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Perspective

ADVANCES IN MUSHROOM PRODUCTION IN CHHATTISGARH VIS-À-VIS INDIA

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Fungi are the most diverse organisms on this universe and are defined as a eukaryotic, heterotrophic organisms, devoid of chlorophyll which obtain nourishment from living, non-living and dead organic matter (Taylor, 1998). Macrofungi are those that form large fructifications visible to the naked eye and include *Basidiomycota* and *Ascomycota* with large observable spore bearing structures. Only about 6.7% of the 1.5 million species of fungi estimated in the world have been described mostly from temperate regions (Tonjock *et al*., 2017). The tropical region of the country has the highest fungal diversity which has yet not been fully exploited (Hawksworth, 2001). Wild edible mushrooms are one of the most important natural forest resources on which forest people rely for their livelihood, nutrition and medicine (Yang, 2002). The wild mushrooms also seem to have been traditionally consumed by man since very early times, but these were then probably considered a food in wilderness, which now have come to occupy a very popular place in the modern dietic regimen because of their nutritive value. Ethnomycology investigates the indigenous knowledge of mushroom utilization and consumption as nutrition, medicine, and several other uses (Kinge *et al*., 2011). Even in the present context of modern shrinking world, two billion people lack essential nutrients while 870 million people get less calories than minimum dietary requirement. Further, the challenge to feed the entire population is compounded by the increasing population pressure, depleting land, water shortage as well as climate change. Another biggest challenge in feeding humans is to provide a sufficient amount of the body-building protein content.

The only option or way forward is diversification of agriculture with the aim to add value to primary agriculture. Mushrooms offer a unique opportunity for diversification and integration in the existing farming systems. Mushroom technology is one of the most efficient and economically viable microbial technologies, which recycles agricultural residues into food and manure. As a result, mushroom production has rapidly advanced all over the globe in the last two decades. China is the number one country in the world involved in production, consumption and export of mushrooms. It produces varieties of mushrooms on a commercial scale and mushroom farming has become the 5th farming business in China (Thakur, 2020). Indian production of mushroom has also increased from 40,000 MT in 1994 to 2.10 lakhs tons in 2019. It could have been possible only due to lot of advancements in spawn and crop production technology, research and innovations on different mushrooms, modification in production technology, mushroom production systems which has resulted in upgradation of rural livelihood in tribal, peri-urban and urban areas and also brought the significant change in socio-economic conditions of the society. It is with this background that the present article documents the information on mushroom diversity prevalent in various parts of the country, exploring rich mushroom diversity for multiple uses (as food, health and medicine), status on global and national production, innovations in different production systems and ultimately use of these mushroom species in start-ups, skill upgradation or human resource development to ensure food, nutritional, employment and income security in the modern society.

Mushroom diversity

India is blessed with a rich mushroom diversity as we have vast forest covers and varied agro climatic conditions from temperate to tropical.The diversity of climatic conditions prevalent in India made this country a natural habitat of a number of mushrooms. There are 1.5 million species of fungi in nature, of which 2000 species of edible fungi are known to man out of 10,000 species of macrofungi (Hawksworth, 1991; Thakur and Singh, 2020). Watling and Gregory (1980) predicted that since India is richer in flowering plants than any other country of its size, the fungal wealth of India is also expected to be equally diverse. Globally, an estimated 1,069 species of mushrooms have been reported to be used for food purposes (Boa, 2004). The fruiting bodies of these macrofungi develop from the underground fungal mycelium visible to the naked eye and are easily harvested by hand (Chang and Miles, 1992). They occupy diverse natural niches in the forest ecosystem and are seasonal in occurrence. They can be observed in the forests during the rainy seasons and sometimes post winter season when the snow melts in the hilly temperate areas.

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Termitomyces is a wild growing mushroom associated with termite nests in Central Africa and East Asia (Pegler, 1994). *Termitophilic agaricales* due to their unique mutualistic association with termites, unique habitat and habit, seasonal appearance, bountiful fruiting and traditionally established edibility have occupied a special place in ethnomycology (Osarenkhoe *et al*., 2014; Panda and Tayung, 2015; Aryal and Budathoki, 2016) and ecotheology (Kamat 1999).

Fig. 1. Termitomyces spp. sold in local market of Ambikapur

The genus *Termitomyces* (Fig. 1) recorded worldwide is also reported to occur in Western Ghats and on the west coast of India. The total number of species recorded from the Western Ghats are about 19 species. In Kerala, the inventory on *Termitomyces* possesses a total of 15 species (Farook *et al*., 2013). Ten species of Termitomyces have been recorded from Goa and nine species from Karnataka. Furthermore two species have been recorded from Tamil Nadu and three from Maharashtra. Among the *Termitomyces* species, *Termitomyces microcarpus* is predominantly distributed in these six states of the Western Ghats. The other species like *T. robustus, T. medius*, *T. perforans, T. indicus* (synonym of *T. microcarpus*, Pegler & Vanhaecke, 1994), *T. fuliginosus* (synonym of *T. robustus*; Pegler, 1977), *T. cylindricus* (synonym of *T. aurantiacus*; Tang *et al*., 2006), (might be a synonym of one of the small *Termitomyces* species), *T. sagittiformis*, and *T. schimperi* are recorded from one of the states.

Termitomyces species are well known as a food source and are considered delicacies, with many species on sale in markets and at roadsides in the old world tropics. Almost every species of this genus are a storehouse of nutrients and have commercial value in many regions (Oso, 1975; Parent and Thoen, 1977; Batra and Batra, 1979; Ogundana and Fagade, 1982, Purkayastha, 1985). They have been consumed as food as well as used in several tribal ethnomedicinal preparations by human over years across the globe (Sangvichien and Hawksworth, 2001). Numerous studies on nutritional attributes of *Termitomyces* species have been investigated in different countries by Mukiibi (1973) in Uganda, Ogundana and Fagade (1982) in Nigeria and Parent and Thoen (1977) in Zaire.

Chhattisgarh is bestowed with richness of mushroom flora as it sustains high plant endemicity (tree species representing maximum varieties of tree species in the country). It has the largest tropical forest cover as well as huge diversity and richness in ecological systems within the country. The forests are mostly covered with semi-evergreen true Sal forests (Shukla *et al.,* 2014) that ranges in the northern as well as southern parts in uplands (500–1050 m). Mixed Sal forests are characteristic signatures of the central

Fig. 2. *Cantherellus* spp. sold in local market of Kawardha

Fig. 3 : *Astreaus hygrometricus* sold in the market

part at low elevation gradients (250–400 m). However, Bastar is an exception being the single confined area of Chhattisgarh hugely dominated by Teak tree (*Tectona grandis*). In all, 78 mushrooms were collected from the year 1988 to 2010 during rainy season. Among the collected mushrooms, 33 edible, 22 were as non edible, 2 medicinal, 2 poisonous and 19 were unidentified. Maximum number of mushrooms were collected from Bastar Plateau and most of them were consumed by tribals. The most frequent mushrooms observed from different places of Chhattisgarh were *Volvariella volvacea, Cantherellus* spp. (Fig. 2)*, Tuber* sp., *Rusula* sp. and *Termitomyces spp*. Some mushrooms like *Termitomyces spp, Rusulla* spp, *Volvariella* like and *Ganoderma lucidum* were used as medicine to reduce labour pain, headache, constipation and healing of wounds respectively (Thakur *et al.,* 2011).

Thakur *et al*. (2017) collected 50 mushroom fungi from Bastar Plateau, during monsoon season, 25 mushroom species from different substrates in surveys of Chhattisgarh Plains and Northern Hilly Regions. Commonly identified mushroom floras during survey were: *Agaricus* sp. *Russula, Tuber* sp*., Boletus, Volvariella, Lepiota, Lactarius* etc. *Boletus lipidus, Clavaria sp, Collybia platyphylla, Collybia acerbata, Clitocybe geotropa, Gromphidius vicidus, Hydrophorus protensis, Maramuss rcorodomius, Pholiota apida, Russula crescens, Scleroderma verrucorum, Termitomyces* and *robustus, Volvariella volvacia.*

During the monsoon season, the high humidity provides ideal agro-climatic conditions for mushroom growth. A number of edible mushrooms growing in their natural habitats are being collected across Chhattisgarh by the local people and tribes of several districts during the rainy season for their consumption or sale. It is home to a number of primitive tribes. They are mostly Abujhamarias, Baigas, Bharias, Bhil, Gond, Maria, Muria, Saharia, Kol, Hill Korwa and Kamar (Tiwari, 1994). Among the edible mycoflora *Astreatus, Termitomyces, Russula, Amanita, Canthrellus, Volvariella* are some of the abundant genera. *Termitomyces*, is collected in tons in Chhattisgarh and Jharkhand from mid June to September. It is affluent source of protein, fibres, vitamins and minerals. It also has tremendous medicinal value and used to lower blood pressure, and as purgative (Apetorgbor *et. al.* 2005).

An annual turnover of Rs 25 lakhs to 30 lakhs through sale of forest mushrooms especially *Termitomyces heimii* and *Astreaus hygrometricus* (Fig. 3) (*Sal boda, Sarai boda), Canthrellus, Rassula* and edible *Amanita* spp. has been witnessed in Chhatisgarh. Seasonal collection of *T. heimii* and *A. hygrometricus* (Sal boda, Sarai boda) has been accounted as 300 to 350 tons from Dantewada, Bijapur, Bastar, Narayanpur Gariyaband, Kanker, Nagri, Banjari (Kawardha), Korba, Ambikapur, Jashpur and Tamnar forests of Chhattisgarh (Table 1, Table 2).

Ethno-medicinal information and tribal gastronomy of wild edible mushrooms

Several reports are available from several parts of Africa, Asia, Europe and South America, about collection and consumption of wild edible mushrooms by rural communities especially during the rainy season (Nakalembe *et al*., 2009). They recorded mycological knowledge and usage of termitophilous mushrooms in Mid-Western Uganda. Harkönen (2002) reported the

Table 1. Wild edible mushrooms collected by the villagers during monsoon season from Chhattisgarh State

Name of the mushroom	Months	Price	Place
Termitomyces microcarpus, Termitomyces heimmi, Termitomyces clypeatus	August to September	Rs.1000/-	Raipur, Kanker, Gariyaband, Jagdalpur, Kawardha, Ambikapur, Korea, Jagdishpur
A. hygrometricus	August to September	Rs. 600-800/-	Raipur, Kanker, Gariyaband, Jagdalpur
Canthrellus	August to September	Rs. 300/-	Korba
Volvariella	June to October	Rs. 300/	Raigarh, Janjgir Champa, Jagdishpur, Saraipalli, Mahasamund

Table 2. Wild edible mushrooms from forests of Chhattisgarh

Scientific name	Local vernacular name (Folk taxonomy)	Family
Amanita vaginata	Sugamunda Safed anda,	Amanitaceae
Amanita loosi	Haldi Phutu, Hardula phutu	Amanitaceae
Amanita caesarea	Sugamunda	Amanitaceae
Amanita vaginata var. *fulva*	Munjar dhunda	Amanitaceae
Astraeus hygrometricus (albino-white)	Sal boda, Sarai Boda, Rugda, Gohiya, Bastariya phutu Phutka	Diplocystaceae
Astraeus hygrometricus (niger-black)	Sal boda, Sarai Boda, Rugda Chharkeni phutu, Jaat boda, Rakhdi boda, Sargi phutu Patras phutu	Diplocystaceae
Boletus edulis	Jam Phutu	Boletaceae
Bovista dermoxantha	Dhela phutu	Agaricaceae
Cantharellus subalbidus	Baans Phutu (Khukhadi)	Tricholomataceae
Dacryopinax spathularia	-	Dacrymycetes
Ganoderma lucidum	Lakdi phutu	Ganodermataceae
Ganoderma applanatum	Lakdi phutu	Ganodermataceae
Lycoperdon pyriforme		Agaricaceae
Lentinus squarrosulus	Pihiri, phutu	Polyporaceae
Lentinus cladopus	Pihiri, phutu	Polyporaceae
Macrocybe gigantean	Dudhiya phutu	Tricholomataceae
Macrolepiota procera	Bhiden phutu	Agaricaceae
Pluerotus ostreatus	Pihiri, phutu	Pleurotaceae
Russulla emetic	Paan Phutu	Rassulaceae
Russula rosea	Murga Chundar, Paan Phutu, Paan ki begum, Sargi phutu Lal badar Khukhdi	Rassulaceae
Russula congoana.	-	Rassulaceae
Russula albonigra	-	Rassulaceae
Russula xerampilina	-	Rassulaceae
Lactarius deiciosa	-	Rassulaceae
T. heimii (albino-white) *T. heimii* (niger-black)	Bhadwahi/ Bhundu/Dusherra phutu, Bhimbhora phutu, Goncha phutu (appearing during Dusshera), Dengur phutu (appearing in termitarium) Khukhdi	Lyophyllaceae
T. eurhizus	Desi Chhattisgarhiya Phutu	Lyophyllaceae
T. clypeatus	Patera Phutu,	Lyophyllaceae
T. robustus	Kumha Khukdi/phutu	Lyophyllaceae
T. microcarpus	Kanki Phutu, Chowk Phutu, Chapat phutu	Lyophyllaceae
T. umkowaan	Patera Phutu	Lyophyllaceae
T. globules	Patera Phutu	Lyophyllaceae
T. striatus	Patera Phutu	Lyophyllaceae
T. mammiformis	Patera Phutu	Lyophyllaceae
T. cylindricus	Patera Phutu	Lyophyllaceae
T. aurantiacus	Patera Phutu	Lyophyllaceae
Trametes versicolor	-	Polyporaceae
Sparassis spp.	Dimag phutu	Sparassidaceae
Schizophyllum commune	-	Schizophyllaceae
Volvariella volvacea	Paira phutu, Chhati, Paira ke phool	Pluteaceae
Volvariella bombyciana	Paira phutu, Chhati, Paira ke phool	Pluteaceae
Hericium erinaceus		Hericiaceae

selling of edible species of *Termitomyces*, *Cantharellus*, *Lactarius*, *Russula* and *Amanita* in Tanzania and road side markets.

Panda and Tayung (2015) reported that in India *T. reticulatus* is used in rheumatism and lowering high blood pressure. Syrup prepared from *T. robustus* is used for the remedy of constipation, laziness, indolence and inactiveness. The paste of *T. schimperi* is used for remedy of cut wounds and skin disease. Kumari *et al*., (2012), Tibuhwa (2012) and Aryal and Budathoki (2015, 2016) reported in India, Tanzania and Nepal that *T. mammiformis* is edible and used as food due to its unique flavor and texture.

In a study conducted at IGKV Raipur (Badhai, 2020), the ethnic information from tribals especially Baiga and Maria tribes revealed the use of different *T. heimii* (Raja phutu,) which are having bigger heads normally appearing during Dusshera, to treat persons suffering from sickle cell anaemia. The powder of *Termitomyces* spp. is also used to treat measles, viral fever, diarrhoea, bleeding, constipation, wound, muscular pain, arthritis, skin disease, cough, cold, indigestion, etc. In Bastar, fruiting bodies of several *Termitomyces* spp. are wrapped along with ajwain seeds in banana leaves and kept over low flames; the fumes coming from it help the tribal women and after pregnancy.

Global and national production scenario

Spawn production

With the setting up of the National Research Centre for Mushrooms at Solan, spawn was made available from the Centre to small and marginal farmers. In the late eighties Sylvan, from USA, started operations in India for marketing spawn produced at their European centres. But unfortunately, they did not find the market big enough to set up their own production unit. We do not have large spawn companies operating in India with a R&D backup facility, the spawn companies that are operating just multiply the spawn and sell it. The availability of strains is limited to non hybrid strains of *A. bisporus* and on hybrid strain i.e., U-3. A dozen species of *Pleurotus* are also available in India for cultivation in different agro-climatic zones of India. Indira Sweta 1 is one of the oyster mushroom (*Pleurotus florida*) variety developed by AICRP, IGKV, Raipur in 2006 for commercial cultivation throughout the state of Chhattisgarh.

Several species of *Pleurotus* were also tested by AICRP on Mushroom Raipur centre for cultivation over the years and under varying agro climatic conditions. Some of the most common species identified for cultivation and preparation of spawn in Chhattisgarh were *Pleurotus florida, P. sajor caju, P. membranaceus, P. djamor, P. platypus, flabellatus, P. columbinus*, *P. ostreatus,* etc. Later, with the continuous research efforts from ICAR-DMR (earlier NRCM), 11 new strains were released for commercial cultivation viz., DMR-Button-03; U3-54 (High yielding strains of white button mushroom); DMR-Button-06 (High yielding strains of brown button mushroom); NBS-1 & NBS- 5 (Browning resistant strains of white button mushroom); DMRO-247 & DMRO-484 (High yielding strains of paddy straw mushroom); DMRO-38 & DMRO-388s (High yielding strains of shiitake mushroom); DMR-334 (High yielding strains of milky mushroom); DMR-*Macrocybe* - 01 (High yielding strains of *Macrocybe* mushroom). The cultures of all these strains are available from the culture bank maintained at the centre at ICAR-DMR, Solan (Table 3).

Table 3. Mushroom varieties released for commercial cultivation in India

Name of the Institute	Varieties released
DMR, Chambaghat, Solan	DMR-Button-03, DMR-Button-06, DMR-Shiitake-38, DMR-Shiitake-388, DMRO-247, DMRO-484 (Paddy straw mushroom) DMR Milky-334, DMR-Macrocybe-01
IIHR, Bangalore	Arka-OM-1 (Pink Oyster), Hu (Elm Oyster), Le (Shiitake)
PAU, Ludhiana	APK-2 (*Tricholoma giganteum*)
TNAU, Coimbatore	PAU-Les (Shiitake), Mm3 (Milky Mushroom)
IGKV, Raipur	Indira Shweta (Oyster Mushroom)

*University and Institute Websites

Some big spawn companies are supplying spawn to commercial growers in India at almost the local price. The quality of the spawn produced by Indian companies is comparable to the best in the world except that it is in small packs of 1kg and the choice of strains is limited. The big companies from US and Europe can make it big in India if they cater to the markets from surrounding areas like China, Indonesia, Thailand and other countries. The biggest advantage India offers is the lower cost of production of spawn with low cost of inputs. Presently, Indian market demand is about 8000-10000 tons of commercial spawn. Out of this requirement, the share of spawn supplied from public organizations (including ICAR-DMR, AICRP networks centres and KVKs) is limited to less than 10%. In the last five years, demand for quality spawn is still fulfilled by private spawn suppliers in India. This trend is very clear with the mushroom production status, where the higher production is recorded from the states viz., Punjab, Haryana, Uttarakhand, Tamil Nadu, Maharashtra and Odisha where more number of private spawn labs are located.

Crop production

Though, mushroom production in Asian countries started 1000 years ago, cultivation of mushrooms is relatively new phenomenon in India. Mushrooms such as *Auricularia, Flammulina* and *Lentinula* were most likely cultivated for the first time around the year 600-800 AD in China and other Asian countries (Chang and Wasser, 2017). Scientific cultivation, however, started only at the beginning of the 20th century when pure cultures of mushroom were prepared from spore and tissue. Cultivation in the beginning of the 20th century was focused on button mushroom mainly in USA and Europe. In first half of the 20th century, the focus was on cultivation of button mushroom in the West and to a lesser extent on shiitake in the East. In the second half of 20th century, there were rapid changes in rate of growth of mushroom production and number of species brought under commercial cultivation. By the end of 20th century, the share of button mushroom in total world production was less than 40 per cent, which in next ten years became around 30 per cent. Sudden rapid rise in cultivation of mushrooms other than button has been witnessed in the 21st century, particularly in last ten years. Net result is an exponential growth in world mushroom production. Due to almost unimaginable growth in production of shiitake, oyster mushrooms, wood ear mushroom and *Flammulina*, the contribution of these mushrooms to total world mushroom production has increased tremendously as compared to button mushroom, which is no more the number one mushroom in terms of share in global mushroom production. Presently shiitake, oyster, wood ear and button mushroom contribute 22, 19, 18 and 15%, respectively in terms of total mushroom production in the world (Singh *et al*., 2017). The contribution of medicinal mushrooms in world trade has increased over last few decades. The research focusing on validation of medicinal benefits and number of trials on use of novel chemicals derived from mushrooms in cancer research has attracted attention of industry.

In India, mushroom as a vegetable is yet to find regular place among the Indian consumers. Despite favourable agro-climate, abundance of agro wastes, relatively low-cost labour compared to Europe and a rich fungal biodiversity, India has witnessed a lukewarm response in its growth. At present, the total mushroom production in India is approximately 0.21 million tons (Sharma, 2020). The mushroom industry in India has registered an average growth rate of 4.3% per annum between 2010-2017. In the year 2016-2017, Indian mushroom industry generated revenue of Rs. 7282.26 lakh by exporting 1054 quintals of white button mushroom in canned and frozen form. Out of the total mushroom produced, white button mushroom share is 73% followed by oyster mushroom (16%), paddy straw mushroom (7%) and milky mushroom (3%). At present, highest production of button mushroom is registered from Punjab followed by Haryana and Maharashtra contributing for about 43% of total white button mushroom production. It is followed by oyster mushroom (25,000 metric tons), paddy straw mushroom (about 10,000 metric tons), milky mushroom (2000 tons) and other mushrooms totalling about 2.10 lakhs tons in India.

By effectively utilizing the seasonal variations, the farmers of Punjab and Haryana region have revolutionized the seasonal cultivation process with very less inputs. Many growers started adopting the seasonal cultivation of white button mushroom and its processing in a commercial scale as a livelihood and income generating activity in this region. The advantages like nearness to market, availability of raw materials at cheaper price coupled with the availability of good quality of spawn triggering the mushroom production from this region. However, the seasonal growers are facing the market gluts in December and January months resulting in distressed selling of button mushroom crop (Mehta *et al.,* 2011). Initially, white button mushroom production was confined to temperate hilly regions of India. However, with the development of short method of composting and optimization of fruiting conditions using the chilling system, there has been a remarkable change in its production scenario and spread to all the corners of the country. Some of the big mushroom units contributing immensely to the white button mushroom production are mentioned below (Table 4).

Seasonal cultivation became more popular in Haryana and Punjab region producing more than 8000-8500 tons of white button mushrooms per year. Many medium to small scale units are located in the states of Himachal Pradesh, Gujarat, Tamil Nadu, Uttarakhand, Uttar Pradesh and Goa.

In Chhattisgarh State, oyster and paddy straw mushroom cultivation is spreading very fast and is mainly dominated by oyster mushroom in the entire state while paddy straw mushroom is dominated in the districts of Mahasamund, Janjgir-Chapa, Raigarh, Dhamtari contributing for about 5000 tons annually. There are five commercial units of button mushroom in Chhattisgarh mainly located near the capital of Chhattisgarh i.e. Raipur producing about 2500 metric tons of button mushroom annually. Seasonal button mushroom cultivation is rapidly becoming popular in Northern hill regions of Chhattisgarh especially in the districts Sarguja, Mainpat, Korea and Balrampur.

The per capita consumption of mushrooms in India, is very meagre compared to that of other vegetables and data indicates that it is less than 100 grams per

Table 4. Some key players of button mushroom in India

Button mushroom industry (key players)	Production capacity per annum (in tons)
Himalaya International Pvt. Ltd.	10000
Agro Dutch Mushrooms Pvt. Ltd.	8000
Zauri Agro Farm	4000
Inventa Foods	4000
Himalaya International Pvt. Ltd.	4000
Tirupati Balaji Agro Products Pvt. Ltd.	3000
Cambium Biotech Pvt. Ltd.	3000
Flex Foods Pvt. Ltd.	2600
Weikfield Foods Pvt. Ltd.	2250
Inka Food	1500
SR Mushroom Industries	1500
Kulkarni Farm Fresh	1000
Welkin Overseas Pvt. Ltd	500
Vikas Mushroom Farm	500
Amrit Button Mushroom Farm, Godhi, Durg	800
Kakkad Mushrooms, Siltara, Raipur	800
Green Tech Agro- Button Mushroom Farm, Limtara, Durg	300
North Star Button Mushroom, Koteshwar Raipur	200

year compared to >20kg by China. By considering the production statistics, the spawn demand in India is estimated about more than 12000 tons per annum. Majority of this commercial spawn to the growers is being supplied by the private units and the contribution of public sector organizations in spawn supply was limited to 10% only.

Mushroom production systems

In India, there are five mushroom species viz., white button mushroom (*Agaricus bisporus*), oyster (*Pleurotus* spp.), paddy straw (*Volvariella volvacea*), milky (*Calocybe indica*) and shiitake (*Lentinula edodes*) are in commercial cultivation. Even though, cultivation technologies of many exotic species were standardized, the commercial markets are still dominated by *Agaricus bisporus*, *Pleurotus* spp. and *Volvariella volvacea.* These three mushrooms are contributing about 96% of total mushroom produced in India. Milky mushroom (*Calocybe indica*) is indigenous tropical mushroom of the country (Kumar *et al*., 2017). However, the commercial cultivation is restricted to south Indian states only and contributing up to 3% to the total mushroom production. Production of paddy straw mushroom became more popular in the states of Odisha and Chhattisgarh and its production was registered at 7% to the total mushroom production. The short duration cultivation technology of shiitake under indoor conditions was standardized at ICAR-DMR, Solan (Sharma *et al*., 2017), but still this valued mushroom has so far not been exploited at commercial scale in India. Few of the growers in Uttarakhand and Himachal Pradesh successfully cultivated the shiitake mushroom using the technology developed by ICAR-DMR, Solan. However, the markets are dominating by the dried mushrooms imported from China and Taiwan. In North Eastern states, Uttarakhand and Chhattisgarh states, oyster mushroom cultivation is emerging as the leading cottage industry. The important edible and medicinal mushrooms whose cultivation technology has been standardised in Chhattisgarh are as under:

Cultivation of Button mushroom (Agaricus bisporus) in solar panel enabled units

The standard protocol of compost preparation by long method from paddy straw as well as wheat straw has been standardised along with evaluation of different high yielding strains for advocation to different agro-climatic zones of Chhattisgarh. Almost year round cultivation of button mushroom is practised in Baster region by partial modification of the growing conditions and a biological efficiency of 14-16% was obtained. Northern hilly region of Chhattisgarh has comparatively lower temperature than Bastar Plateau and Chhattisgarh Plain regions where two crops of button mushroom can be cultivated in an ordinary thatched house with very poor management and achieving 10-12% biological efficiency. Similarly, year round cultivation of button mushroom in solar panel enabled units is one of its

Fig. 4. Solar Panel

Fig. 5. Button mushroom grown inside panel

kind of production in India which can be a prototype for designing standard cropping rooms (Fig. 4, 5) for upscaling it in near future. The biological efficiency recorded for button mushroom has been 15%.

Oyster mushroom (Pleurotus spp.)

It is generally referred as 'Dhingri' in northern India. It is a lignocellulolytic fungus growing on dead and decaying wooden logs or sometimes on drying trunks of deciduous or coniferous woods. The history of oyster mushroom cultivation is of recent origin in comparison to *Auricularia* (600 A.D.), *Lentinula edodes* (1100 A.D.) and *Agarcius bisporus* (1650). First successful experimental cultivation of *Pleurotus ostreatus* was achieved in Germany by Falck (1917). He inoculated tree stumps and wooden logs with mycelium of *P. ostreatus (Agaricus – ostreatus)* and could harvest fresh oyster mushroom. Block *et al.* (1958) cultivated *P. ostreatus* for the first time under laboratory conditions on sawdust medium.

In India, cultivation of *P. flabellatus* on paddy straw was reported by Bano and Srivastava in 1962 at CFTRI, Mysore. Corn cobs were used under sterile conditions for growing *P. ostreatus* (Toth, 1969). Kaul and Janardhanan (1970) cultivated a white form of *P. ostreatus* on dried *Euphorbia royleana* (Thor) stems. A Hungarian method for growing oyster mushroom based on a sterile production was patented in 1969 (HTTV patent). Stanek and Rysava (1971) developed a method of application of thermophilic micro-organisms in the fermentation of substrate for the cultivation of *P. ostreatus.* With inception of National Centre for Research and Training, Solan (H.P.) in 1983 and its cooperating centres called All India Coordinated Mushroom Improvement Projects established at different centres of the country, the cultivation of oyster and other edible mushrooms got a big jump in production through research and extension activities imparted to the mushroom growers.

In nature, 39 species of *Pleurotus* did exist, but only about a dozen are under cultivation and these are suited to different climatic zone. Some of the most common species whose production technology has been well standardized (Table 5) are as under:

Table 5. Specialty mushrooms grown and their temperature range.

Common name	Scientific name	Optimum temperature range
Grey Oyster	*Pleurotus sajor-caju*	20-28ºC
Black Oyster	*Pleurotus ostreatus*	18-22ºC
White Oyster	*Pleurotus florida*	20-28ºC
Pink Oyster	Pleurotus djamor	20-26ºC
King Oyster	*Pleurotus eryngii*	18-22ºC
Black Ear Mushrooms	*Auricularia polytricha*	22-26ºC
Shimeji Mushroom	*Hypsizygus tessulatus*	18-22ºC
Shiitake Mushroom	*Lentinula edodes*	18-22ºC
Milky Mushroom	*Calocybe indica*	28-32ºC
Paddy Straw Mushroom	*Volvariella volvacea*	30-35ºC

Paddy straw mushroom (Volvariella volvacea)

Volvariella volvacea (Bull. ex Fr.) Singer is an edible fungus with a large pileus. It is a tropical and sub-tropical basidiomycetes macrofungus and is also known as Chinese or Warm Mushroom belonging to the family Pluteaceae in order Agaricales (Kotl. & Pouz). The fruiting body of *Volvariella* is represented by six different developmental stages. Successively these stages are pinhead, tiny button, button, egg, elongation and mature stage. Each stage is characterized by its unique morphology and anatomy. It bears two kinds of spores. The sexual basidiospores are borne exogenously as tetrad form and the asexual spores are called chlamydospores. Monosporous as well as vegetative hyphae are multinucleate without clamp connections. *V. volvacea* is one of the easiest mushrooms to cultivate with a short incubation period of fourteen days thriving best at 30-35°C for development of mycelia (Reyes *et al.,* 1998a) and 28-30°C for production of fruiting body (Reyes *et al.,* 1998b). *V. volvacea* accounts for 5% of the total world mushroom production and is placed at fifth position along with *Flammulina velutipes* (Bao *et al.,* 2013). China is the main producer of this mushroom and more than 80% of the world production comes from Chinese mainland (Bao *et al.,* 2013). In earlier records this mushroom was known as “Nanhua mushroom” after the name of Nanhua Temple located in the Northern Guangdong Province of China.

Paddy straw mushroom was cultivated in India in 1940 for the first time. However, first attempt in systematic cultivation of *Volvariella* was in1943. Presently in India, Odisha state alone produces approximately 10,000 tonnes of this mushroom (Thakur, 2014). Chhattisgarh also accounts for more than 3000 tonnes of this mushroom. Other states like Jharkhand, Andhra Pradesh, Bihar, West Bengal, Tamil Nadu, Kerala and Karnataka are also actively involved in its production. Being cellulolytic in nature, the paddy straw mushroom can be easily grown on a number of cellulosic substrates *viz.* cotton wool, cotton wastes, wheat straw, sugarcane bagasse, paddy straw (Chang, 1993; Khan and Dogar, 1991; Reyes *et al.,* 1998b; Philippoussis *et al*., 2001). The dead palm tree, abandoned after the production of palm wine, is also a real production support of this mushroom (Delmas, 1989; Tiécoura *et al*., 2013). The mushroom is cultivated traditionally on uncomposted and partially pasteurised paddy straw or banana leaves bundles which are tied at both ends and laid one on top of the other in a criss-cross pattern to form a bed. The mushroom beds are covered with plastic sheets to avoid exposure to direct sunlight. It is the fastest growing mushroom among all edible mushrooms. The cropping period varies from 20 to 30 days which largely depends on the substrate and environmental conditions used for cropping (Ahlawat *et al*., 2009).

Compact Bag method of cultivation of Paddy straw mushroom (Volvariella volvaceae)

At IGKV, Raipur paddy straw mushroom *Volvariella volvaceae* cultivation has been standardised in bags of size 22”x40” for 2 kg dry paddy straw as substrate soaked in 1% lime (Fig. 6,7). Spawning @150gm / bag along with supplements 200 gm Red gram flour and wheat bran in 2:1 ratio gave biological efficiency of 20-25 % at 35°C and 85-90% relative humidity. Bag method of cultivation saves labour used for preparation of paddy straw bundles. It is less labour intensive and easy to manage. Compact bag method also aids in maintaining the requisite temperature for growing this mushroom.

Compost Method of cultivation of Paddy straw mushroom (Volvariella volvaceae) in mini green houses

Cultivation of paddy straw mushroom (*Volvariella volvaceae*) in mini poly houses has been standardised. Spawn along with supplements is sandwiched between paddy straw bed and semi-composted cow dung in a mini poly house (Fig. 8-13). The biological efficiency though recorded was in between 15-20%.

Fig. 6. Paddy straw mushroom in pp bags

Fig. 7. Fruiting bodies of Volvariella volvacea

Fig. 8. Mini poly house

Fig. 9. Button stage of PS mushroom

Fig. 10. Close up view of egg stage of PS

Fig.11. Egg stage turning towards umbrella stage

Fig. 12. Umbrella stage of paddy straw

Fig.13. Umbrella stage of paddy straw in Mini Poly house

Open cultivation of Volvariella spp. in mango orchard

Different production systems have been identified for *Volvariella volvacea* cultivation. Open cultivation of *Volvariella* in mango orchards, bamboo plantations, border rows of green houses in protected cultivation sheds and indoor cultivation in growing rooms has been popularized across Chhattisgarh (Fig. 14-15). A low cost viable button mushroom production model has been developed for farmers using long method of composting. Similarly button mushroom production in solar panel enabled growing rooms has also been initiated at pilot scale.

d) Lion's Mane (Hericium erinaceus) mushroom

Lion's Mane (*Hericium erinaceus*) strain *He-08* was successfully cultivated at IGKV Raipur on pasteurised/ sterilized sawdust and wheat straw during the month of October to February (Fig. 16-18). Both the substrates were comparatively good with biological efficiency of 55-60%.

Future roadmap for mushroom development

- Promotion of mushroom consumption through extension advertisements using its nutritional and medicinal values
- Development of cook book of all recipes of

Fig. 14. Bed method of PS cultivation

Fig.15. Cultivation of *Volvariella* in open orchards

Fig. 16. Fruiting body of Lion's Mane

Fig. 17. F.B. in PP bags

Fig.18. Cultivation of Lion's Mane

mushroom present in India using extension, AICRP and KVK networks and translating them in different regional languages of India

- Development of strategies to promote indigenous promising strains of mushrooms.
- Increase in supply of quality spawn.
- SWOT analysis of technologies and pushing promising ones to the farmers.
- Collection of more wild edible mushroom through AICRP network .
- Strategies to develop export market.
- Development of resistant strains for diseases such as wet bubble by screening the germplasm.
- Breeding for strains with multiple traits with improved quality.
- Circulation of list of all the varieties developed to NHB, DAC and other stakeholders in States so that these find place in their programmes.
- Analysis of the technologies and strain to identify the worth of technology in the market.
- Data bases of growers, machinery supplier, canners and other stakeholders in production and supply chain of mushrooms may be developed for different regions.
- Analysis of the technologies and strain to identify the worth of technology in the market. Analysis of markets and consumer preference may be undertaken by different AICRP centres in their respective regions.
- Technologies for use of paddy straw, mustard straw and other agri-residues may be developed for preparation of white button mushroom compost
- Considering lack of label claims for use of pesticides in mushrooms and also to promote mushroom as a health food, experiments on use of biologicals for control of various pests and diseases may be undertaken.

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