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Biodiversity of Fleshy Fungi, their Conservation and Applications for Human Welfare

RC Upadhyay
ICAR-Directorate of Mushroom Research, Solan–173 213, Himachal Pradesh, India

Mushrooms have a long history of use in oriental traditional medicines and healthy food. The biodiversity of mushroom is attracting common man and scientific community due to its attractive colour, fascinating shapes, sizes and spontaneous appearance. Nature is the biggest source of all microbial diversity including fleshy fungi or mushrooms. Mushroom biodiversity is very much influenced by biotic and abiotic factors. deciduous and evergreen forest with plenty of organic matter and less soil cover by grasses, shrubs and weeds favours profuse growth of mycorrhiozic and lignicolous mushrooms like *Russula, Lactarius, Pleurotus* and *Lentinus* etc. Dense growth of grasses and weeds favours less growth of saprophytic and mycorrhizal mushrooms. India has enormous biodiversity of mushrooms in the world and several regions have so far been not explored for their flora and fauna. There has been enormous loss of mushroom biodiversity due to forests fires, grazing by domestic animals, environmental pollution, non-scientific methods for the collection of fruiting bodies for consumption and trade. Every year 15 billion trees are lost due to human activities and the world has lost almost half of the total forest cover from the day of civilization. The loss of forest has affected the mushroom biodiversity especially mycorrhizic, ligninolytic and saprophytic mushrooms which are mainly dependent on forest trees for their growth, spread and survival. Several ligninolytic and mycorrhizic fleshy fungi like *Pleurotus*, *Lentinus*, *Hericium*, *Amanita*, *Russula* and *Lactarius* are fast disappearing from their natural habitat. The loss of humus and organic biomass with soil erosion is also responsible for biodiversity loss due to fluctuation in soil temperatures and poor humidity in the microclimate of forest ecosystem. Several mushroom species are also reported endophytes of forest trees benefitting their host trees of vital nutrients and vitamins. However, studies on endophytes of Indian plants and trees have not been thoroughly studied. The studies on mushroom biodiversity of India started by Berkeley in 1851-52 and several fleshy fungi were reported from north western Himalayas. Earlier attempts to study the mushroom biodiversity were confined to only academic interest in the form of dried specimens in various herbaria.

The systematic collection, conservation, identification and exploitation of mushrooms started with the establishment of ICAR-Directorate of Maize Research (ICAR-DMR), Solan as National Mushroom Research and Training Centre in 1983. Today more than 3,500 specimens of wild edible, non-edible, medicinal, wood rotting, poisonous and mycorrhizal mushroom specimens and about 3,000 tissue cultures have been conserved in the genebank of ICAR-DMR, Solan. The studies on mushroom biodiversity has not progressed much due to limited collection period (only during monsoon season), difficult terrain, danger of wild animals, lack of trained men power, non availability of literature and scientists working in isolation.

Importance of Mushroom Biodiversity

(a) *Mushrooms as Source of Nutrition and Vitamins:* Due to exotic flavour and texture mushrooms are liked by the mankind from the earliest civilization. Several mushroom species like *Pleurotus, Lentinus, Termitomyces, Morchella, Scleroderma, Phellorinia, Podaxis, Schizophyllum, Sparaciss* etc. are consumed by local people in Chhattisgarh, Maharashtra, Rajasthan, Jharkhand and most of the states in north easte of India. Edible mushrooms are rich in potassium and poor in sodium which is good for persons suffering from high blood pressure. Mushrooms are good source of quality protein and amino acids like lysine, tryptophan, methionine etc. they are also rich in Vitamin-B complex including folic acid and Vitamin-B12. Mushrooms are the only source of Vitamin-D in vegetables. We have found very high Vitamin-D contents in most of the cultivated edible mushrooms and recently cultivated one of the tropical indigenous species *Macrocybe gigantea* is a rich source of Vitamin-D. We can augment Vitamin-D in mushrooms by exposure to

**Author for Correspondence: Email- rc_upadhyay@hotmail.com*

UV light and sunlight. The mushroom growers are enriching their product for Vit-D content by artificial methods. Due to alkaline in nature and high fiber they are suitable food for persons suffering from hyperacidity and constipation. Mushroom mycelia due to absorption of various elements like selenium, copper, iron can be used for fortification of food items.

(b) *Mushrooms as a Source of Novel Metabolites:* Out of one lakh metabolites 33,000 are from fungi and with the loss of every species we are losing a good source of bioactive compounds. Only a little fraction of mushroom species have been evaluated for bioactive compounds. Medicinal mushrooms have an established history of use in traditional oriental therapies. Historically, hot water-soluble fractions (decoctions and essences) from medicinal mushrooms were used as medicine in the Far East, where knowledge and practice of mushroom use primarily originated mushrooms such as *Ganoderma lucidum* (Reishi), *Lentinus edodes* (Shiitake), *Inonotus obliquus* (Chaga)*,* and many others have been collected and used for hundreds of years in Korea, China, Japan and eastern Russia. Mushroom metabolites are increasingly being utilized to treat a wide variety of diseases, particularly as they can be added to the diet and used orally which could be efficient in possible treatments of diseases like allergic asthma, food allergy, atopic dermatitis, inflammation autoimmune, joint inflammation such as rheumatoid arthritis, atherosclerosis, hyperglycemia, thrombosis, HIV infection, listeriosis, tuberculosis, septic shock, and cancer. Major substances with immune modulatory and/or antitumor activity have been isolated from mushrooms mainly polysaccharides (in particular *β-D-glucans, polysaccharopeptides (PSP),* polysaccharide proteins, and proteins, triterpenes, lipids, statins and phenols. A new class of fungicide-strobilurin which is a broad spectrum fungicide has been extracted from a mushroom species *Strobilurus tenacellus*.

(c) *Agro and Forest Waste Recycling:* Several saprophytic and wood rotting mushrooms due to production of extracellular enzymes specially oxidases and peroxidases are able to degrade cellulose, hemicellulose, lignin and release glucose which can be utilized by the secondary microbes for faster degradation. We have utilized several agro and forest wastes like mentha, dried leaves of poplar, pipal, mango, pine for oyster mushroom cultivation. Mushroom species with faster mycelia growth can be used for glucose production and bio ethanol.

(d) *Animal Feed:* Mycelia colonized wastes are more digestible as animal feed than fresh straw and also helps in preventing parasites of animals due to mushroom metabolites.

(e) *Bioremediation:* The extracellular enzymes like laccase, aryl alcohol oxidase, ligninase and several other peroxidases which produces free radical oxygen are able to myco remediate contaminated sites with phenols, chloro phenols, TNT, poly aromatic hydrocarbons and azo dyes. Mycelia colonized straw can be also used to increase humus contents for water absorption and retention.

(f) *Biological Control:* Some mushrooms have the potential as antifungal due to chitinase and proteases production. Although their potential as antibacterial and antifungal has not been thoroughly investigated. Members of *Issaria* and *Beauveria* are largely used to control various insect pests.

(g) *Other Industrial Applications*: Mushrooms can be exploited for producing nano particles of oxalates, iron, zinc etc. The culture conditions to produce nano particles have to be standardized. Almost all kinds of colors like blue, pink, red, black, purple, yellow have been found in mushroom fruit bodies. These colors are also present in mycelia. There is a need to standardized methods to produce maximum pigments either in liquid broth or on cereal grains for producing organic colors for use in food industry and dying of cloths.

Culture Conservation

It is easy to maintain cultures of sporulating fungi but most of mushrooms do not produce any spores and only the mycelia culture are to be conserved. Moreover it has been our experience that mushrooms which grows at sub tropical and tropical conditions like *Calocybe indica*, *Volvariella volvacea*, *Auricularia* spp, *Macrolepiota* sp, *Ganoderma lucidum* some *Morchella* and *Pleurotus* spp. are sensitive to low temperature conditions (less then10° Cel.) and often do not revive on sub-culturing due to low temperature sensitive proteins. Such cultures are to be conserved at 15-17° C and sub-cultured regularly after 60-70 days. Lyophilized cultures of mushrooms on jowar grains are a better substrate for maintain cultures for a long time without the loss of natural vigour. Similarly mycorrhizal fungi when conserved in the genebank either the cultures cannot be revived or they loss their mycorrhization potential. Not only the survival but to obtain cultures of *Cantharellus* spp., *Russla* spp., *Lactarius* spp., *Termitomyces* spp. and *Amanita* spp is very difficult and specific growth media are to be prepared with specific carbon and nitrogen sources, vitamins, micronutrients and suitable pH. More than 5000-6000 species belonging to basidiomycetes, (45 genera) some ascomycetes (18 genera) and few zygomycetes (members of the genus *Endogone*) are reported as ectomyccorrhizal (Smith and Read, 1997, Futai *et al*., 2008). Members of *Cantharellus*, *Russla*, *Lactarius*, *Cortinarius, Inocybe, Suillus*, and *Amanita* are well recognized as ectomycorrhizal fungi. All the cultures at ICAR-DMR are maintained at +4° Cel in cold room, at 15-17° C in incubators and in mineral oil at room temperature. However, the cultures of mycorrhizal fungi should be maintained *in situ* or myco-silviculture to maintain their vigour. We need "Fungal Gardens" in tropical, sub-tropical and temperate forests with all the common trees under protected conditions and the inoculums multiplied in bulk is put under host trees for ECM fungi. Cultures of saprophytic and mycorrhizal fungi in the genebanks conserved for a long a time in the same culture medium may not be useful for their beneficial utilisation as the looses their potential to secrete extracellular enzymes for utilisation of natural substrates. Some of the culture banks are using systemic fungicides to prevent mould infestation which are responsible for mutation and ultimately loss of original culture.

Future Plan to Conserve Mushroom Bio-diversity

(a) We are discussing more about biodiversity but we have very limited expert taxonomist to study the biodiversity. The mushroom biodiversity is little bit more complicated because mushrooms can be collected only for a limited period (during rainy season) and due to perishable nature they have to be studied and conserved immediately. Moreover, dangers from wild animals, snakes, leeches, etc. make mushroom collection very difficult and unattractive. We should strengthen our future team of mushroom taxonomists by utilising the experts available in the country for giving training for 30-45 days.

(b) Advance centre for mushroom biodiversity should be established in any central university, Indian Council of Agricultural Research institute or in Council of Scientific and Industrial Research labs with full research facility for traditional taxonomy substantiated by molecular tools.

(c) We should develop networking research projects on mushroom biodiversity with minimum 15-20 scientists /researchers to document the entire diversity of our country before we lose our national mushroom wealth. We should also study the medicinal, nutritional and novel compounds from the entire collections.

The biodiversity of common edible and medicinal mushrooms like *Agaricus*, *Pleurotus*, *Volvariella*, *Termitomyces*, *Lepista*, *Flammulina* and *Cordyceps* will be presented. The diversity in *Amanita* spp. which has both edible and poisonous members will be also presented.