

Theme: Global Food Security

Opinion

## Mushroom cultivation: A means of nutritional security in India

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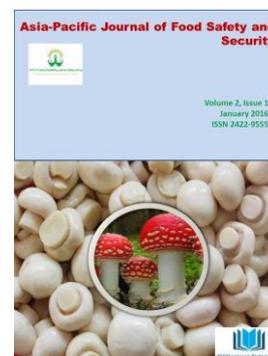
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By 2050, agriculture will be an industry that requires precise information and specific protocols. The complete recycling of nutrients, water and agro-wastes will be a necessity rather than a luxury. With the world's increasing population and its decrease in per capita arable land, along with rapid urbanization and industrialization, climate change, and a demand for quality and functional foods, it will be necessary to focus on secondary agriculture and novel crops, such as mushrooms. Diversification in farming system improves sustainability, and mushrooms production contributes to this. The commercial production of edible mushrooms represents the unique exploitation of a microbial technology for the bioconversion of agricultural, industrial, forestry and household wastes into nutritious food (mushrooms). Currently, 14,000 mushroom species are known to exist. Of these, 31 genera are regarded as prime edible mushrooms. To date, only 200 of these are experimentally grown, and 100 of them are cultivated economically, with approximately 60 being commercially relevant and ~10 having reached industrial scale production. The most acceptable varieties among the cultivated types are *Agaricus bisporus* (button mushroom), *Pleurotus* spp. (oyster mushroom), *Lentinus edodes* (Shiitake), and *Volvariella* spp. (Paddy straw mushrooms).

India produces ~700 million tonnes of agricultural residues which can profitably be utilized for mushroom cultivation. Currently, India is using only 0.03% of these residues to produce ~1.2 lakh tonnes of mushrooms. India contributes <1% of the total world mushroom production. Even if it uses 2% of its total agro-residues for mushroom production, the production would be ~7.0 million tonnes of fresh mushrooms, which will be equal to current global button mushroom production. This hi-tech horticultural venture is a promising means to meet world food shortages, without undue pressure on

the land. For people in a developing country like India, the two main issues are the quality food and the level of unemployment, in addition to environmental concerns, which can be resolved by popularizing mushroom cultivation among rural masses and the younger generation.

Mushroom cultivation recycles agricultural wastes into an easily digestible protein source that enriches the human diet. Mushrooms are an important source of quality protein, minerals and various novel compounds of medicinal value. After mushroom cultivation, the substrate can be composted and applied to the soil as an amendment to increase soil health. Cultivation of mushrooms using low production technologies that are labour intensive can provide ample employment potential to augment the income of the rural population.

### Scenario of mushroom production in India

Mushroom farming is today being practiced in more than 100 countries, and its production is increasing at an annual rate of 6-7%. Cultivated mushrooms have now become popular all over the world. In 1999, the world production of cultivated edible mushrooms was estimated to be >7 million tonnes, showing a steady increase over the last two decades. China is the largest producer, consumer and exporter of mushrooms in the world, followed by the United States and the Netherlands (Table 1). Mushroom production in China in 2010 was 21,524,473 tonnes (Li, 2012). Mushroom cultivation and its processing have been beneficial to millions of people in China, India and other developing countries in terms of financial, social and health improvement. In addition, cultivation and development of mushroom industries have positively impacted on economic growth, and this impact of mushroom cultivation and mushroom derivatives and products on human welfare in the 21<sup>st</sup> century can be considered globally as a “Non-green revolution”.

**Table 1. World mushroom and truffle production (million tonnes)**

Country	1999	2009
China	2.18	4.68
USA	0.38	0.37
Netherlands	0.25	0.23
Poland	0.11	0.17
India	0.014	0.04
<b>World</b>	<b>3.89</b>	<b>6.50</b>

Source: FAO Statistics, 2011); Verma, 2013

### Mushroom cultivation in India:

The history of mushroom cultivation in India goes back to the ages of “vedas”, wherein the mention was made in the classical religious scriptures like ‘Rig veda’ and ‘Atharva veda’ about the use of juice from fly agaric mushroom (*Amanita muscaria*) as an intoxicating drink, named “Soma”. Although time to time, small efforts and simple research were conducted to introduce mushroom cultivation to India, scientific and systematic research only started in 1961, when the Indian Council of Agricultural Research, New Delhi, first cultivated *Agaricus bisporus* at Solan in Himachal Pradesh, a hilly state of North India. Solan is today better known as Mushroom City, India. Research

conducted during the 1960s and 1970s was more or less adaptive in nature, and production technology *per se* lacked refinement.

Mushrooms, being an indoor short season crop and utilizing vertical space, offer a viable solution to a shrinking land base and a limited water supply. The artificial cultivation of mushrooms requires very little expenditure, as numerous cheap and easily available agro wastes can be utilized to grow them. Mushroom cultivation offers a high Benefit:Cost ratio to growers. In India, the total production of mushroom is about 113,315 tonnes (Wakchaure, 2011), Button mushrooms have the majority share (80%), and the remaining share (20%) goes to tropical mushrooms, such as oyster, paddy straw and milky mushrooms (Verma, 2013).

**Table 2. Mushroom production in India**

Mushroom	Annual Production (tonnes)
Button mushroom	100,683
Oyster mushroom	6,399
Paddy straw mushroom and other	5,313
Milky mushroom	920

Source: Prakasam, 2012

India, primarily being an agrarian economy, is rich in terms of agro wastes that are not properly utilized by the nation's farmers. Keeping this in view, the availability of abundant agro-wastes and varied agro-climatic conditions are prevalent in the country, and mushroom cultivation has great potential as an economic activity and means of societal development, with significant remunerative returns. However, mushroom cultivation is yet to be adopted by Indian farmers and mushroom growers on a large scale. The gap in technology knowledge and its adoption needs to be bridged by providing training to farmers regarding various aspects of mushroom cultivation. The enterprise of mushroom cultivation offers employment opportunities for unemployed youth and rural women. The high benefit:cost ratio, the easily obtained and inexpensive agro wastes and congenial weather conditions make adoption of mushroom cultivation a lucrative means of societal development.

Mushroom production depends mainly on the availability of raw material (substrate), labour and quality spawn. The first two components are readily available in India, so it is the supply and timely availability of quality spawn at fair prices which is the main determinant for mushroom cultivation and its adoption by growers. Non-availability of quality spawn is thus the main obstacle for the low production and non-popularization of mushroom growing in India. Presently, mushroom growers do not get the required quantity of quality mushroom spawn from reliable government agencies. Due to this, mushroom growers are continuously being exploited and allured to purchase spawn from private agencies. The growers are frustrated with the poor quality of traditional spawn being distributed and provided by the private growers.

### **How are mushrooms produced?**

Mushroom cultivation represents a very basic, natural process - that of fungal decay. One particular class of fungus, the basidiomycetes, produces a large fleshy reproductive organ (fruit body) which

we know more commonly as the mushroom. Many of these mushrooms are choice edibles, and in fact represent very high quality nutrition, often equaling or exceeding meat in their quantity of protein and essential amino acids (WHO, 2007).

The basis of mushroom cultivation is the breakdown of cellulose. The cell wall structure of virtually all plants is a fibrous structure composed of cellulose and hemicellulose, surrounded by a structural compound called lignin. Only a few organisms can breakdown the lignin and utilize it as a food source, thus exposing the underlying cellulose and hemicellulose for food use by other organisms. The best known and most effective of these lignin-breakdown organisms known as the white rot fungus, of which the oyster mushrooms are the prime examples. The most basic concept of mushroom cultivation is that we need to produce an environment in the substrate that is selectively preferential to the growth of our target mushroom species and less amenable to other types of microorganisms and pests. This involves sterilization or pasteurization. Once the substrate is treated in this way, and the majority of the microorganisms are killed, the substrate is suitable for the introduction of our target species of mushroom. Another potential treatment method is simply to soak the substrate in water. It prepares a substrate which is more selective to the higher cellulose degrading organisms, such as oyster mushrooms. This is the simplest method of substrate preparation, but the chemical treatment methods are much more effective and not considerably more difficult or expensive.

### **Types of cultivated mushrooms**

At present, four types of mushrooms *viz.*, the button mushroom (*Agaricus bisporus*), the Oyster mushroom (*Pleurotus* spp.), the paddy straw mushroom (*Volvariella* spp.) and the milky mushroom (*Calocybe indica*), have been recommended for round the year cultivation in India. Button, oyster, milky and paddy straw mushrooms are cultivated in different parts of the country, as per temperature profiles during different seasons. Two-three crops of button mushroom are grown seasonally in temperate regions with minor adjustments of temperature in the growing rooms, while one crop of button mushroom is raised in the northwestern plains of India seasonally. Oyster, paddy straw and milky mushrooms are grown seasonally in the tropical/sub-tropical areas. The cultivation methods for these sub-tropical/tropical mushrooms and others like *Lentinula*, *Flammulina*, *Auricularia*, *Agrocybe*, *Stropharia*, *Macrocybe*, *Hericium*, *Ganoderma*, etc. have also been standardized at different research institutes, universities and primarily at the Directorate of Mushroom Research, ICAR, Govt. of India.

Temperature is one of the critical factors for the successful cultivation of the different types of mushrooms. Table 4 gives an indication of the temperature requirements for different phases of mushroom growth during their cultivation.

### **Round the year mushroom cultivation**

The Indian subcontinent is known worldwide for its varied agro-climatic zones, with a variety of habitats that favour rich mushroom biodiversity (Verma *et al.*, 2003; Thakur *et al.*, 2011). The practice of taking crops alternatively to utilize the principles of crop rotation can also be implemented in mushroom cultivation. However, the cultivation of different mushrooms in rotation is not yet popular in India because mushrooms are a non-traditional crop. The majority of farmers are cultivating mushrooms only during a particular season. Farmers in the plains of north India cultivate white button mushrooms during the winter only, and they stop mushroom cultivation during the summer and dismantle their temporary growing houses. It is also paradoxical to note that India is largely a tropical country, yet mainly temperate mushrooms (*A. bisporus*) are cultivated there. The

**Table 3. Leading states in Mushroom cultivation in India**

State	Annual Production (tonnes)
Punjab	60,000
Uttarakhand	8,000
Haryana	7,178
Uttar Pradesh	7,000
Tamil Nadu	6,500
Himachal Pradesh	5,993
Orissa	5,846
Andhra Pradesh	3,022
Delhi	3,070
Maharashtra	2,975
Kerala	800

Source: Singh *et al.*, 2011

**Table 4. Temperature requirements of some important mushrooms**

Scientific name	Common name	Temperature requirement (°C)	
		Spawn run	Fruiting
<i>Agaricus bisporus</i>	White button mushroom	23-25	14-16
<i>Agaricus bitorquis</i>	Summer white button mushroom	28-30	25
<i>Auricularia</i> spp.	Black ear/ Wood ear mushroom	20-30	20-30
<i>Lentinula edodes</i>	Shiitake mushroom	22-27	15-20
<i>Pleurotus eryngii</i>	Kabuli Dhingri	18-22	14-18
<i>P. flabellatus</i>	Dhingri ( <i>flabellatus</i> )	25-30	22-26
<i>P. florida</i>	Dhingri (Florida)	25-30	18-22
<i>P. sajor caju</i>	Dhingri	5-32	22-26
<i>Vovlariella volvacea</i>	Paddy straw/ Parali mushroom	32-34	28-32
<i>Calocybe indica</i>	Milky/ Dudhiya mushroom	25-30	30-35

Source: Shirur, 2011

tropical and sub-tropical mushrooms like oyster (*Pleurotus* spp.), paddy straw (*Volvariella* spp.), milky (*Calocybe* spp.), reishi (*Ganoderma* spp.) and wood ear (*Auricularia* spp.) are not cultivated on a large scale.

Mushrooms can also be cultivated year round, like other field crops. In the plains of north India, white button mushroom can be cultivated during the winter, and in the summer, the sub-tropical or tropical mushroom species, like high temperature tolerant white button mushroom, milky, oyster or paddy straw mushroom, can be cultivated.

### **Benefits of year round mushroom cultivation**

Farmers can achieve the following benefits by following year round cultivation of different edible mushrooms, depending on the season.

#### *Year round employment opportunities*

Continuous mushroom activity will definitely “keep the hands busy” throughout the year. The problem of disguised unemployment can be effectively addressed with the promotion of year round mushroom cultivation.

#### *Year round resource utilization on the farm*

With the adoption of year round mushroom cultivation, resources like raw materials, machineries and labour are continuously being put to use. The same resources would go unused during the off season among seasonal cultivators of a particular mushroom.

#### *Year round economic returns*

It is quite understandable that farmers would choose enterprises that are rewarding throughout the year. Growing any specific mushroom in a particular season and stopping the mushroom activity during the rest of the season may not interest farmers. Hence, the continuous cultivation of different mushrooms, depending on the season, is certain to increase the economic return of the mushrooms growers. Year round cultivation assumes considerable significance, especially for rural livelihood security.

#### *Continuous nutrition to family members*

Mushrooms are known as a health food by virtue of their nutritional and medicinal properties. Mushrooms contain essential amino acids, like lysine and tryptophan, which are deficient in a cereal diet. Their high potassium:sodium ratio and low cholesterol content makes them ideal food for pregnant and lactating women and people with heart ailments. Hence with round the year mushroom cultivation, the consumption of mushrooms will increase among people. This would certainly help to address the issue of malnutrition in India.

#### *Break in the chain of pest and disease epidemics*

Growing single mushrooms throughout the year may cause repeated incidences of some pest and disease outbreaks in mushrooms. However, growing different mushrooms in rotation would help to break this chain of pest and disease epidemic. This insures farmers against the loss they may incur with mono-cropping. Hence, looking at the opportunities that various mushroom cultivations offer throughout the year, farmers should practice year-round cropping to reap maximum benefits.

#### *Health benefits*

Mushrooms are rich in protein, carbohydrates and vitamins. They are low in caloric value and hence are recommended for heart and diabetic patients. They are rich in protein as compared to cereals, pulses, fruits and vegetables, on a dry weight basis. In addition to protein, they also contain carbohydrate, fiber, minerals, vitamin C, thiamine, riboflavin, niacin, biotin and pantothenic acid. Folic acid and vitamin B<sub>12</sub>, which are normally absent in vegetable foods, are present in mushrooms. The minerals present include potassium, sodium and phosphorus, but mushrooms do not contain calcium or iron. Mushrooms are low in calories, high in protein and fiber, a high K:Na ratio, and they

are low in fat (but rich in linoleic acid and devoid of cholesterol). They are a good choice for dieticians to include in the diets of those suffering from or prone to obesity and hypertension. Besides their nutritional and medicinal value, mushrooms are relished as a source of food due to their pleasant aroma, taste and fleshy nature. The consumption of mushrooms can make a valuable addition to the often unbalanced diets of people in developing countries. Fresh mushrooms have a high water content (~90 percent), so drying them is an effective way to both prolong their shelf-life and preserve their flavour and nutrient content (FAO, 2009).

## **Mushrooms under cultivation in India**

A brief account of some popularly grown mushrooms in India follows:

### *Button mushroom*

The white button mushroom is the most popular of the cultivated mushrooms. This was the first mushroom to be commercially exploited on an industrial scale. At the global level, it ranks first. The genus *Agaricus* has two cultivated species, namely *A. bisporus* (temperate button mushroom) and *A. bitorquis* (tropical or high temperature tolerant white button mushroom). *A. bisporus* requires 23-25°C for a spawn run and 16-18°C for cropping, whereas *A. bitorquis* requires a temperature of 28-30°C for a spawn run and 25°C for cropping. Both mushrooms need high relative humidities of more than 85-90 per cent.

### *Oyster Mushroom*

*Pleurotus* mushroom, which is generally referred to as 'oyster mushroom' the world over and as 'Dhingri' in India, has its origin from the Greek word "pleuro", which means formed laterally or in a side way position, particularly referring to the lateral position of the stipe (stem) in relation to the pileus (cap). Species of the genus *Pleurotus* are well appreciated for their broad adaptability under varied agro-climatic conditions. The several species of this mushroom occur commonly as wood decomposers in forests throughout the world. *Pleurotus* has always been most attractive to commercial mushroom growers because of the ease by which most of these species can be cultivated. This mushroom consists of species that are suitable for both temperate and sub-tropical regions. For temperate regions, *Pleurotus ostreatus*, *P. florida* (winter strain) and *P. fossulatus* (Kabul dhingri) and *P. eryngii* (King oyster) are ideal. The areas suitable for the button mushroom are equally suitable for the cultivation of these species. The majority of the oyster species can be best grown in the temperature range of 20-30°C with high relative humidity in excess of 85 per cent. The majority of the *Pleurotus* species require 25-30°C for spawn runs and 20-25°C for fruiting. The oyster Mushroom is a low investment, low risk, low labour intensive, and moderate profit enterprise. The greatest advantage of the oyster mushroom is that its production technology is simple and that it can be easily grown at the village level in small makeshift sheds (huts). Growing the oyster mushroom is less expensive and more convenient compared to other species, such as the button mushroom. The method of cultivation is also very simple; in fact, much simpler than growing the button mushroom. Unlike the button mushroom, it does not need any compost preparation or precise temperature control. It can be sold both in fresh as well as dried form.

### *Milky mushroom*

The milky white mushroom grows during the summer, and it is a tropical mushroom known for its nutritional value. Its robust size, sustainable yield, attractive colour, delicacy, long shelf life and lucrative market value have attracted the attention of both mushroom consumers and prospective growers. *Calocybe indica* is rich in protein, lipids, fiber, carbohydrates and vitamins, and it contains an abundant amount of essential amino acids and is low in fat. These qualities make it suitable as a dietary food supplement. The milky mushroom (*Calocybe indica*) is purely of Indian origin and highly suitable for the tropical climatic conditions of central India, northern India and southern India. Its cultivation is now spreading quickly in many Indian states, including Tamil Nadu, Kerala, Orissa, Haryana and West Bengal due to its longer shelf life and adaptability to warm and humid conditions.

At present, Tamil Nadu is the major producer of the milky mushroom in India. The mushrooms need 25-30°C for their spawn run and 30-35°C for cropping. The mushroom can tolerate temperatures up to 40°C, however, the yield may be reduced.

#### *Paddy straw mushroom*

The paddy straw mushroom (*Volvariella volvacea*) is a world famous edible mushroom variety that enjoys high demand due to its deliciousness and nutritive value. It is a popular variety among people because of its distinct flavor, pleasant taste, high protein content and short cropping season compared to other cultivated mushrooms. The paddy straw mushroom is the sixth most important cultivated mushroom in the world (Ahlawat and Tewari, 2007). No other vegetable or cultivated mushroom can be served as a table dish within a short time after planting, but *V. volvacea* can do this as it comes to harvest 10-days post-planting. The paddy straw mushroom *Volvariella* sp. prefers to grow on paddy straw; hence, it is known as paddy straw mushroom. It originally grew in rice straw stacks in tropical and sub-tropical zones located in high temperature zones with rainy climates. Chinese growers developed its cultivation more than 300 years ago. Therefore, it was named “Chinese Mushroom” (Zhanxi and Zhanhua, 2000). In India, it was cultivated for the first time in Combiatore. Species of *Volvariella*, grown in India are viz., *V. esculenta*, *V. diplasia* and *V. volvacea*. The climatic conditions prevailing in India are best suited for the cultivation of this mushroom. Currently, Orissa is the leader in commercial cultivation of this mushroom. This mushroom needs 30-35°C for spawn runs and 28-32°C for cropping. The spawn is usually prepared using paddy straw as substrate. In addition to the conventional, Bundle method of cultivation, new techniques viz., the Improved Cage Method, Outdoor Cultivation (Open Field Cultivation), the Indoor Method (Compost Method), the Circular Compact Method and the Polybag Method have also been developed. The *per annum* production of paddy straw mushroom has been estimated to be approximately 10,000 tonnes (Verma, 2013). However, Orissa alone contributes ~8007.2 tonnes of paddy straw mushrooms *per annum*. It is also popular in Tamil Nadu, Kerala, West Bengal and Punjab. Orissa is now known for the production of paddy straw mushrooms in the entire state, and especially in coastal areas from April to December, when moderate temperatures with high humidity prevail.

#### *Medicinal mushrooms*

Mushrooms as medicine have long been used, but the full extent of their therapeutic properties is still unknown to us. Modern scientific studies on medicinal mushrooms have now expanded exponentially during the last two decades in Japan, Korea, China and the USA (Thakur and Singh, 2013). Medicinal mushrooms are the golden medicinal fungi and are yet to be exploited commercially in India. The extractable bioactive compounds from medicinal mushrooms enhance the human immune system and improve the quality of life. The most significant medicinal effect of mushrooms and their metabolites that have attracted the attention of the public is their anti-tumor properties. A plethora of antimicrobial compounds and bioactive metabolites with potential pharmacological and therapeutic properties viz., immunomodulation, anti-atherosclerotic, anti-inflammatory, analgesic, chemo-preventive, anti-tumor, chemo- and radio-protective, sleep promoting, antibacterial, antiviral (including anti-HIV), hypolipidemic, hypoglycemic, anti-fibrotic, hepatoprotective, anti-diabetic, anti-androgenic, anti-angiogenic, anti-herpetic, anti-oxidative and radical scavenging, anti-aging, estrogenic activity, anti-ulcer and many other exceptional nutritional and medicinal properties have been isolated from different species of medicinal mushrooms. Oyster mushrooms are best known medically for their cardiovascular and cholesterol-controlling benefits. *Volvariella volvacea* (Chinese or straw mushroom) are edible fungi with medicinal properties widely diffused and cultivated. Other species, such as *Auricularia* (muer), *Flammulina* (enokitake), *Tremella* (yiner) and *Grifola* (maitake), all have varying degrees of immune system boosting, lipid lowering, anti-tumour, microbial and viral properties, blood pressure regulating, and other therapeutic effects.

## Future prospects

India has tremendous potential for mushroom production, and all commercial edible and medicinal mushrooms can be grown. There is increasing demand for quality products at competitive rates both in domestic and export markets. To be successful in both domestic and export markets, it is essential to produce quality fresh mushrooms and processed products devoid of pesticide residues and at competitive prices. It is also important to commercially utilize the compost left after cultivation for making manure, vermi compost and briquettes for additional income and the total recycling of agro-wastes. Mushrooms can make an important contribution to the livelihoods of rural and peri-urban dwellers, through food security and income generation, and mushrooms can make a valuable dietary addition through their protein and micronutrient contents as well as their medicinal properties. Mushroom cultivation can represent a valuable small-scale enterprise option.

Growing mushrooms also helps to avoid some of the challenges facing collectors of wild fungi, including species identification, obtaining access and permits for collecting, and practicing sustainable harvesting. Cultivation is also independent of weather, and can recycle agricultural by-products as composted substrate which, in turn, can be used as organic mulch in growing other horticultural crops, including vegetables. Mushroom cultivation is highly compatible with a variety of other traditional agricultural and domestic activities, and can make a particularly important contribution to the livelihoods of the disabled, of women and the landless poor who, with appropriate training and access to inputs, can increase their independence and self-esteem through additional income generation.

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