protect against atherosclerosis by inhibiting angiotensin converting enzyme (by ganoderic acid F 8f) [56] and also by inhibiting platelet aggregation (by ganoderic acid S 17b) [57]. Several studies have revealed that the antioxidative and free radical scavenging activity effects of polysaccharide analyzed in different oxidative injury models such as in tert-butyl hydroperoxide damaged mice peritoneal macrophages, alloxan-induced diabetes, and experimental liver injury, models. Mushroom *L. edodes* showed antilipidemic effect due to the presence of bioactive compound eritadenin, which is a nucleotide derivative [58, 59].

The excellent antioxidant property was observed for *Thelephora ganbajun*, *Thelephora aurantiotincta*, *Boleptosis grisea*, and *Paxillus curtissii* due to the presence of compound p-Terphenyl. Similarly, betulinan A (20) from mushroom *Lenzites betulinus* is much more active (about 4 times) as a radical scavenger than vitamin E concerning inhibition of lipid peroxidation. Sterins A and B isolated from *Stereum hirsutum* also inhibits lipid peroxidation [60, 61, 62, 63]. Compound ergotsa-4-6-8(14), 22-tetraen-3-one isolated from many mushrooms posses anti-aldosteronic diuretic properties. Compounds which potentiate the ADP induced platelet aggregation can be found in *Polyporus umbellatus* [64].

Mushrooms Showing Hypoglycaemic Activity: Diabetes mellitus is the most common and major metabolic disorder which affects about 250 million people worldwide. A polysaccharide fraction, SX fraction isolated from mushroom *G. frondosa* revealed hypoglycemic action in five patients with type 2 diabetes [65]. Similarly, hypoglycemic effects of mushroom compounds Ganoderan A and B, glucans from fruiting bodies of *G. lucidium*, coriolan obtained from submerged grown *T. versicolor* biomass were observed in various test systems, an acidic component glucuronoxylomannan isolated from fruiting bodies of *Tremella aurantia* [66, 67]. 71 patients suffering from type 2 diabetes were prescribed with the poly-saccharide fraction of *G. lucidium* (Ganopoly, dosage 1800 mg three times daily for 12 weeks). Therefore, it was observed that after 12 weeks, the group that received ganopoly, the mean postprandial glucose values declined to 11.8 m/mol and the significant difference was noticed concerning placebo group [68].

Bioactive compound tremellastin (dosage: p.o. 100 mgk/h; 500 mg/kg) mainly consisting of 40-45% acidic polysaccharide glucuronoxylomannan reduced blood glucose and triglyceride levels in rats as observed after 15 days of treatment [69]. Crude polysaccharide obtained from cultured mycelium of *Cordyceps* revealed hypoglycaemic effect as evident after intraperitoneal injection [70]. Bioactive components isolated from several polypore mushrooms such as *Fomitopsis officinalis*, *Wolfiporia cocos*, *Laricifomes officinalis*, *Laetiporus sulphureus* namely dehydrotrametenolic acid acted as an insulin sensitizer in glucose tolerance test and reduced hyperglycemia in mice models showing noninsulin- dependent diabetes [71].

Mushrooms Responsible for Anti-Inflammatory Action: A proteoglycan extracted from mushroom *P. linteus* and also its ethanolic extracts revealed anti-inflammatory effect in case of collagen-induced arthritis and the croton-oil induced ear edema test in mice [72, 73]. Notable other compounds which showed effective writhing test extracted from mushrooms *G. lucidium* are ganoderic acids A (8c), B (8a), G (8g) and H (8h). They exhibit a stronger effect in animal models study in comparison to acetylsalicylic acid [74]. Methanol extract prepared from fruiting bodies of mushroom *Pleurotus pulmonarius* (500 and 1000 mg/kg) reduced carrageenan-induced and formalin-induced paw edema in mice and the activity was compared with standard diclofenac (concentration 10 mg/kg).

The antioxidant activity of the extract assayed based on IC_{50} value for hydroxyl radical scavenging activity was found to be 476 µg/mL. Lipid peroxidation was also assayed based on IC_{50} value found to be 960 µg/mL. The extract also

revealed noteworthy solid tumor- reducing activity in mice models [75]. It was also observed that the compounds ergosterol, ergosta-4-6-8(14),22-tetraen-3-one and 1-oleoyl-2-linoleoyl-3- palmitoyl glycerol isolated from edible mushroom *G. frondosa* can inhibit cycloxygenases 1 and 2 activity [76].

Mushrooms Showing Hepatoprotective Action: Many compounds such as ganoderic acids R (17a) and S (17b), galactosamine showed *in-vitro* antihepatotoxic activity, isolated from mushroom *G. lucdium* induced cytotoxic test upon primary cultured rat hepatocytes [77, 78]. By encouraging the activity of scavenging enzymes for hepatic free radicals which in turn raises the ability of antioxidation in mice, a relation could be achieved with hepatoprotective effects [79]. In a double-blinded randomized and multicentered study with patients suffering from chronic hepatitis B, ganopoly was administered for 12 weeks (dosage: 600mg three times per day which is equivalent to the 27g fruiting body, oral.). It was followed by 13 weeks follow up. Thereafter it was observed that within 6 months study period, 33% of patients, *i.e.*, 17/52 of treated patients showed the values of aminotransferase within the normal range and also 13% (7/52) had revealed clearance of hepatitis B surface antigen from serum though none of the controls showed normal enzyme values or had lost HBsAg. Therefore the drug got well tolerated [80].

Mushrooms are having Action on Central Nervous System: Mushrooms such as *Amanita muscaria* or *Psilocybe sp.* and also some other mushroom extracts contains certain compounds affects our nervous system, and therefore those compounds can be of immense pharmacological interest. Compounds analogous to phenol named hericenons C (23), D, E, F, G, H extracted from mushroom *H. erinaceus* stimulates synthesis of nerve growth factor and proposed to have an ameliorative effect in Alzheimer's dementia [81]. Interestingly, a compound named Erinacin E isolated from *Hericium coralloides* exhibits antinociceptive activity without revealing any side effects with the μ receptor similar to morphine [71]. Inhibitory effects of certain mushrooms like *P. betulinus, G. applanatum, H. annosum* and *Fomitopsis pinicola* and *Daedaleopsis confragosa* was observed on neutral endopeptidase having IC_{50} value between 40 and 55 μg/mL. Such selective inhibitors of mettaloendopeptidase are of immense importance regarding the treatment of pain with a spectrum of activity very much similar to opiods compounds [82]. Another isolated compound named Scutigeral (25) sourced from fruiting bodies of *Scutiger ovinus* shows affinity to the brain dopamine receptor D1 and therefore acts as an oral active pain killer targeting vanilloid receptor VR1 [83]. Albaconol, isolated from fruiting bodies of *Scutiger confluens* acts as an antagonist to VR1 receptor having an IC_{50} value of 5μM [84].

Bioactive Component Evaluation by HPLC/MS Study: A recent upsurge in interest regarding the biochemical composition of fruits, vegetables, and medicinal plants was observed mainly due to the different type, number, and mode of action of various compounds which are referred as "phytochemicals." They have gained importance mainly due to their presumed role against various chronic diseases such as cancers and cardiovascular diseases. Plants are a rich source of a variety of functional dietary micronutrients, fibers and an array of phytochemicals such as ascorbic acid, carotenoids and phenolic compounds which may act as singly or in combination and may have a beneficial effect on health and also reveals antioxidant activity *in-vitro* [60, 85, 86 87].

Phenol Compounds and its Therapeutic Properties: Phenol compounds can be classified as secondary metabolites which bear one or more hydroxyl groups, and they resemble a simple phenolic molecule or a complex polymer structure. A wide range of therapeutic properties such as antiallergenic, anti-inflammatory, anti-microbial, antithrombotic, cardioprotective and vasodilator effects can be attributed to phenol compounds. The most important characteristic of a phenol compound is antioxidant activity because it can act as reducing agents, free radical scavengers, singlet oxygen quenchers or metal ion chelators [88, 89, 90]. They have wide structural diversity; therefore they are often referred to as "polyphenols." These compounds are derived via pentose phosphate, shikimate and phenylpropanoid pathway in plants[91, 92, 93]. Quality of polyphenols depends on various factors like plant genetics and cultivar, soil composition and growing conditions, maturity state and post-harvest conditions [94].

Flavonoid Compounds and its Therapeutic Properties: Flavonoid belongs to a large group of polyphenolic compounds consists of a benzo-γ-pyrone structure, and it is ubiquitously present in plants. They are synthesized by the phenylpropanoid pathway, and various kinds of literature reveal that they are responsible for various pharmacological activities [95, 96]. These compounds are synthesized by plants in response to microbial infection [97]. The chemical nature depends on factors like structural class, a degree of hydroxylation, other substitutions and conjugations and also upon the degree of polymerization [98]. The antioxidant effect gets mediated by scavenging free radicals or by chelating metal ions and this, in turn, depends on the presence of functional hydroxyl group. Chelation of metals is crucial for prevention of which in turn damage target biomolecules [99, 100]. They also induce human protective enzyme systems. Literature survey revealed that there are protective effects of flavonoid against many infectious diseases such as bacterial or viral against many degenerative diseases such as cardiovascular diseases, cancers and other age-related diseases [96 100, 101, 102].

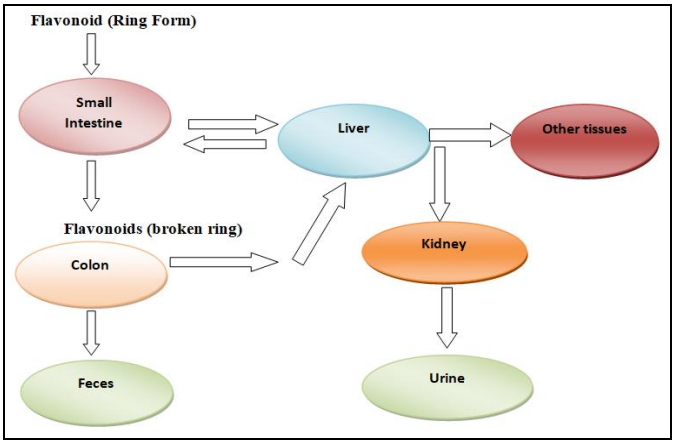

FIG. 6: SCHEMATIC REPRESENTATION OF METABOLISM OF FLAVONOID WITHIN HUMAN BODY [103]

DISCUSSION: Like plants, mushrooms can also be considered as a prolific resource for drugs. The bioactive components are classified to various groups mostly being polysaccharide or triterpenes in nature. Whole mushrooms or mainly fruiting bodies extracts and compounds isolated from them are of medicinal importance. Extraction with suitable solvents leads to the isolation of various principle compounds. Pure compounds can also be isolated from natural material or can be synthesized chemically. 80-85% of all medicinal mushroom products are isolated from fruiting bodies [104].

CONCLUSION: Therefore, we can formulate suitable galenic formulations in the form of capsules, tea, tablets or other nutritional supplements which depends on the isolated material. Mixing of several mushroom components to prepare certain therapeutic formulation can be considered to be a beneficial approach for our near future.

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