

MUSHROOM CULTIVATION & SPAWN PRODUCTION



CENTRE FOR ENVIRONMENTAL STUDIES (CES)
Forest, Environment & Climate Change Department, Odisha

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CENTRE FOR ENVIRONMENTAL STUDIES

Forest, Environment & Climate Change Department
Government of Odisha, Bhubaneswar

Mushroom Cultivation & Spawn Production

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PREFACE

Mushroom cultivation has gained prominence as a sustainable, eco-friendly, and profitable livelihood option, contributing significantly to food security, employment generation, and environmental conservation. As a low-cost and high-return enterprise requiring minimal land, it holds immense potential for empowering rural youth, women, and self-help groups.

The Centre for Environmental Studies (CES), functioning under the Department of Forest, Environment & Climate Change, Government of Odisha, has been consistently working towards promoting environmentally sustainable livelihoods and capacity-building among youth communities under Environmental Education Programme (EEP) of MoEF&CC, Government of India. Mushroom cultivation perfectly complements these objectives by converting agricultural residues into nutritious food and valuable organic manure, thereby supporting the circular economy and reducing environmental pollution.

This publication, "Mushroom Cultivation: Opportunities and Practices," is an outcome of CES's continued efforts to provide practical and scientific guidance to youth, students, and teachers. It presents a comprehensive overview - from the

global, national, and state scenarios of mushroom production to detailed cultivation techniques, post-harvest handling, pest and disease management, and economic viability.

The manual elaborates on the cultivation of Oyster and Paddy Straw mushrooms, which are ideally suited to the climatic conditions of Odisha. It provides step-by-step guidance on harvesting at the right stage, packaging, drying, and value addition for market-ready products. The book also highlights the importance of recycling spent mushroom substrates through vermicomposting, animal feed, and organic manure - demonstrating how waste from one process can become a valuable input for another.

I express my sincere appreciation to the technical team of CES and all experts involved in compiling this valuable publication. It is our hope that this manual will inspire wider adoption of mushroom cultivation across Odisha, promoting rural entrepreneurship, women's empowerment, and environmental sustainability.



(Dr. K. Murugesan)

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MUSHROOM CULTIVATION

1.1 Backdrop

The global mushroom industry in 2025 is a robust, growing market valued at approximately USD 71.76 to 73.14 billion, driven by increasing consumer interest in health, wellness, and plant-based diets. The market is expected to expand at a CAGR of over 9% in the coming years. The world produces around 43–45 million metric tons of mushrooms and truffles annually. The global mushroom market value (2025) is estimated at USD 70–75 billion, and expected to reach USD 100 billion by 2030 (with ~7% CAGR growth rate). Mushrooms are now recognised as a “future protein source” due to their nutritional and environmental advantages.

China is the world’s largest mushroom producer, accounting for approximately 94% of global production, followed by Japan and the United States. China produces over 35 million tons annually through their vast smallholder network and low-cost production systems. Other significant producers include India, Italy, the Netherlands, and Canada, which contribute to the top rankings for mushroom and truffle

output Mushroom cultivation began in Asia (China) around 600 AD, Europe (France) in the 17th century, and the United States (America) in the 1900s. About 14,000 to 16,000 species of fungi are considered mushrooms; only a few are edible, and an even smaller number are grown for commercial purposes. Approximately 200 species of mushrooms are successfully cultivated globally, with around 100 having commercial importance and a smaller number being produced on an industrial scale. The global market is dominated by just a few types, such as the white button mushroom (*Agaricus bisporus*) and the shiitake mushroom (*Lentinula edodes*).

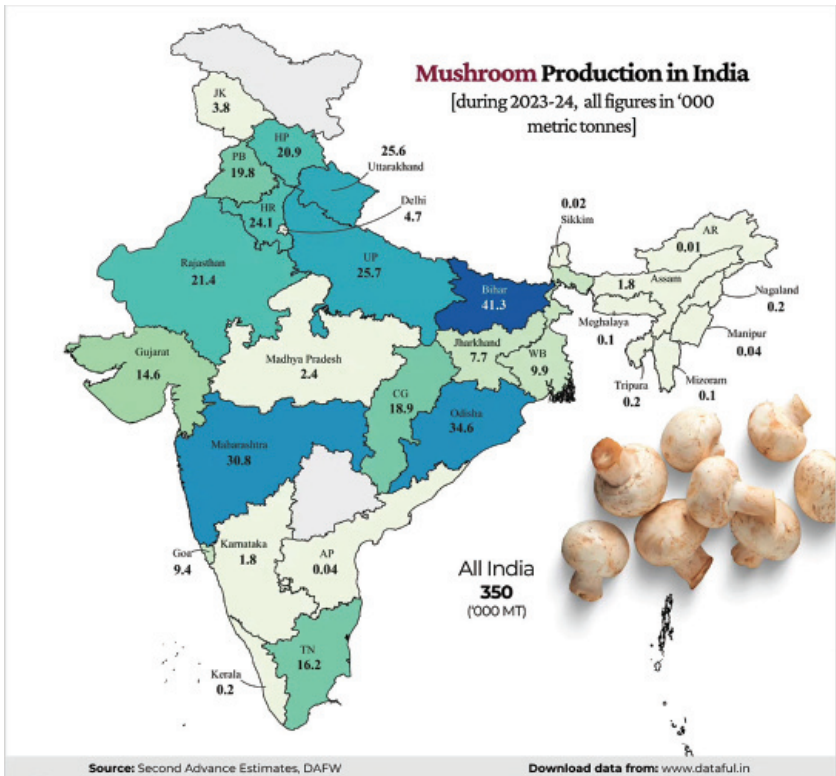


Fig 1, Mushroom production in India

India has also emerged as a strategic producer of mushrooms, steadily increasing its output to meet the growing demand both domestically and internationally. India is blessed with a diverse agro-climate condition with an abundance of agricultural waste and manpower, making it most suitable for the cultivation of all types of temperate, subtropical and tropical mushrooms. Mushroom cultivation in India has gained significant momentum in recent years due to its high demand, nutritional value, and profitability. It can profitably be started by landless farmers, unemployed youths and other entrepreneurs. It requires less land than other crops and is basically an indoor activity. These are the ideal tools for recycling agricultural wastes, which otherwise may pose a problem of disposal and atmospheric pollution. The top mushroom-producing countries are as follows in Table 1.

Table 1, Top Mushroom-Producing Countries

| Rank | Country | Share of Global Production | Popular Types |
|------|----------------------------------|-----------------------------------|-------------------------------------|
| 1 | China | 75% | Button, Shiitake, Oyster, Wood Ear |
| 2 | United States | 5% | Button, Portobello, Oyster |
| 3 | Netherlands | 3% | Button (<i>Agaricus bisporus</i>) |
| 4 | Poland | 2% | Button, Oyster |
| 5 | India | 2% | Button, Milky, Oyster |
| 6 | Vietnam, Indonesia, Korea, Japan | Small but rapidly growing markets | |

Mushrooms are fungi that have been used as food since time immemorial. The scientific name of mushrooms is *Agaricus bisporus*, and they belong to the family *Agaricaceae*. From a nutritional point of view, mushrooms are considered a delicacy, placed between meat and vegetables. Mushrooms are rich in protein, carbohydrates and vitamins. Mushrooms are low in caloric value and hence are recommended for heart and diabetic patients. The top 10 mushroom-producing states of India are Bihar, Odisha, Maharashtra, Uttar Pradesh, Uttarakhand, Haryana, Chhattisgarh, Rajasthan, Himachal Pradesh and Punjab. Bihar ranks first in mushroom production in 2023-24, with a total production of 42.19 kilotonnes, accounting for 12% of the country's total mushroom production. Solan, a city in Himachal Pradesh, is known as the "Mushroom City of India."

Odisha ranks second in mushroom production in 2023-24, with a total production of 34.60 kilotonnes, contributing 9.9% of the country's total mushroom production. Odisha is a leading state in India in producing mushrooms, particularly Paddy Straw mushrooms, which account for 67% of its

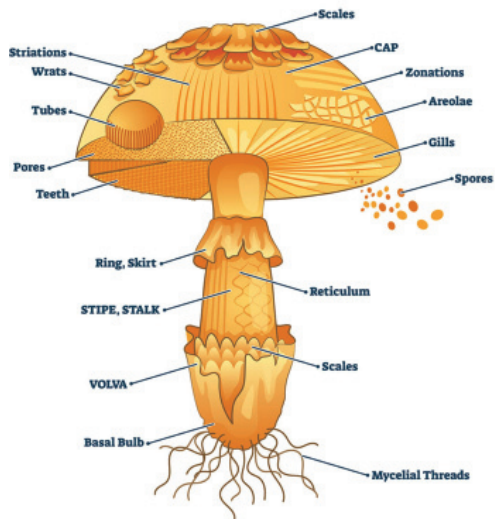


Fig 2, Various parts of mushroom production in India

total production, followed by Oyster mushrooms at 32%. The major mushroom-producing regions in Odisha include Puri, Ganjam, Khorda, and Dhenkanal. The state's humid, coastal climate is well-suited for mushroom cultivation, with coastal districts like Puri leading in production. Mushroom farming is a low-investment, high-profit venture in Odisha, popular among farmers and women entrepreneurs who can adapt it to a homestead environment.

1.2 Definition of Mushrooms

A mushroom is the fleshy, spore-producing fruiting body of a fungus that typically grows above ground. Mushrooms were classified among the lower parts in the Division Thallophyta by Linnaeus. This was largely due to the relatively simple, anatomically uncomplicated structural attributes (lack of true roots, true stems, true leaves, true flowers, and true seeds).

A mushroom is the reproductive, or fruiting, body of a fungus. As a fungus, it belongs to its own kingdom, separate from plants and animals, and cannot produce its own food through photosynthesis. They obtain nutrients by absorbing organic material from their surroundings, such as decaying wood or soil. Some species can also form symbiotic relationships with living plants.

Many people believe that mushrooms are vegetables. All vegetables and fruits come from edible plants. A mushroom (*Agaricus Bisporus*) is one of the many species of fungi. They have been given their own kingdom due to the sheer number of species that exist: 'The Kingdom of Fungi'.

Mushroom is broadly defined as follows: "A mushroom is a macro fungus with a distinctive fruiting body which can be either epigeous (above ground) or hypogeous (underground) and large enough to be seen with the naked eye and to be picked by hand." According to this definition, mushrooms need not be Basidiomycetes, nor aerial, nor fleshy, nor edible.

The mushroom is only the visible part of the organism; the majority of the fungus lives underground in a network of thread-like filaments called the mycelium. More than 10,000 known species of mushrooms, and they come in many shapes, colours and sizes. A typical mushroom consists of a cap, a stalk (or stipe), and gills or pores on the underside of the cap. These gills or pores contain millions of microscopic spores that are released to form new fungi.

1.3 Nutritive Value of Mushroom

Mushrooms are rich in proteins as compared to cereals, fruits and vegetables. In addition to proteins (3.7 %), they also contain carbohydrates (2.4 %), fat (0.4%), minerals (0.6 %) and water (91%) on a fresh weight basis. Mushrooms contain all the essential nine amino acids required for human growth. Mushrooms are an excellent source of thiamine (vitamin B1), riboflavin (B2), niacin, pantothenic acid, biotin, folic acid, vitamin C, D, A and K, which are retained even after cooking.

Mushrooms are more closely related to humans than plants on the evolutionary tree. Unlike plants, they do not perform photosynthesis; instead, they obtain energy by breaking down organic matter from their environment. Mushrooms play a crucial role in environmental clean-up.

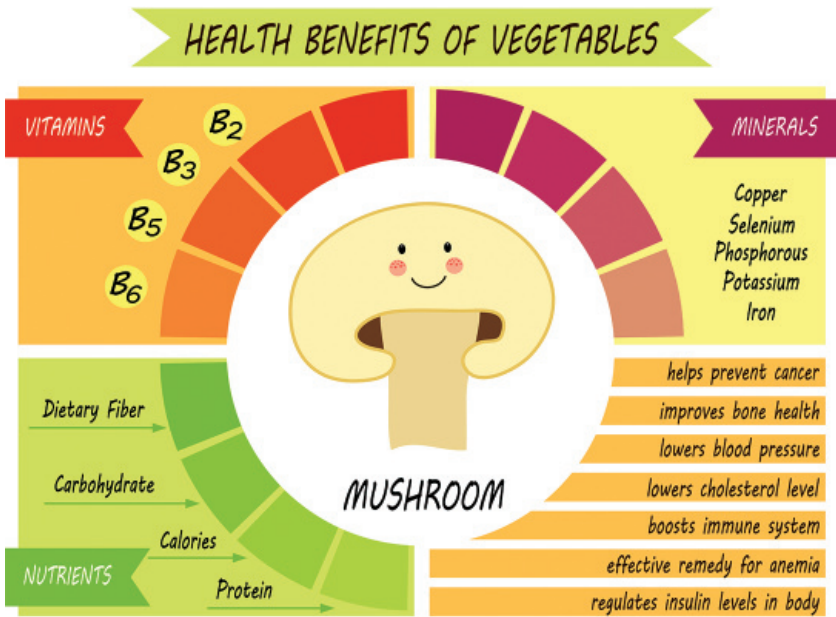


Fig 3, Mushroom: source of minerals and vitamins production in India

Mycoremediation, a process using fungi to break down pollutants, has been successfully used to clean oil spills and remove heavy metals from contaminated soil. Mushroom mycelium is being used to create eco-friendly alternatives to plastic, including biodegradable food containers, packaging materials, and even sustainable building materials. Mushrooms are one of the richest natural sources of umami, the savoury "fifth taste" found in foods like tomatoes and cheese. Varieties such as shiitake and porcini are known for enhancing flavours in many cuisines.

Since mushrooms have a low caloric value, high protein content, high fibre content, and a high K: Na ratio, they are ideally suited for patients with diabetes and hypertension. They are also reported to possess anticancer activities. Mushrooms

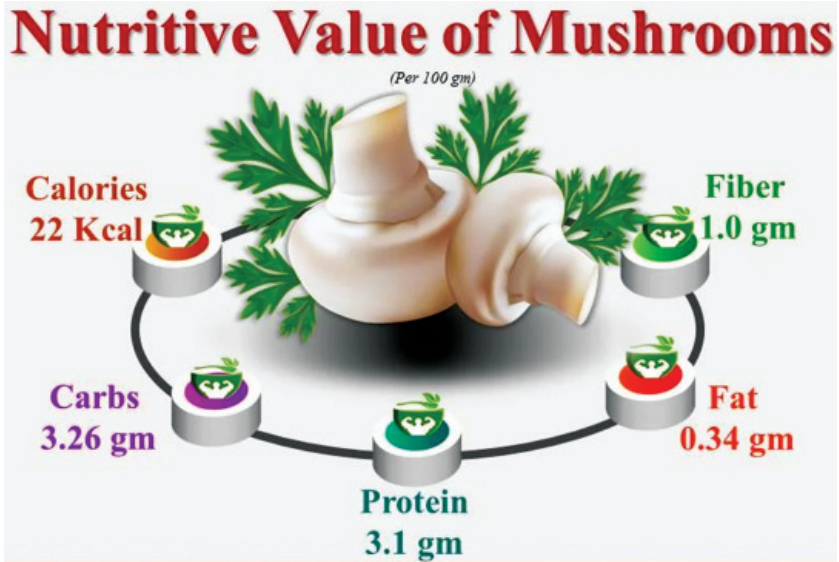


Fig 4, Nutritive value of Mushroom production in India

are enriching with macronutrients, vitamins, minerals and other beneficial compounds.

1.3.1 Macronutrients

The macronutrient values per 100 grams contain 22 Kcal, 3.26 gm carbohydrates, 3.1 gm protein, 0.34 gm fat and 1.0 gm fiber.

1.3.2 Vitamins

Mushrooms are an excellent source of several vitamins, particularly B vitamins.

- **B Vitamins:** Contain a significant amount of riboflavin (B2), niacin (B3), pantothenic acid (B5), and folate (B9). These vitamins are crucial for releasing energy from food and maintaining a healthy brain.
- **Vitamin D:** Mushrooms are one of the only non-animal food sources of vitamin D. The amount is greatly increased

when they are exposed to ultraviolet (UV) light, such as sunlight

- **Vitamin C:** Provides a moderate amount of this vitamin, which functions as an antioxidant and boosts the immune system.

1.3.3 Minerals

The mineral content in mushrooms is also noteworthy.

- **Potassium:** High in potassium, which helps regulate blood pressure and counteracts the negative effects of sodium.
- **Copper:** An excellent source of copper, a mineral essential for making haemoglobin and maintaining healthy connective tissues.
- **Selenium:** Rich in this powerful antioxidant, which helps prevent cell damage and boosts the immune system.
- **Phosphorus:** Contains a good amount of phosphorus, a key mineral for strong bones and energy production.
- **Other minerals:** Also provide smaller amounts of zinc, magnesium, and iron.

1.3.4 Other beneficial compounds

Beyond standard nutrients, mushrooms offer other health-promoting compounds.

- **Antioxidants:** Contains several antioxidant compounds, including polyphenols, carotenoids, and glutathione, which protect cells from damage.
- **Beta-glucans:** A type of soluble fiber found in mushrooms that may help lower cholesterol levels.
- **Prebiotics:** The fiber in mushrooms acts as a prebiotic, feeding beneficial gut bacteria and supporting digestive health.

- **Low in sodium:** Naturally low in sodium, making them a heart-healthy addition to your diet.

Therefore, mushroom cultivation is not only of economic importance but also has an important role to play in the integrated rural development programme by increasing income and self-employment opportunities for the individual, village youths, unemployed rural men and women, womenfolk and housewives to make them financially independent.

1.4 Key Aspects of Mushroom Farming in Odisha

Mushroom farming has an enormous potential in the state of Odisha. The small, marginal and vulnerable community are cultivating mushrooms for better livelihood and income. Mainly, the individual farmer, SHG members, FPO members, JLGs, CIGs and WIGs are growing mushrooms as an Income Generating Activity(IGA) in the various parts of Odisha. Odisha is the 2nd largest State producing mushrooms in India. The very common mushroom species grown in Odisha are paddy straw, oyster and button mushrooms. The key aspects include leveraging the state's climate, government policy support & technical guidance to farmers, and the interest of farmers makes them empowered to become an agripreneur in the state. The current agro-climatic conditions are very conducive for mushroom cultivation across the state, and the various opportunities are as follows.

- **Dominant Species:** Paddy Straw mushrooms are the most cultivated, known for their low space, capital, and short crop cycles. Oyster mushrooms are also a significant crop.

- **Climate and Geography:** The state's climate, with high humidity and coastal proximity, is ideal for growing various mushrooms. Coastal districts such as Puri, Khurda, and Ganjam are major production centers.
- **Economic Viability:** Mushroom farming offers a lucrative opportunity with a lower investment compared to other crops, leading to higher profits for farmers.
- **Growth and Demand:** The state has seen substantial growth in paddy straw mushroom production, with significant yield increases over the past decade. There is a strong demand for edible mushrooms due to their nutritional benefits.
- **Adaptability and Accessibility:** The practice is adaptable to homesteads, requiring minimal land, and is a sustainable agricultural practice.
- **Socio-Economic Empowerment:** Mushroom farming is a sustainable way to empower both farmers and women, offering opportunities for increased income and socio-economic development.
- **Training and Support:** Government policies, training programs, and a growing market demand are fostering participation in mushroom farming, especially among women and rural youth.
- **Entrepreneurship:** Many individuals are successfully becoming entrepreneurs by cultivating oyster mushrooms, leveraging social media and horticultural department support to start their ventures.

1.5 Types of Mushroom Production

The main types of mushroom production worldwide are centred around a few dominant species that account for about 90% of the total global output, including button, shiitake, and oyster mushrooms. These are further categorised by the substrate they grow on, such as straw, logs, or compost, and production can be small-scale in urban settings or large-scale in rural areas. The major types of mushrooms commercially grown across the Globe are as follows:



1. **Button mushroom (*Agaricus bisporus*):** A popular choice in the USA and Europe, it is grown on compost.
2. **Shiitake mushroom (*Lentinula edodes*):** Highly popular in East Asia, this mushroom is a leading cultivated edible mushroom globally and can be grown on logs or sawdust.
3. **Oyster mushroom (*Pleurotus spp.*):** A fast-growing and popular choice worldwide, with various species suitable for different climates.
4. **Wood ear mushroom (*Auricularia spp.*):** Another major player in global production, particularly in Asia.
5. **Paddy straw mushroom (*Volvariella volvacea*):** A tropical mushroom that grows on paddy straw, commonly cultivated in warmer climates.

6. **Enoki mushroom (*Flammulina velutipes*):** Also known as the velvet foot, this mushroom is grown on a substrate of sawdust, paper, or cardboard.
7. **Milky mushroom (*Calocybe indica*) :** A popular choice for round-the-year cultivation in certain tropical and subtropical regions.

Odisha's diverse climate supports the cultivation of various mushroom species. Paddy straw mushroom is the most dominant, thriving in Odisha's humid climate and often cultivated as an intercrop in coconut plantations. Paddy straw mushroom is the most popular and highest-producing type in the state, especially in the coastal regions, due to its suitability for the climate and availability of raw materials. While oyster and button mushrooms are also cultivated, their production levels are lower in comparison. Oyster and button mushrooms are also grown commercially, though in smaller quantities, and are suitable for year-round cultivation.

- **Paddy straw mushroom (*Volvariella volvacea*):** This variety thrives in the warm and humid conditions of Odisha, where it can be grown for up to 10 months a year, primarily from February to November. Odisha is the country's leading producer of this mushroom, which is often grown outdoors and requires a short crop cycle of 21-25 days.
- **Oyster mushroom (*Pleurotus spp.*):** Known for its higher yields and better shelf life than the paddy straw variety, oyster mushroom cultivation is popular in Odisha during the winter months, from November to February.

- **Milky mushroom (*Calocybe indica*):** Although its ideal cultivation time overlaps with that of the more dominant paddy straw mushroom, this variety, with its attractive white appearance and long shelf life, is being explored for commercial production.
- **Button mushroom (*Agaricus bisporus*):** While traditionally grown in cooler climates, Odisha has successfully initiated indoor, controlled-environment cultivation of button mushrooms, with production expected to grow further.

1.6 Major Substrates used for Mushroom Production

Major substrates for mushroom production worldwide include straw (such as wheat, rice, or cotton), sawdust, and other agricultural waste like sugarcane bagasse, coffee pulp, and corn cobs. The specific substrate choice depends on the mushroom species being cultivated, with some, like *Agaricus bisporus*, preferring straw-based compost. In contrast, oyster mushrooms (*Pleurotus* species) can be grown on a wider variety of materials. The major substrate used for mushroom production in Odisha is paddy straw (rice straw). The abundant availability of paddy straw at cheap rates throughout the state makes it the primary and most popular choice, particularly for the cultivation of the paddy straw mushroom (*Volvariella spp.*) and oyster mushrooms (*Pleurotus spp.*). Various other locally available lignocellulosic wastes are also used or have been evaluated for mushroom cultivation in Odisha, including wheat straw, maize stalk, sugarcane bagasse, green gram stalk, groundnut shell, coir pith, mustard stalk, and Niger stick.

- **Straw:** Used for a variety of mushrooms, especially *Agaricus bisporus* and *Pleurotus* species. Examples: Wheat straw, rice straw, cotton straw, soybean straw, and corn straw.
- **Sawdust:** A primary substrate for wood-loving mushrooms, particularly hardwoods like oak or aspen. Examples: Hardwood sawdust, often supplemented with other materials.
- **Agricultural by-products:** A wide range of plant-based wastes can be used. Examples: Sugarcane bagasse, coffee pulp, corn cobs, corn stalks, and various other plant materials.
- **Other materials:** Tea leaves, banana leaves, coconut husk, oil palm waste, mustard stalks, Jute sticks, sugarcane bagasse and niger sticks.

For mushrooms like the milky or button mushroom, a casing layer is applied over the fully colonized substrate. This layer is typically a mixture of garden soil and aged farmyard manure (FYM), or a peat moss and ground limestone blend, to provide physical support and maintain moisture.

1.7 Govt. Initiative for Promotion and Empowerment of Mushrooms

Mushroom cultivation is the most emerging sector in Odisha, which can be promoted by involving women beneficiaries. Nevertheless, the involvement of women SHGs/farmers in horticultural activities will lead to the empowerment of women farmers in the years to come. Efforts are needed to alter the role of women from hired labour to entrepreneurs,

which can lead to a healthy and prosperous farming community. The state government has established initiatives and infrastructure to support mushroom cultivation.

Mushroom Mission and Women SHGs:

The state's "Mushroom & Floriculture Mission" focuses on doubling mushroom production, particularly by involving women farmers and SHGs. The program aims to make Odisha self-sufficient in button mushrooms and a net exporter of paddy straw and oyster mushrooms.

Mushroom Mission:

- I. Doubling mushroom production across the State through area expansion through involvement of women farmers/ WSHGs to make the state self-sufficient in button mushroom & net exporter of paddy straw & oyster mushroom.
- II. Promotion of processing units for value addition and development of entrepreneurship in mushrooms, and promotion of value-added products of mushrooms through enabling processing infrastructure.
- III. Training & capacity building of stakeholders like women farmers, WSHGs, and entrepreneurs engaged in mushroom cultivation & processing.
- IV. Establishment of marketing linkage for mushroom, flower and their value-added products.

Infrastructure development:

The government actively supports the establishment of spawn production units and processing infrastructure for

value-added products. A help desk was also created to provide farmers and entrepreneurs with information and support.

Training and capacity building:

The Horticulture Department, Krishi Vigyan Kendras (KVKs), and agricultural universities like the Odisha University of Agriculture and Technology (OUAT) provide training to farmers on scientific cultivation methods and spawn production.

Subsidies and financial aid:

Through schemes like the Mushroom Kit Vitaran, farmers can receive kits at a subsidized cost, along with financial aid for training. Financial institutions like NABARD also offer credit facilities for establishing production and spawn-making units.

MEDICINAL PROPERTIES OF MUSHROOMS

Mushrooms possess a wide range of medicinal properties and are utilised in both traditional and modern medicine for their diverse health benefits. Mushrooms contain a wide range of bioactive compounds, including polysaccharides, proteins, phenolics, terpenoids and vitamins, that contribute to numerous medicinal properties. For centuries, mushrooms have been used in traditional medicine to support health and treat various diseases. Modern research continues to explore and confirm these effects, including anti-inflammatory, antimicrobial, immunomodulatory effects, antioxidant, anticancer, and antimicrobial properties. Mushrooms have numerous medicinal properties, including boosting the immune system, fighting cancer, and reducing inflammation. These properties have led to their use in folk

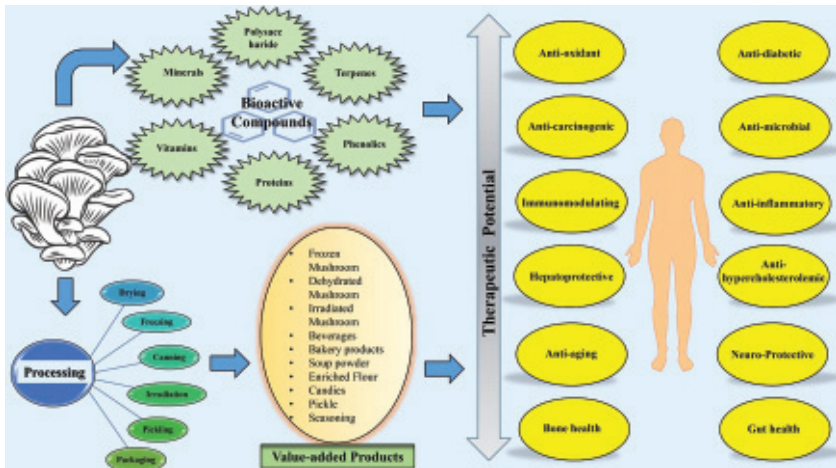


Fig 1, Medicinal value of mushrooms

medicine and as a complementary treatment alongside conventional therapies, particularly in countries such as Japan and China. Mushrooms can strengthen the immune system through their high levels of selenium, vitamin D, and B6.

Mushrooms are recognised for their anti-tumour properties and ability to inhibit tumour growth. Some species have compounds that can help destroy cancer cells without harming healthy cells. In Japan and China, certain medicinal mushrooms are approved as an addition to standard cancer treatments. Mushrooms can help manage blood sugar levels, making them beneficial for people with diabetes. Their high potassium content can help lower blood pressure by counteracting the effects of sodium and relaxing blood vessels. They may have cholesterol-lowering effects and protect against certain cardiovascular diseases.

2.1 Key Medicinal Properties of Mushrooms

Antioxidant:

Mushrooms are rich in antioxidants, primarily ergothioneine and glutathione, which help protect the body from oxidative stress and cell damage. They also contain other antioxidant compounds like selenium, vitamin C, polyphenols, and beta-glucans, which contribute to their overall health benefits, including supporting skin health, immune function, and brain health. Protects cells from damage and may help slow ageing processes.

Immunomodulatory:

Mushroom immunomodulatory refers to compounds found in mushrooms that can regulate the immune system, and they are classified into four main groups: polysaccharides,

lectins, fungal immunomodulatory proteins (FIPs), and terpenoids. These compounds are used in various applications, including as immune-boosting supplements, in cancer treatments (like lentinan from shiitake mushrooms, which is approved in Japan), and in the development of new vaccines. Support and regulate the immune system, partly due to high levels of selenium and vitamin D. Mushrooms can enhance and regulate the immune system by activating various immune cells, such as macrophages, natural killer (NK) cells, and T-lymphocytes. This helps the body fight against infections and diseases.

Anti-Cancer:

Evidence suggests that some mushroom species possess anticancer properties and can be used as complementary therapies alongside conventional cancer treatment. However, no type of mushroom is proven to prevent or cure cancer on its own. The therapeutic effects are largely attributed to compounds that modulate the immune system and inhibit cancer cell growth. Contain compounds that may help inhibit tumour development and fight cancer cells.

Mushrooms are widely studied and used as an adjunct therapy in cancer treatment, particularly in Asia. Mushrooms contain compounds that act as biological response modifiers (BRMs), stimulating the host's immune system to fight cancer cells, inhibiting tumour growth, suppressing cell proliferation and metastasis, and inducing apoptosis (programmed cell death) in cancer cells. Polysaccharides like lentinan (from shiitake), PSK (Krestin) and PSP (from turkey tail), and D-fraction (from maitake) are well-known for these effects.

Ganoderma lucidum (reishi), *Lentinula edodes* (shiitake), *Trametes versicolor* (turkey tail), and *Grifola frondosa* (maitake) are commonly used.

Antimicrobial:

Mushrooms have antimicrobial properties due to bioactive compounds like polysaccharides, terpenoids, phenols, and peptides, which can inhibit the growth of bacteria and fungi. These compounds have potential for use in pharmaceuticals and functional foods to combat antibiotic resistance and treat infections. Examples include extracts from *Pleurotus ostreatus* showing broad-spectrum activity and specific compounds like lentinamicin from *Lentinus edodes*. Exhibit antibacterial, antifungal, and antiviral properties.

Anti-inflammatory:

Many mushrooms have anti-inflammatory properties due to compounds like polysaccharides, terpenoids, and phenolics. These compounds work by inhibiting inflammatory mediators, reducing oxidative stress, and modulating immune responses in the body. Edible varieties like oyster, shiitake and lion's mane have shown particular promise in research. It can help reduce inflammation in the body.

Antidiabetic:

Scientific research indicates that various mushrooms contain bioactive compounds that exhibit potential antidiabetic properties through multiple mechanisms. While these findings are promising, most studies have been conducted in laboratory or animal settings, and more clinical research on humans is needed. May help regulate blood sugar and support the management of diabetes.

Cardio protective:

Mushrooms have cardio-protective effects due to their antioxidant, anti-inflammatory, and cholesterol-lowering properties, which help protect the heart and blood vessels. These effects are attributed to bioactive compounds that can improve lipid profiles, lower blood pressure, and reduce oxidative stress. Support heart health by helping to lower cholesterol and regulate blood pressure.

Neuroprotective:

Mushrooms are considered neuroprotective due to compounds that support nerve growth, reduce oxidative stress, and fight inflammation. Key neuroprotective mushrooms include Lion's Mane (*Hericium erinaceus*), which stimulates nerve growth factor (NGF), and Reishi (*Ganoderma lucidum*), which contains triterpenoids with anti-inflammatory and antioxidant properties. Other mushrooms like Cordyceps, Chaga, and various others also contain compounds that help protect brain cells, support cognitive function, and may have benefits for neurodegenerative diseases. May help protect against neurodegenerative conditions.

Hepatoprotective:

Many mushrooms have hepatoprotective (liver-protecting) properties due to their rich content of antioxidants and other bioactive compounds like polysaccharides and triterpenoids. Species such as *Ganoderma lucidum*, *Coriolus versicolor*, and *Agaricus blazei* have demonstrated protective effects against liver damage from toxins, fatty liver disease, and other liver disorders in scientific studies.

2.2 Most popular Medicinal Mushrooms

Edible mushrooms have been extensively used for human nourishment for quite a long time and are acknowledged for their appealing texture, flavour, and medicinal traits. The fruiting bodies of mushrooms generally have approximately 90% moisture, except for the hard, bare fruiting body of *Ganoderma lucidum*. Their dry matter is rich in carbohydrates (50-65%) and proteins (19-35%) with small amounts of fats (2-6%). Mushrooms have been recognised for their culinary attributes for a long time and were relished in the most influential civilisations in history. Currently, they are the focus of renewed research because of their therapeutic abilities. Nutritional benefits from mushrooms are in the form of a significant source of essential proteins, dietary non-digestible carbohydrates, unsaturated fats, minerals, as well as various vitamins, which have enhanced their consumption, and also resulted in the development of various processed mushroom products. Mushrooms are also a crucial ingredient in traditional medicine for their healing potential and curative properties.

Medicinal mushrooms are fungi that are used in the form of powder or extracts for the prevention, alleviation, or healing of numerous diseases, and/or in balancing a healthy diet. Due to the long list of health advantages, medicinal mushrooms have been used in Eastern medicine for thousands of years. For example, these miracle mushrooms may have brain-boosting, cholesterol-lowering, blood sugar-lowering, hormonal-balancing, immune-stimulating, stress-relieving, and antioxidant effects. However, each mushroom is unique and provides its own specific health benefits. So it might be



Fig 2, Medicinal mushrooms

confusing to pick the one that suits you best. Thereby, here, in this article, we try to clear up some of the confusion by making

a list of the 14 most popular medicinal mushrooms in order of importance as we see it, their effects, and medicinal uses.

2.2.1 Chaga Mushroom:

Chaga mushroom helps fight against the free radicals, cancer and aging. The Chaga mushroom (*Inonotus obliquus*), also called "Mushroom of Immortality" is the most nutritious wild mushroom



Fig 3, Chaga mushroom

that has been used in folk medicine to treat several disorders. Chaga is an exceptionally powerful antioxidant that delivers you an impressive dose of antioxidant, SOD enzymes, essential amino acids, minerals and other vital substances.

2.2.2 Cordyceps:

Cordyceps helps to stimulate energy levels. Cordyceps (*Cordyceps Sinensis*), also known as caterpillar fungus, is a powerful medicinal mushroom that has been acknowledged in Chinese medical books and Tibetan medicine for a long time. This plant is a rare combination of caterpillar and fungus. Some different beneficial effects on the human body, which include:

- Boosting the immune system
- Anti-tumour effect
- Boosting energy
- Stimulating libido
- Anti-metastatic property
- Antioxidant effect
- Anti-inflammatory



Fig 4, Cordyceps mushroom

- Antimicrobial
- Hypolipidemic
- Hypoglycemic
- Anti-aging
- Neuroprotective
- Anti-stress
- Reno protective effect

Helps your body utilise oxygen more efficiently, stimulate blood flow, improve exercise and athletic performance, and speed up post-workout muscle recovery, which can be especially helpful for athletes or people who regularly work out.

2.2.3 Red Reishi

It helps to calm your mind, boosts energy and encourages good night's sleep. Red Reishi mushroom (*Ganoderma Lucidum*), also known as Lingzi, "10,000 Years Sponge", "Queen of Plants", "Immortal Sponge", and "Life Elixir", has been known in China, Japan, and other Asian countries for its miraculous health-enhancing, stress-relieving, and longevity-promoting effects for thousands of years. It's like nature's Xanax. In nature,

there are 6 types of Reishi, but Red Reishi mushroom (*Ganoderma lucidum*), is the most studied one and possesses the strongest medicinal effects. Due to its variety of potential health benefits and rich composition, people use Reishi mushroom to:

- Boost the immune system
- Fight cancer cells
- Enhance many body functions
- The mood-boosting compounds in Reishi (triterpenes) have calming properties, so this mushroom may also lessen anxiety, relieve depression, calm the mind and reduce stress
- Triterpenes in Reishi may also promote wound healing
- Sharpen focus
- Relieve cough and asthma
- Reduce insomnia and stimulate better sleep
- Lessen fatigue
- Improve the work of vital organs
- Strengthen and heal overall health
- Fight obesity



Fig 5, Red Reishi mushroom

2.2.4 Lion's Mane (*Hericium erinaceus*)

Lion's mane is an edible mushroom native to Europe, North America, and Asia. Similarly, to other medicinal mushrooms, Lion's mane contains antioxidants and boosts the immune system.



Fig 6, Lions mane mushroom

In addition, it promotes the production of the bio protein nerve growth factor (NFG), and myelin (an insulation around nerve fibres), which are both absolutely vital to brain health.

2.2.5 Shiitake

This edible mushroom is native to East Asia, and considered a medicinal mushroom in some traditional medicine. For instance, shiitake mushrooms:

- Good for your heart
- Have been shown to lower LDL cholesterol
- As well as maintain healthy blood pressure and circulation.



Fig 7, Shiitake mushroom

2.2.6 Turkey Tail

Turkey tail is a common polypore mushroom (*Trametes Versicolor*, also *Coriolus Versicolor* and *Polyporus Versicolor*) that grows all over the world. In addition to high amounts of antioxidants that show anticancer properties (like most of the

medicinal mushrooms on this list), turkey tail also contains polysaccharide-K (PSK). Polysaccharide-K is an approved anticancer prescription drug in Japan. PSK also helps to stimulate your immune system. Therefore, turkey tails may:



Fig 8, Turkey Tail mushroom

- Fight leukemia cells
- Improve the survival rate of people with certain cancers.
- In addition, improve the immune system of those receiving chemotherapy.

2.2.7 Oyster Mushroom (*Pleurotus Ostreatus*), also Oyster Fungus, or Hiratake

The oyster mushroom is a common edible mushroom that is related to the king oyster mushroom. People now grow this popular mushroom commercially worldwide. Oyster mushrooms contain a high amount of antioxidants, fibre, vitamins, minerals, and other important nutrients. Some research suggests that oyster mushrooms may:

- Reduce high blood pressure
- Lower cholesterol levels
- Lessen blood sugar
- Improve cardio metabolic health
- As well as possess immune-supportive benefits



Fig 9, Oyster mushroom

2.2.8 Hen-Of-The-Wood (*Grifola Frondosa*), also Maitake

Maitake is a soft-fleshed polypore mushroom that grows at the base of trees (particularly oaks), and is native to Europe, China, and North America. This mushroom may:



Fig 10, Maitake mushroom

- Improve artery functionality
- Help lower LDL (bad) cholesterol levels
- Better overall cardiovascular health, and therefore lower your risk for heart disease.

In addition, Maitake mushrooms may lower your blood sugar levels, support the immune system and help in targeting and destroying cancerous cells.

2.2.9 Enokitake (*Flammulina Velutipes*), also known as Enoki, and Velvet Shank

Enoki is an edible mushroom, and well known in Japanese cuisine. It grows wild in Western Europe, Eastern Asia, and much of North America. Enoki mushrooms are highly nutritious and rich in antioxidants. For instance, these mushrooms are said to:



Fig 11, Enoki mushroom

- Slow cancer cell growth
- Support heart health
- Improve brain function
- As well as boost immunity

2.2.10 China Root (Wolfiporia Extensa)

China root is a wood-decay fungus with a large, long-lasting underground sclerotium that resembles a small coconut. This fungus is thought to possess various medicinal properties, such as:

- Removing pus from wounds
- Controlling swellings (anti-inflammatory)
- Promoting urine (diuretic)
- Removing gas (flatulence)
- Clearing bowels
- Bringing down high body temperature



Fig 12, China Root mushroom

2.2.11 Yellow Morel (*Morchella Esculenta*), also known as Morel, Guchi, Common Morel, True Morel, Morel Mushroom, Sponge Morel, etc.

Yellow morel is an edible mushroom that is much in demand. It may possess health benefits such as:

- Antitumor activity
- Antioxidant effects
- Anti-inflammatory action
- Immune stimulating activity



Fig 13, Yellow Morel mushroom

2.2.12 *Auricularia Auricula-Judae*, also known as Wood Ear or Black Wood Ear

Auricularia auricula-judae grows worldwide. It is an edible ear-like shape fungus that grows on wood (especially elder). This mushroom is claimed to be a significant source of both vitamin B5 and copper (contains also small amounts selenium and vitamin B2), and possess health benefits such as:

- Anti-inflammatory effects
- Antimicrobial effects
- Anticoagulant action

- Anti-cancer action
- Anti-cholesterol properties
- In addition, cardioprotective effects.



Fig 14, Auricularia mushroom

2.2.13 Lentinus

Lentinus is a genus of fungi in the family Polyporaceae. This widely distributed mushroom has many species that all grow in subtropical regions. Lentinus edodes is a popular edible mushroom that is used for conditions such as:

- Cancer
- Fungal infection
- Depressed immune function (including AIDS)
- Environmental allergies
- Frequent flu and colds
- Bronchial inflammation
- Heart disease
- Hyperlipidemia (including high blood cholesterol)
- Hypertension
- Diabetes
- In addition, infectious diseases



Fig 15, Lentinus mushroom

2.2.14 Tremella

Tremella is a genus of fungi that grows as a slimy, mucus-like film until it encounters its preferred hosts. Yes, all Tremella species are parasites of other fungi, and there are over 100 species of Tremella presently recognised worldwide. The most important tremella mushroom benefits are considered to be effects such as:

- Anti-inflammatory
- Anti-aging
- Cholesterol-lowering
- Obesity combating
- Cancer fighting
- Nerve-protecting effects



Fig 16, Tremella mushroom

2.3 Conclusion

Medicinal mushrooms are valued for their diverse bioactive compounds and health-promoting properties. A growing body of research supports their nutritional and therapeutic potential, leading to their integration into modern wellness and supplement industries. However, further clinical studies are necessary to confirm dosage, safety, and specific mechanisms of action, especially for vulnerable groups and in combination with conventional therapies. Since medicinal mushrooms may help treat numerous health conditions and are usually safe, they can be great natural health boosters for those who believe in traditional treatment methods and herbal remedies. Though, before using, consult your healthcare provider for further information.

PADDY STRAW MUSHROOM

Scientific name: *Volvariella volvacea*

Kingdom: Fungi

Family: Pluteaceae

Class: Agaricomycetes

Genus: *Volvariella*

Order: Agaricales

Division: Basidiomycota

Paddy straw mushroom (*Volvariella volvacea*) is a species of edible mushroom cultivated throughout East and Southeast Asia, and it is used extensively in Asian cuisine. Since the 18th century, *V. volvacea* has been cultivated traditionally in Southeast Asia. They are often available fresh in regions where they are cultivated, but elsewhere are more frequently found canned or dried. *Volvariella volvacea*, commonly referred to as paddy straw mushroom, holds a significant place among edible mushrooms and is cultivated using a wide range of substrates. It is cultivated primarily in tropical and subtropical regions due to its rapid growth, high nutritional value and consumer preference. These compounds exhibit a wide range of therapeutic activities, including anti-tumour, antimicrobial, antioxidant, antimalarial, anticancer, anti-inflammatory, and anti-allergic effects. Nutritionally, *V. volvacea* is an excellent source of carbohydrates, proteins, fibres, ascorbic acid, and essential minerals.

In coastal districts of Odisha and adjoining states, another mushroom, commonly called paddy straw mushroom, is highly popular. It is cultivated almost throughout the year. *V.*

volvacea mushroom has several advantages, like the requirement of a tropical or sub-tropical climate, fast growth rate, easy cultivation technology and good acceptability at the consumer level. Its scientific name is *Volvariella volvacea*. It can be grown in other parts of the country as well during the hot months. The production of this mushroom is around 15,000 tons/year in our country. In India, it was experimentally cultivated in the early 1940s. It grows at relatively high temperatures (30-38°C) and high relative humidity (80-90%). It is a fast-growing mushroom, and the total crop cycle is completed within 3-4 weeks. *Volvariella* comprises 5% of the total mushroom production of the world. This mushroom can use a wide range of cellulosic materials, and the C: N ratio needed is 40 to 60, quite high in comparison to other cultivated mushrooms. The unique flavour and textural characteristics distinguish this mushroom from other edible mushrooms

3.1 Nutritional contents of *Volvariella volvacea*

Mushrooms have great nutritional value for human health and are also a great source of protein, carbohydrates (such as chitin), vitamins, fats and minerals. On a dry weight basis, their composition can vary widely, with protein content ranging from 10 % to 40 %, carbohydrates from 3 % to 28 %, fats from 2 % to 8 %, ash from 8 % to 10 %, and fibres from 3 % to 32 %. They also contain essential minerals such as calcium (Ca+), magnesium (Mg+), iron (Fe+), potassium (K+), phosphorus (P+), copper (Cu+), and zinc (Zn+). The table presents the proximate composition of the edible mushroom *V. volvacea*. Mineral content seems predominant at the button stage of paddy straw mushroom as compared to other stages, e.g., it contains a high amount of potassium and magnesium at the

button stage as compared to the elongation stage. Glycoproteins, terpenoids, nucleotides, and polysaccharides are the bioactive molecules found in edible mushrooms. Mushrooms also contain a low proportion of fats, having no cholesterol, but are rich in unsaturated fatty acids. *V. volvacea* is the most popular mushroom due to its exceptional delicacy and high protein, amino acids, vitamins and mineral content. *V. volvacea* contains only 10 %/100 % dry matter, in which 56.8 % constitutes carbohydrates, 5.7 % fats, 14–27 % of crude protein and all essential amino acids. Fibres, chitin, minerals and water-soluble vitamins such as biotin, riboflavin and thiamine are also present. A total phenolic content in paddy straw mushroom was reported to be within the range of 10.05 mg/g to 16.72 mg/g dry weight.

Table 1, Composition of the Edible Mushroom *V. volvacea*

| Sl. No. | Minerals | Percentage | Parameters analyzed | Percentage |
|---------|-------------|------------|---------------------|------------|
| 1 | Sulphur | 2.72 | Ash | 8–10 % |
| 2 | Aluminum | 0.27 | Crude protein | 28–32 % |
| 3 | Calcium | 0.62 | Dry matter | 9–10 % |
| 4 | Chlorine | 3.57 | Fat | 2–4% |
| 5 | Copper | 0.07 | Fiber | 4–9% |
| 6 | Iron | 0.38 | Free fatty acid | 0.3–0.7 % |
| 7 | Magnesium | 0.99 | Moisture | 89–91 % |
| 8 | Manganese | 0.05 | Carbohydrate | 50–52 % |
| 9 | Phosphorous | 8.96 | | |
| 10 | Potassium | 52.52 | | |
| 11 | Oxygen | 28.72 | | |

Protein is a crucial component of nutritious and functional food for humans. Different mushrooms contain variable protein content. Proteins in each species vary according to the size of the pileus, type of mushroom, substratum and harvesting time. *V. volvacea* contains 14–27 % of crude proteins. Volvarin, a ribosome-inactivating protein, is also obtained from the paddy straw mushroom. Lectin protein was also obtained from the fruiting body and mycelia of *V. volvacea* mushroom.

Table 2, Amino acid content of *V. volvacea* mushroom (g/100g of protein)

| S. No | Amino acids | Content in grams (g) |
|-------|---------------|----------------------|
| 1 | Alanine | 7.14 |
| 2 | Aspartic acid | 12.4 |
| 3 | Cystine | 0.95 |
| 4 | Glutamic acid | 27.9 |
| 5 | Leucine | 7.55 |
| 6 | Lysine | 5.20 |
| 7 | Phenylalanine | 6.22 |
| 8 | Proline | 6.60 |
| 9 | Threonine | 4.88 |
| 10 | Tryptophan | 14.7 |
| 11 | Tyrosine | 4.79 |
| 12 | Valine | 3.77 |

Mushrooms appear to be a good source of many vitamins, therefore, having great nutritional value. Edible fungi are a good source of minerals and vitamins such as biotin, folates, riboflavin, vitamin B complex, such as B1 (thiamine), B2 (riboflavin), B3 (niacin), ascorbic acid or vitamin C, D2 and vitamin E.

Table 3, Concentration of vitamins in *V. volvacea*

| Sl. No | Vitamins | Concentration |
|--------|-------------------------------|---------------|
| 1 | Vitamin A | 0.001 mg/kg |
| 2 | Vitamin B1 (Thiamin) | 0.024 mg |
| 3 | Vitamin B2 (Riboflavin) | 0.127 mg |
| 4 | Vitamin B3 (Niacin) | 0.408 mg |
| 5 | Vitamin B5 (Pantothenic acid) | 0.75 mg |
| 6 | Vitamin B6 (Pyridoxine) | 0.025 mg |
| 7 | Vitamin B9 (Folate) | 69 µg |
| 8 | Vitamin D | 50.711 mg/kg |
| 9 | Vitamin E | Nil |
| 10 | Vitamin K | 0.006 mg/kg |

A variety of minerals are found in the fruiting bodies of mushrooms. The proportion of minerals found in mushrooms varies according to the type of species, age of species, substratum and diameter of the fruiting body. Macronutrients such as K, P, Ca, Na, and Mg are abundant in mushrooms, whereas micronutrients such as Cu, Fe, Zn, Mo and Cd are also reported to be present in them. *V. volvacea* contains major

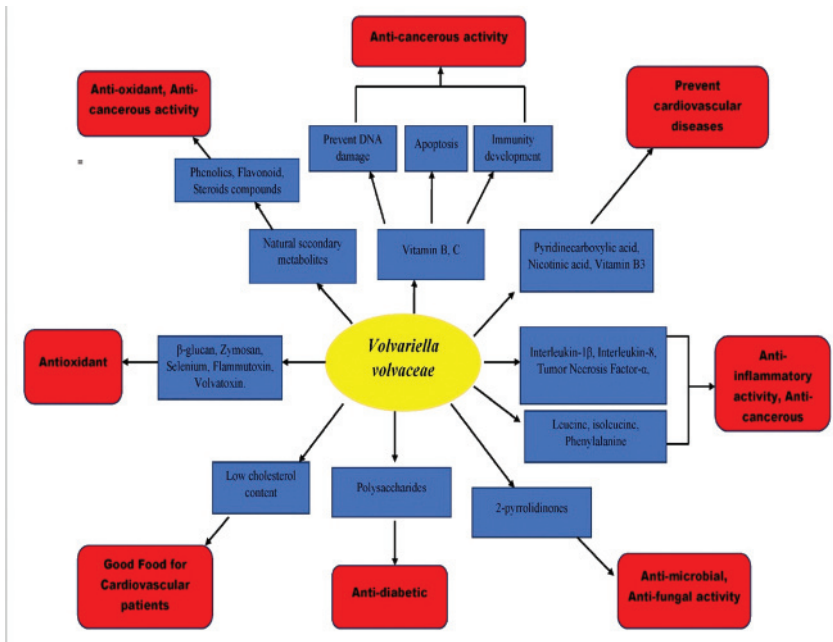


Fig. 1, Biological activities of some compounds identified in the methanol extract of *V. volvacea*.

minerals between 36 and 3232 mg/100 g of dry weight, and trace elements are 5.2–426 mg/100 g of dry weight. Minerals such as K, P, Na, and Mg make up 56–70 % of total ash, in which K alone makes 45 % of the ash content in *V. volvacea* mushrooms. In *V. volvacea*, 52.52 % of potassium, 28.72 % of oxygen, and 8.96 % of phosphorous and many other elements (S, Mg, Si, Ca, Fe, Al, Zn, Cu, Mo, Na and Mn) are also present. *V. volvacea* also has a medicinal importance in addition to its nutritional value and is an ideal source of compounds with antitumor, antimicrobial, anticancer and antioxidant activities. Antioxidant activity of *V. volvacea* prevents from risk of chronic angiogenic ailments like arthritis, cancer, cardiovascular and inflammation.

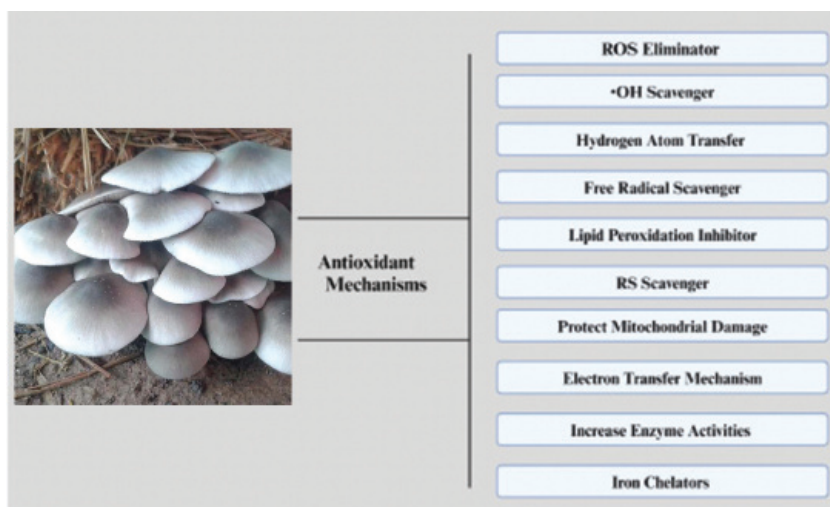


Fig. 2, Antioxidant mechanisms of *Volvariella volvacea*

3.2 Spawn Preparation

Spawn is the mycelium of mushrooms growing in its substratum and prepared for propagating mushroom production. In simpler language, it is defined as a medium impregnated with mushroom mycelium that serves as the “seed” for mushroom cultivation. You can obtain a starting culture for making spawn from any authorised agency. The culture of paddy straw mushrooms cannot be kept at a low temperature. Hence, normally, cultures are kept at 17-20°C or above. We can prepare the spawn of this mushroom on several substrates, like grains, straw, etc. Many prefer to use paddy grains or even paddy straw for spawn. In the case of paddy straw mushroom, however, after inoculation, the bags are incubated at temperatures of 30-35°C. It takes only 5-7 days for complete colonisation of the substrate, and the spawn becomes ready for use within a week. Spawn cannot be stored and may be used within 10-15 days. The different stages of spawn production are as follows:

3.2.1 Starting Culture

The starting culture can be obtained from any authorised agency or can be raised by any of the following three methods:

3.2.1.1 Single Spore Culture Technique

- Selection of an unopened mushroom fruiting body, removing dirt with clean cotton, followed by wiping of the mushroom with 70% alcohol & removing the lower portion of the stipe with a sharp-edged knife.
- Placing the fruiting body on the pointed end of the spiral wire stand, placing it in a sterilised petri dish and covering the whole unit with a round mouth beaker.
- Leaving the whole assembly for 30 minutes at room temperature and removing the beaker as well as the fruiting body along with the spiral wire stand under a laminar flow chamber, followed by covering of petri dish aseptically.
- Serial dilution of spore collection up to 10^{-7} or 10^{-8} till a 10-20 spore/ml count is reached and pouring with molten plain agar medium in sterilised Petri dishes.
- Incubation of dishes at $32 \pm 2^{\circ}\text{C}$ in a BOD incubator for 3-4 days and visualisation of germlings under an inverted microscope for single spore isolates selection.
- Selection of single spore isolates and multiplying on Malt Extract Agar (MEA) medium by incubating at $32 \pm 2^{\circ}\text{C}$ for the next 7-10 days in a BOD incubator.

3.2.1.2 Multispore Culture Technique

- The sterilised loop of the inoculation needle is used for lifting the spores from the spore print.

- The loop bearing thousands of spores is touched on the top surface of the petridishes containing the Malt Extract Agar or any other fungal media, followed by incubation of plates at $32 \pm 2^{\circ}\text{C}$ for 4-5 days in a BOD incubator.

3.2.1.3 Tissue Culture Technique

- Disinfection of the working area and hands with disinfectant and wiping of the mushroom fruiting body with 70% alcohol.
- Making two halves of a mushroom with the help of a sterilised but cooled knife without touching the inner surface of the mushroom fruiting body.
- Removing small pieces of tissue from the stipe pileus connecting point and placing several pieces on the Malt Extract Agar plate at different locations.
- Incubation of plates at $32 \pm 2^{\circ}\text{C}$ for 4 to 5 days in a BOD incubator or at room temperature.
- Transferring of the small mycelium-bearing portion of medium on the fresh MEA slants followed by incubation at $32 \pm 2^{\circ}\text{C}$ for a further 4-5 days.
- Use of cultures directly in the spawn substrate.

3.2.2 Culture Media

There are several media on which the mushroom cultures can grow, the compositions of which are given below:

a) PDA (Potato Dextrose Agar) medium

- Washing, peeling & slicing of 200g potatoes.
- Boil in 1000ml distilled water until potatoes become soft enough to be eaten, but not overcooked.

- Straining through cheesecloth & collecting of liquid in a graduated cylinder, followed by restoring of volume to 1000 ml by adding fresh distilled water.
- Addition of 20g dextrose and 15g agar, followed by boiling while stirring occasionally until agar is dissolved completely.
- Transferring of the medium into 10 ml tubes or 250 ml Erlenmeyer flasks, followed by plugging with non-absorbent cotton.
- Sterilization at 121°C or 15p. s. i. for 15-20 minutes.
- Preparation of slants by putting still hot tubes in a slanting position or pouring medium in sterilised petri dishes and leaving them as such for the next 24 hours for cooling.

b) Malt Extract Agar

- Water 1000ml, Malt extract 25g, peptone 5g, Agar 20g, pH 7.0 – 7.5.
- Mixing of a weighed quantity of each ingredient in 1000ml of distilled water.
- Constant heating with intermittent stirring till complete mixing of agar.
- Pouring of medium in tubes or Erlenmeyer flasks, followed by plugging with a non-absorbent cotton.
- Sterilisation at 121°C or 15p. s. i. for 15-20 minutes.
- Putting still hot medium containing tubes in a slanting position for slant preparation or pouring of medium in sterilised petri dishes, followed by cooling at room temperature.

3.2.3 Spawn Media

Several materials, alone or in different combinations, are popular as spawn substrates. The most common substrates are rice straw cuttings, sorghum, wheat & rye grains, cotton waste, used tea leaves, etc. The protocols adopted for these substrates are mentioned below.

a) Grain Spawn (Rye/sorghum/wheat)

About 100 kg of grains are first boiled with about 150 litres of water for 20-30 minutes, followed by spreading of grains on a sieve for 12-16 hours under shade.

- Mixing of 2kg calcium carbonate and 2kg calcium sulphate with the surface dried cereal grains, followed by their thorough mixing and filling in glucose bottles up to 2/3 portion of the available space or in polypropylene (PP) bags of 100 gauge thickness up to 2/3 available space, depending upon the size of the PP bags. Putting in plugs of non-absorbent cotton, neither very tight nor very loose.
- Sterilisation of glucose bottles or PP bags containing spawn substrate at 126°C or 22 p. s. i. for 2 hours followed by cooling under a laminar flow bench under aseptic air.
- Inoculation of sterilised spawn substrate with mycelium culture followed by incubation at 32 + 20C for about 2 weeks.
- By the time spawn is ready for use.

b) Straw Spawn (Paddy straw)

Rice straw is first soaked in water for 2 to 4 hours, then cleaned and cut into pieces of 2.5 to 5cm long. Calcium

carbonate and rice bran are mixed @ 1% and 1 to 2%, respectively, followed by filling in wide-mouth glucose bottles or polypropylene bags of 100gauge thickness. The bottles/PP bags are closed with plugs of non-absorbent cotton.

- Sterilisation of bottles/PP bags containing the spawn substrate at 126^oC or 22 p.s.i for 2 hours.
- Cooling of the spawn substrate and inoculation with the mycelial culture under a laminar flow chamber.
- Incubation of bottles/PP bags at 32 + 2^oC for 2 weeks.

c) Used Tea leaves Spawn

The used tea leaves are to be collected first & washed to remove any debris, drained & mixed with 2% calcium carbonate to adjust the pH in the range of 6.8 to 7.8.

- Filling in glucose bottles or polypropylene bags & rest procedure is as for the grain or straw spawn.

d) Cotton waste Spawn

Card fly grade of cotton waste is mainly used for spawn making. The further protocol is similar to that for used tea leaves.

e) Manure-husk Spawn

A mixture of fresh horse manure and lotus seed husk is used in equal proportions, first by steeping in water until enough moisture is absorbed. The compost is piled up to 1m height in the form of a pyramid and left as such for the next 4 to 5 days. The pile is broken, and if needed additional quantity of water is added and replied. This is repeated 5 times after every 4 to 5 days.

- The compost is filled in glucose bottles or in air-tight aluminium cans and sterilised.
- After cooling of the compost, mushroom mycelium is inoculated and the compost is incubated at $32 + 2^{\circ}\text{C}$ for 2 weeks or till the spawn is ready.

3.2.4 Key Points of Spawn Making Protocol

1. Substrates such as rice straw and cotton waste, etc., should not be over-wet, as if water stands on the bottom, the mycelium will not grow.
2. The container should not be tightly sealed, as air cannot escape and steam cannot enter properly. Autoclaving will be imperfect.
3. One can prevent the entry of moulds from outside after sterilisation by:
 - a) Using only very clean cotton stoppers.
 - b) Leaving at least 3-4 cm free space between the lower surface of the cotton stopper and substrate.
 - c) Avoiding the spoilage of container walls around the stopper and between the stopper and the substrate surface.
 - d) Preventing the cotton plug from getting wet during autoclaving by loosely covering it with aluminium foil.
 - e) Keeping the outside of the containers clean as far as the aluminium foil reaches.
4. Inoculate under clean conditions in a room without any air movement (close door and windows) or under a laminar flow bench.
 - a) Clean the table with disinfectant

- b) Disinfect the hands with soap and disinfectant
 - c) Safe transfer of autoclaved substrate in the inoculation room
 - d) Use only pure culture spawn
 - e) Cover the opening after inoculation with aluminium foil and press around the neck of the container.
5. Place the spawn under optimal growth conditions. Spawn which is not needed for inoculation can be used for mushroom production.

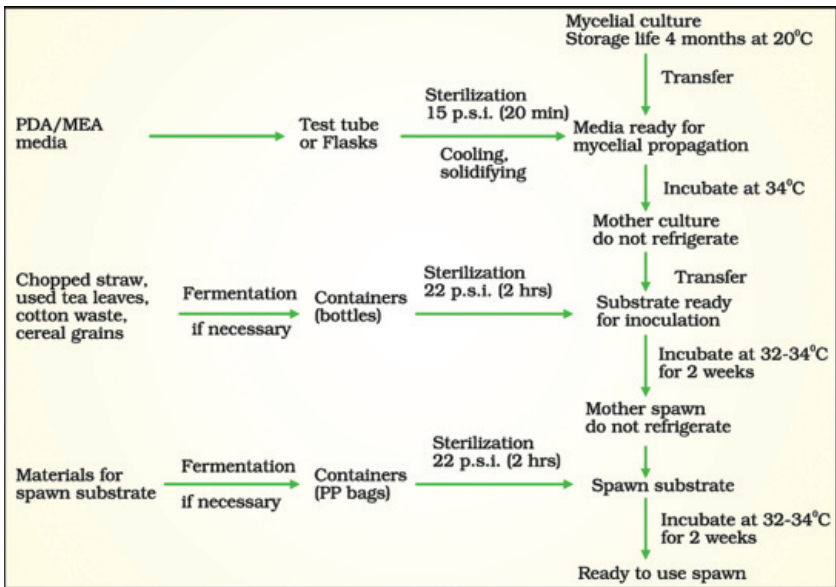


Fig 3, Spawn Production flow chart for *V. volvacea*

3.2.5 Storage of Pure Culture and Spawn

The optimal temperature for growth of *V. volvacea* ranges from 30-35°C and the most suitable temperature is 32°C. Mycelium does not grow at all when the temperature is raised to 45°C or dropped to 15°C. At a temperature of 15±10C most strains of *V. volvacea* survive for the longest period.

After complete colonization of spawn substrate with mushroom mycelia, it is ready to be used. However, if it is not to be used immediately, then it should be removed from incubator and stored at a lower temperature to prevent further growth, aging and death. The storage temperature should range from 15-20°C as at this temperature the growth of mycelium is arrested and mycelia are unharmed and remain viable for longer period.

3.3 Biological Characteristics

The fruiting body of the paddy straw mushroom is divided into six different developmental stages, viz., pinhead, tiny button, button, egg, elongation and mature stage. Each has its own morphology and anatomy.

1. **Pinhead Stage:** The pinhead stage is of the size of a pinhead, in which the veil is spotlessly white (Fig. 4). In vertical section, the pileus and stipe are not visible. The whole structure is a knot of hyphal cells.



Fig 4, Pinhead stage

2. **Tiny Button Stage:** Both the tiny button and pinhead stages are formed from inter-woven hyphae. In a young tiny button, only the top of the veil is brown, while the rest is white. It is round in shape, and if a vertical cut is made through the button, the lamellae are seen as a narrow band on the lower surface of the pileus.

3. **Button stage:** This stage of paddy straw mushroom is sold in the market at a premium price. In this stage, the whole structure is wrapped by a coat, which is called as the universal veil (Fig. 5). Inside the veil, a closed pileus exists. As such, the stipe is not visible, but in the longitudinal section of the mushroom, it is visible.



Fig 5, Button stage

4. **Egg stage:** This stage also fetches a premium price in the market. At this stage, the pileus is pushed out of the veil, and the veil remains as volva (Fig. 6). The stipe is again not visible at this stage. The lamellae of this stage do not bear basidiospores. The size of the pileus remains very small up to this stage.



Fig 6, Egg stage of mushroom

5. **Elongation stage:** The pileus remains close and the size is smaller than mature stage, while the stipe attains the maximum length (Fig. 7).



Fig 7, Elongation stage

The stipe is marked with water proof drawing ink.

6. **Mature stage:** At mature stage, the structure is divided into three regions: (i) the pileus or cap, (ii) stipe or stalk

and (iii) the volva or cup (Fig. 8). The pileus is connected in the centre with stipe and is of usually 6 to 12 cm in diameter.



Fig 8, Mature stage

The fully grown pileus is circular in shape with an entire margin and smooth surface. The surface is dark grey at the centre and light grey near the margin. The lower surface of the pileus bears lamellae, and their number varies from 280 to 380. The lamellae vary in size from full size to one-quarter the size of the pileus. Under the microscope, each lamella is seen to be composed of three layers of interwoven hyphae. The outermost layer is called the hymenium and it forms the club-shaped basidia and the cystidia. The basidia bear basidiospores. Usually, one basidium bears four basidiospores. The basidiospores vary in shape: egg-shaped, spherical or ellipsoidal. The colour of basidiospores again varies, and it may be of light yellow, pink or dark brown. Another important part of the mature fruiting body is the stipe, which connects the volva and the pileus. The length of the stipe depends upon the size of the pileus, and it is usually about 3 to 8 cm in length and 0.5 to 1.5 cm in diameter. It is white, fleshy and without any annulus. At the base of the stipe remains the volva, which is basically a thin sheet of interwoven hyphae around the bulbous base of the stipe. The volva is fleshy, white and cup-shaped with irregular margins. The base of the volva bears rhizomorphs, which absorb the nutrition from the substrate.

3.4 Mushroom Cultivation Technology

A variety of waste materials have been used for cultivation of the paddy straw mushroom, which include: paddy straw, water hyacinth, oil palm bunch, oil palm pericarp waste, niger stick, banana leaves & saw dust, cotton waste, sugarcane bagasse, etc. Paddy straw mushroom prefers high cellulose, low lignin-containing substrate and produces a family of cellulolytic enzymes. The cultivation of *Volvariella* is less sophisticated, less extensive and can be rewarding in tropical & subtropical climates. Before 1970, it was only paddy straw, which was used for paddy straw mushroom cultivation. However, in 1971, cotton waste (Ginning mill waste) was first introduced as the heating material for growing of straw mushroom, followed by the complete replacement of paddy straw with cotton waste by 1973 in Hong Kong. This was practically the turning point in the history of paddy straw mushroom because cotton waste gives a higher and more stable yield (30 to 40%) along with early fructification and harvesting.

With many parts, the adoption of paddy straw and niger waste used for the cultivation of paddy straw mushrooms has become commercialised in Odisha. The common methods employed for paddy straw mushroom cultivation are given below:

3.4.1 Conventional Method

The different steps involved in this method are as follows:

- Preparation of paddy straw bundles of 0.75 – 1.0 kg (80-95cm long & 12.16cm wide) preferably from hand-threshed paddy.

- Immersing bundles in clean water for 12-18 hours in a cemented water tank.
- Draining out excess water by placing bundles on a raised bamboo platform.
- Making a bed by placing 4 bundles side by side and another four bundles similarly but from the opposite side, forming one layer of eight bundles. The open ends of bundles from opposite sides should overlap in the middle.
- Forming of the second, third & fourth layers by intermittent spawning between the first and second, second and third and third and fourth layers.
- Spawning on the entire surface of the layers of the beds at a space of 5cm apart, leaving a margin of 12-15cm from the edges.
- Sprinkling of red gram powder over the spawned surface.
- Using 500 gm of spawn and 150 gm of red gram powder for a bed of 30-40 kg of dried paddy straw.
- Pressing of bed from the top and covering with a clean plastic sheet for maintaining the required humidity (80-85%) and temperature (30-35°).
- Removal of plastic sheet after 7-8 days of spawning and maintaining the temperature of 28-32°C and relative humidity of about 80%.
- Mushrooms will start appearing after 4-5 days of sheet removal and will continue for the next 20 days.
- After crop harvest, the substrate can be used for manure in the field.

- For hot regions, the width of the bed can be decreased by placing the first layer of 4 bundles
- Followed by another layer of 4 bundles from the opposite side, but directly on the first layer. It is to be followed in the 3rd, 4th & 5th layers. The 5th layer can be of bundles or of loosened paddy straw.
- The size of beds may vary from 100cm x 100cm x 100cm; 60cm x 60cm x 30cm and 60cm x 60cm x 120cm.



Fig 9, Conventional method of paddy straw mushroom cultivation

Alternatively, the beds can be prepared with the help of boxes of 80cm x 80cm x 10cm and of 60cm x 40cm x 30cm size. In this method, the material is to be chopped to a uniform length of 20cm and followed by filling in the box parallel with the length of the box. It is followed by soaking of the material along with the box in 2% CaCO₃ solution for 2 hrs or until the straw becomes dark brown. It is followed by draining of excess water and spawning of substrate at a depth of 5 cm from the sides of the box, followed by plugging the openings with

previously water-soaked newsprint. The boxes are to be incubated at a temperature of 35 to 38°C with an RH of 75% for the next 4-5 days. It is followed by a lowering of temperature to 28 to 30°C with RH of 75 to 85% along with the introduction of fresh air. Use only superfine mist for maintaining a proper level of humidity in the room. The bedding material can also be sprayed with a fine mist if it is getting dry. Controlling ventilators is a must for maintaining optimum aeration and temperature inside the room.

3.4.2 Improved Cage Cultivation

i) Material required

1. Paddy straw 60/Cage
2. Spawn bottle 2/Cage
3. Wooden cage 1 No.
(1m x 50cm x 25cm)
4. Drum 1 No. (100-liter)
5. Polythene sheet 4 meters
6. Binding thread 3 meters
7. Sprayer/Rose can 1 No.
8. Dithane Z-78/ 1 Pkt (200 gm) Bavistin
9. Malathion 1 bottle (250 ml)
10. Dettol/Formalin 1 bottle (1/2 liter)
11. Dao (Hand 1 No. chopper)
12. Thermometer 1 No.



Fig 10, Improved Cage method of paddy straw mushroom cultivation

ii. Process of Cage Cultivation

- Select dry, fresh and hand-threshed paddy straw free from moulds and leafy portions.

- Make 25 cm long and 10 cm thick bundles @ 60 bundles for each cage (Bed).
- Soak the bundles in boiling water for 20-30 minutes and allow cooling and draining of excess water.
- Disinfect the cage and polythene sheet with 2% Formaline or Dettol solution.
- Arrange ten bundles uniformly in the cage as the bottom layer and put some spawn grains over and inside the bundles. Put a second layer of ten bundles over the first and spawn as before. Repeat this till six layers of bundles are achieved or till filling of the cage.
- Spray solutions of 0.1% Malathion and 0.2% Dithane Z-78 all over the bed. Cover the whole bed with a polythene sheet and bind securely with a binding thread.

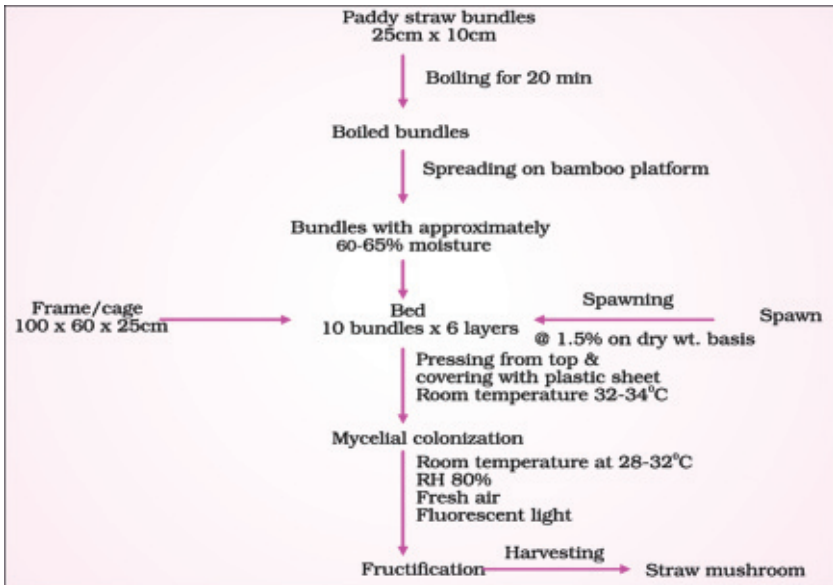


Fig 11, Cage method of paddy straw mushroom cultivation

- Keep the spawned cage in a room or a shed for the mycelial run. A warm place with a temperature around 30°C is helpful for better mycelial growth.
- Remove the polythene sheet after the mycelial run is completed. Maintain high humidity in and around the bed till pinheads appear.
- Pinheads appear within 10-15 days after spawning. Harvest at the egg stage.
- Continue spraying water for the next flush of mushrooms to appear within a week or so.

3.4.3 Outdoor Method

The best place to cultivate paddy straw mushrooms outdoors is in shade created by trees or creepers. The steps involved are as follows:

- Preparation of a raised platform, either with sand or bamboo poles or wooden planks or bricks.
- Preparation of bundles of 40cm length and 10 cm width.
- Soaking of bundles in running water or in 2% CaCO₃ solution.
- Driving of bamboo pole into the center of each end of the bed.
- Preparation of a layer of bundles followed by spawning.
- Laying down of 4 layers of bundles during the summer months and 7 layers during the rainy season.
- Topping of the bed with a 20cm deep layer of rice straw, followed by covering with a polythene sheet.
- Removing of polythene sheet after 4 days and sprinkling water carefully on the 6th day. Spraying of water can be avoided during the rainy season.

- Prohibit spraying of water after the appearance of the mushroom pinheads.



Fig 12, Outdoor method of paddy straw mushroom cultivation

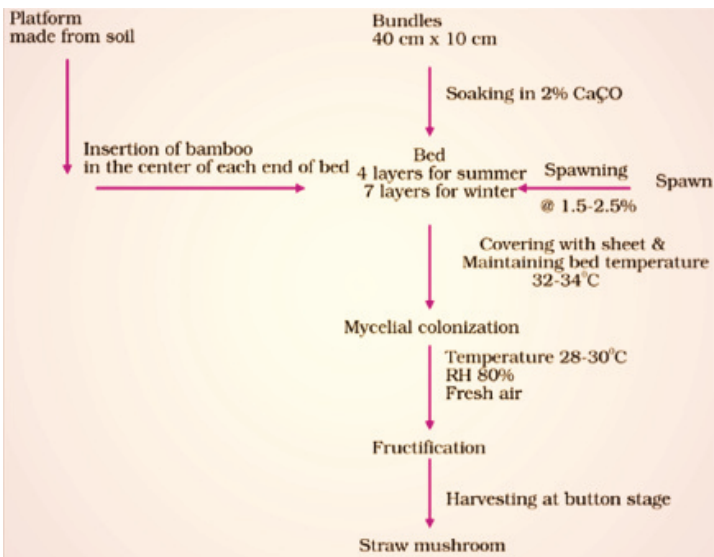


Fig 13, Outdoor method of paddy straw mushroom cultivation

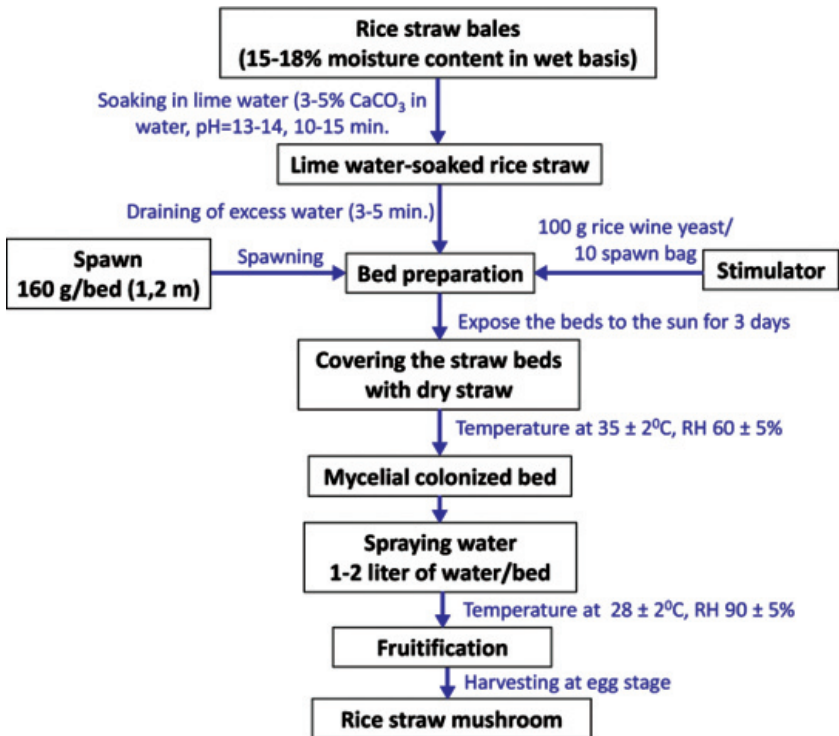


Fig 14, Outdoor process of paddy straw mushroom cultivation

3.4.4 Indoor Method

The indoor method can be divided into the following 5 steps:

i) Substrate:

Cotton waste is the preferred substrate for the cultivation of paddy straw mushroom by this method. However, paddy straw can also be used. Cotton waste is preferred over paddy straw as it contains more cellulose and hemi-cellulose. The fine texture of cotton waste helps in retention of moisture, which minimises the water requirement at later stages of cropping, and thus helps in avoiding damage to mushroom primordia.

ii) Compost preparation:

Substrate is wetted with 1% lime (on dry weight basis), and for cotton waste, a square wooden rack (92x92x28cm) is used for holding a layer of cotton waste about 30cm deep. The workers are used to tread the cotton waste so that it absorbs a sufficient quantity of water. After the first layer is trodden, another layer is applied. This process is repeated until the required quantity is trodden. However, in the case of paddy straw, a pile is made (1.5 m high x 1.5 m wide) by adding a sufficient quantity of water mixed with 1% lime. The pile is

Table 4, Carbohydrate composition in popular substrates of paddy straw mushroom

| Carbohydrate | Cotton waste | Rice straw | Banana leaf |
|----------------|--------------|------------|-------------|
| Total Nitrogen | 1.22 | 0.66 | 1.71 |
| Total Carbon | 49.94 | 54.26 | 50.52 |
| C:N ratio | 40.90 | 84.00 | 29.50 |
| Hemi-cellulose | 8.73 | 17.11 | 19.95 |
| Cellulose | 50.76 | 29.68 | 10.85 |
| Lignin | 10.47 | 12.17 | 18.21 |

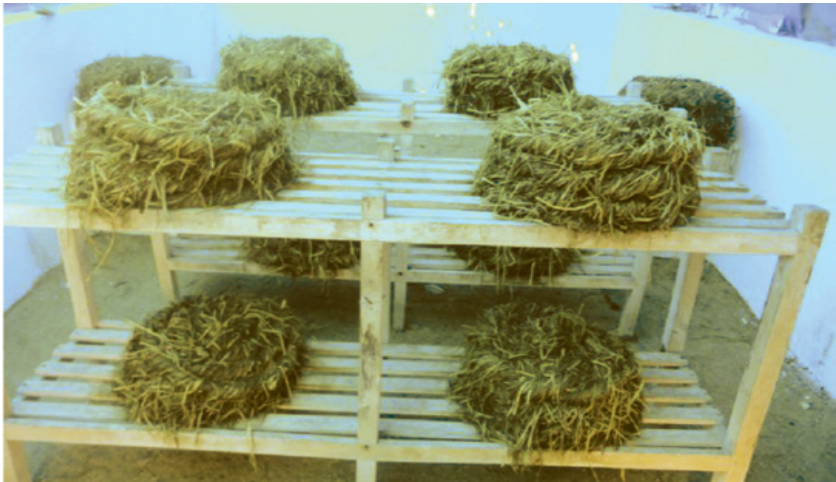


Fig 15, Indoor method of paddy straw mushroom cultivation

also made with wet cotton waste and left to ferment in the open but under cover during the rainy season or extreme cold. First turning is given after 2 days, and 5% rice bran is mixed in case of paddy straw substrate, and water is added if needed. However, nothing is added in the case of cotton waste substrate. Again pile is formed and left for fermentation for the next 2 days.

iii) Bedding and Pasteurisation:

The compost is spread on shelves in rooms or in a pasteurisation tunnel to a suitable thickness. The thickness of the substrate on shelves varies in different seasons from 5 cm to 10 cm. During the summer months, a lesser thickness is needed, while a higher one is needed in winter to preserve moisture and heat. The surface is made even by pressing lightly. After 8-12 hours of compost spreading live stream is introduced with the help of a rubber hose of 6cm in diameter. A temperature of 62°C is maintained for 2 hours for cotton waste compost and of 65°C for 6 hrs for paddy straw compost. After steaming, the shed or room is closed to keep a temperature of 50°C for next 24-36 hrs and followed by natural cooling of the substrate. The compost is spawned on reaching the temperature near 35°C.

iv) Spawning:

The compost is spawned with fresh spawn @ 1.4% of dry weight or 0.4% of wet weight basis of the compost. The pieces of broken spawn are inserted in compost at a depth of 2 to 2.5 cm at a distance of 12 to 15 cm. The spawn is covered with displaced compost and the bed is covered with thin plastic sheet. The room temperature is maintained at 32 to 34°C

during spawn running and the compost will be colonized within next 4-5 days in cotton waste and 5-6 days in paddy straw compost

v) Fructification and Crop Management:

During the spawn running period, water and light are not needed, but a little ventilation is needed. By the end of 3-4 days, fluorescent light, along with a little more ventilation, is provided in the rooms. The plastic sheets are removed on 4-5th day, followed by a little sprinkling of the beds with water. The pinheads start appearing on the 5th – 6th day of spawning. After another 4 to 5 days, the first flush of mushrooms will be ready for harvesting. The room conditions needed for better fructification are a temperature 30^o C, relative humidity 80%, fluorescent light and intermittent fresh air. The quick growth rate of this mushroom demands an ample supply of water and oxygen, which are antagonistic to each other in practice. Watering of the compost is not frequently recommended as it lowers the temperature, suffocates the tiny primordia and reduces yield. Crop management to achieve the best possible combination of light, temperature, ventilation, relative humidity, and compost moisture is, in fact, an art of judgment, experience and effort.

3.4.5 Circular Method

The steps involved in this method are:

- Preparation of bundles of one kg each from paddy straw.
- Soaking bundles in 2% CaCO₃ for 12 hours.
- Winding of water-soaked bundles around wooden or cemented poles and mixing of mushroom spawn @ 1.5% on a dry weight basis.

- Covering of the spawned substrate with a thin polythene sheet
- Maintaining room temperature at 32-34°C, RH 85%, with no light but little air circulation for 5-6 days.
- Removal of the polythene sheet followed by the spray of water on beds and lowering of the room temperature.
- Temperature to 28- 32°C, RH 80% and fluorescent light with enhancement in fresh air injection.
- Maintaining RH of 80% by fine misting on the floor or walls without any direct spray on beds.
- Development of mushrooms and harvesting by little lifting and twisting at the egg stage.
- Packaging and sealing.

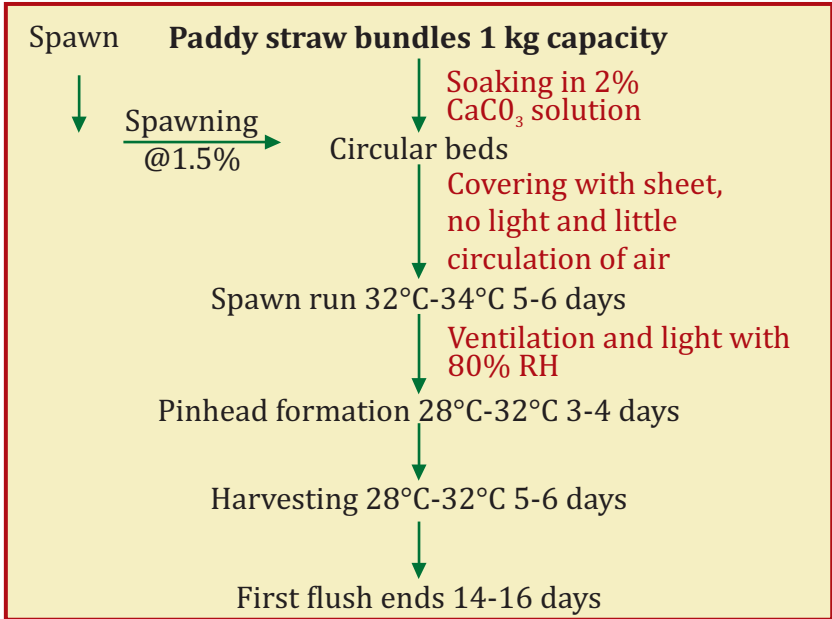


Fig 16, Circular method of paddy straw mushroom cultivation

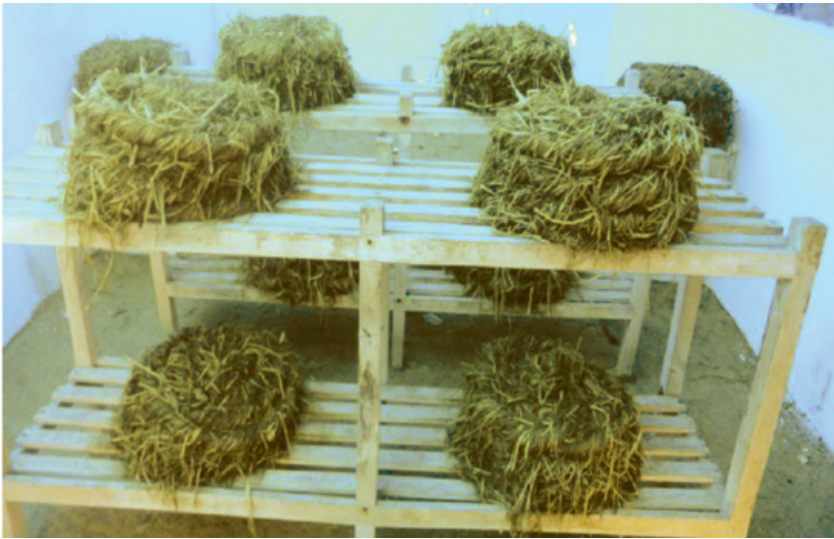


Fig 17, Circular bed method of paddy straw mushroom cultivation

3.4.6 Indigenous Chinese Cultivation Practice

The method adopted at Green Poplar Village, Ping-Shan County, Hebei Province, China, is mentioned below.

a) Compost preparation

- Overnight soaking of wheat straw (10-15cm long pieces) in 1% CaCO₃ solution.
- Draining off excess water by placing straw on the ground.
- Piling of compost and covering with a plastic sheet
- Compost turning after a 1 to 2-day interval, preferably on reaching the pile temperature at 50°C.
- Filling of compost in a 70cm x 35cm x 22cm frame, first by putting a layer of compost, followed by placing of spawn on four sides of this layer along with some wheat bran. The second layer is placed on top of the first one and then spawn and wheat bran are added around the edges. The third and fourth layers are added like the first and second layers.

b) Arrangement of bed blocks

- The soil base is raised several centimetres surrounding the base of the frame.
- The blocks are arranged in two rows with a gap of 20-25 cm in between.
- Poplar branches are used to provide roofing on the blocks and are bowed in a shape to form the frame.
- A plastic sheet is spread over the frame, which in turn is covered by straw.
- Temperature of around 33 to 35^o C is maintained.

c) Harvesting of mushrooms

- Pinheads appear after 4-5 days of spawning.
- A total of 9-10 days is taken for the first harvest after spawning, and the first flush lasts for 3 days, accounting for around 75% of the total mushroom yield.
- The bed blocks are watered with 0.5% CaCO₃ and covered again.
- The second flush appears after a few days, and this flush accounts for the remaining 25% of the total mushroom yield.
- Four to 5 crops are harvested each year.

d) Spent compost

- The spent compost is dried and used for producing *Pleurotus sajor-caju* with a BE of 80%.
- After *P. sajor-caju* cultivation, the spent compost can be used as a good soil conditioner.

3.5 Important Steps for Obtaining a Healthy Mushroom Crop

- Compost moisture in the range of 60 to 65%.
- Immediate spawning on obtaining compost temperature at 35°C followed by covering with plastic sheets, which should be maintained for the next 4 days.
- No ventilation during the first 3 days following spawning.
- Removal of plastic sheets after 4 to 6 days of spawning and sprinkling of water on the bed surface, followed by ventilating the cropping room.

To grow a healthy paddy straw mushroom crop, follow a specific sequence of steps focusing on proper substrate preparation, controlled spawning, and maintaining optimal environmental conditions. The entire process, from preparing the beds to the first harvest, can take as little as 9 to 10 days.

Step 1: Substrate preparation

A healthy crop starts with the right foundation. Paddy straw is the most traditional substrate, though cotton waste can also be used for higher yields.

1. **Select and bundle the straw:** Use fresh, dry, hand-threshed paddy straw, free from mould or foreign materials. Tie the straw into bundles, each weighing about 0.75–1.0 kg and measuring 80–95 cm long by 12–15 cm wide.
2. **Soak the straw:** Immerse the straw bundles in clean water for 12 to 18 hours. Add 2% calcium carbonate (CaCO_3) to the soaking water to help suppress competing moulds and improve yield.
3. **Drain the excess water:** Remove the bundles from the water and place them on a raised, slatted platform to allow

excess water to drain for 2–3 hours. The straw should be moist but not dripping wet.

Step 2: Bedding and spawning

Spawning is the process of inoculating the prepared substrate with mushroom spawn, the equivalent of seeds.

1. **Construct the bed:** Arrange four soaked bundles side-by-side on a raised platform supported by bricks.
2. **Layer the spawn and supplement:** Scatter small clumps of paddy straw mushroom spawn over the surface of the first layer of bundles, leaving a margin of 12–15 cm from the edges. Sprinkle a spoonful of red gram powder or wheat husk over the spawned areas, which serves as a food supplement.
3. **Create additional layers:** Build 3–4 additional layers, placing the bundles at a right angle to the previous layer in a crisscross pattern. Repeat the process of adding spawn and gram powder between each layer.
4. **Compact and cover the bed:** Press the bed from the top to compact the layers and cover the entire bed with a clean polythene sheet to trap heat and moisture.

Step 3: Spawn run and environmental control

The spawn run is the period where the mushroom's mycelium colonizes the straw substrate.

1. **Maintain temperature and humidity:** During the spawn run, keep the bed temperature between 30–35°C and the relative humidity (RH) at 80–85% by keeping the polythene sheet on.
2. **Provide ventilation and light:** After 7–8 days, once the mycelium has fully spread throughout the straw, remove

the polythene sheet. Maintain the room temperature at 28–32°C and humidity at 80%. Introduce fresh air and diffused fluorescent light to encourage fruiting.

3. **Avoid overwatering:** While sufficient moisture is critical, do not water the bed or compost directly, as this can lower the temperature and suffocate the mushroom primordia, reducing yield. A light misting is acceptable if the beds appear dry.

Step 4: Harvesting

With optimal conditions, tiny “pinheads” will appear within a few days of removing the polythene sheet. The mushrooms will be ready for harvest shortly after.

1. **Harvest at the right stage:** Harvest the mushrooms at the “button” or “egg” stage, before the volva (or veil) breaks open. Harvesting at this stage ensures the best flavour, texture, and protein content.
2. **Harvest multiple times per day:** Paddy straw mushrooms grow very quickly and may need to be harvested two or three times daily during the main flush.
3. **Twist to harvest:** Gently twist and pull the mushrooms from the bed rather than cutting them. This prevents the remaining stalks from rotting and contaminating the bed.

3.6 Harvesting

The straw mushroom is harvested before the volva breaks or just after ripening. These stages are called as the button and egg stages. This mushroom grows at high temperature and high moisture; therefore, its growth is very fast. So, for harvesting straw mushrooms in good condition, it has to be harvested twice or thrice in a day (morning, noon &

afternoon). This mushroom usually takes 9-10 days from spawning to first harvest of crop, and the first flush normally lasts for 3 days, which constitutes about 70 to 90% of the expected mushroom yield. The intervening period of 3 to 5 days requires thorough watering and maintenance of optimum conditions inside the cropping rooms. The next flush will again last for 2-3 days and yield fewer mushrooms than the first flush. The second flush adds only 10 to 30% of the total crop. The mature fruiting bodies should be carefully separated from the beds/substrate by lifting and shaking slightly left or right, and then twisting them off. The mushrooms should not be cut off by knives or scissors from the base of the stalk, because the stalk left behind on the bed/substrate will rot and be attacked by pests and contaminated by moulds, which in turn will destroy the mushroom bed.

3.7 Processing

Straw mushroom is more perishable than other edible mushrooms and cannot be stored at 4°C as it undergoes autolysis at this temperature. This mushroom can be stored at a temperature of 10 to 15°C for 3 days and a little more at 20°C or under controlled atmosphere storage. The loss of moisture in 4 days stored mushroom could be as high as 40-50% in unpacked mushroom, while it can be reduced to 10% on packaging in perforated polythene bags. Straw canning, pickling and drying. However, practically the straw mushroom from China to Hong Kong is transported in wooden cases, in which the two compartments of the case are filled with ice, while the central compartment is filled with mushrooms. On the other hand, this mushroom is transported by air from Taiwan to Thailand in bamboo baskets with a central aeration tunnel and packed with dry ice wrapped in paper. However, like

button mushroom, more research work is needed on this mushroom also for studying the effect of blanching, post-harvest storage, soaking and other chemical treatment before canning to increase the drained weight and improve the quality of the canned product. Air Drying: Sun drying is very common in the straw mushroom. The mushrooms are cut longitudinally before drying. Drying by hot air is better than sun drying because mushroom retains better flavour and colour. Drying takes place in 24 hours at 30°C. However, mushrooms can also be dried at a temperature beginning at 40°C then increasing gradually until it reaches at 45°C for eight hours. Blanching of mushrooms for 3-4 minutes in hot water or 4-5 minutes in steam helps in retaining better colour of the dried product during storage. Pre-treatment of mushrooms with 0.1% KMS or a combination of 0.05% KMS and 0.05% citric acid significantly improves the quality of the dehydrated product. The optimum drying temperature, time and critical moisture content for drying of the paddy straw mushroom have been recorded to be 60°C, 7 hrs & 5%, respectively. Fresh mushrooms are reduced to about one-tenth of their original weight after dehydration. Dried mushrooms should be placed in air-tight containers to prevent moisture absorption. Dried mushrooms should be placed in air-tight containers to prevent moisture absorption. Dried mushrooms can be powdered and then used for making soup, ketchup or curry after reconstitution in water.

3.7.1 Freeze Drying

Freeze-drying paddy straw mushrooms involves preparing the mushrooms, freezing them, and then using a vacuum freeze dryer to remove the moisture through sublimation. The process involves slicing the cleaned mushrooms, placing them on trays, and running the freeze

dryer for about 24-26 hours at low temperatures and high vacuum, which preserves their colour, form, nutrition, and allows them to be rehydrated well. Freshly picked mushrooms are to be frozen at 20°C and then freeze-dried. The finished product on rehydration used to be better than the air-dried product. On reconstitution, it becomes almost indistinguishable in appearance from the fresh ones.

3.8 Diseases/Insect-Pests and their Management

Cultivating paddy straw mushrooms (*Volvariella* spp.) is vulnerable to diseases caused by fungi, bacteria, viruses, and environmental factors. Integrated disease management (IDM) is recommended, focusing on prevention through sanitation and environmental control, with chemical treatments used as a last resort. Cultivation of paddy straw mushroom at a commercial scale is a recent development and not much attention has been paid to the diseases and insect-pests aspects of this mushroom. The common diseases and pests are as follows:

3.8.1 Fungal Diseases

Green Mold (*Trichoderma harzianum*): This mold is recognised by dense white mycelial growth that turns green as the fungus spores.

Management: Good sanitation, proper substrate pasteurisation, and maintaining a humidity of 70–90% are crucial. Control flies and mites to prevent spread. Chemical control can be done by covering infected patches with sodium hypochlorite, salt, lime, or a mixture of lime and gypsum.

Yellow-Green Mold (*Aspergillus*): Yellow molds form circular colonies, which can create a dense “mat disease” layer under the casing or in the compost.

Management: Ensure adequate substrate pasteurisation and environmental control, with temperatures between 25–35°C. In some cases, introducing beneficial microbes like *Bacillus subtilis* can suppress pathogens. Fungicides such as copper-based sprays can be used with caution.

Ink Caps (*Coprinus spp.*) : These appear as delicate mushrooms that turn into a black, inky mass due to auto-digestion. Their presence often indicates improperly prepared compost with residual ammonia.

Management: Ensure a thorough composting process to eliminate ammonia. If suspected, turn the compost pile again or use fresh straw. Adding gypsum during composting can help maintain the correct pH.

Bacterial Button Rot (*Sclerotium ssp.*): This rot disease has also been recorded on paddy straw mushroom beds.

Management: Discard infected beds and properly pasteurise the substrate to control this disease.

3.8.2 Bacterial Diseases

Soft Rot (*Pseudomonas fluorescens*): Symptoms include small, water-soaked lesions that rapidly enlarge, making the mushroom soft, mushy, and discoloured.

Management: Pasteurised substrate, optimal temperature (25–35°C) and humidity (70–90%) control, and good air circulation are essential. Use copper-based fungicides or antibiotics like streptomycin with caution.

Bacterial Rot (*Serratia marcescens, Pseudomonas sp.*) : Causes browning of the bulbous base of the mushroom, leading to rotting within 24–48 hours of harvest.

Management: Studies show that some plant extracts, like those from *Trigonella foenum* (fenugreek) and *Aloe*

barbadensis are effective inhibitors. Using selected antibiotics like Ciprofloxacin or Cefaclor has also shown success.

Yellow Blotch (*Pseudononas agarici*): Causes yellow, depressed spots on the caps. Under high humidity, affected fruits can become slimy and give off a foul smell.

Management: Reduce humidity and ensure proper air circulation to prevent moisture from condensing on the mushrooms. Water early infections with a chlorinated solution, but avoid overwatering.

3.8.3 Physiological Disorders

Abnormalities: These can be caused by poor ventilation, leading to high carbon dioxide levels, which result in long-stemmed mushrooms with small caps. High humidity can also cause surface condensation, encouraging bacterial blotch.

Management: Ensure proper ventilation throughout the cultivation cycle. Avoid overwatering and keep the mushroom caps dry, especially after watering.

3.8.4 Insect Pests and Their Management

Pest infestation can lead to significant economic loss. Integrated Pest Management (IPM), including cultural, physical, and chemical controls, is the most effective approach. The more common insect-pests are as follows:

Flies: Sciarid, phorid, and cecid flies are the most common pests. Their larvae feed on mycelium and damage young mushrooms, often spreading diseases.

Management: Practice excellent sanitation by sealing cracks and using fine-mesh netting on doors and windows. Install light traps to monitor and catch adult flies. After a

crop cycle, perform a “cook-out” by steaming the room at 70°C for 4–6 hours. In severe cases, insecticides like malathion or dichlorvos can be sprayed on the walls, but never directly on the mushroom beds.

Mites: These pests, such as hay mites (*Tyroglyphus* mites), can infest mushroom beds, indicating poor compost quality. They feed on mycelium and can spread bacterial diseases.

Management: Use high-quality, properly pasteurised compost. Maintain good hygiene and sanitation practices. Controlling flies will also reduce mite transport.

Nematodes: These microscopic roundworms can destroy mushroom mycelium, leading to bare patches on the beds and potential crop failure.

Management: Proper pasteurisation of the compost is the best control method. For severe infestations, infected bags should be disposed of in a pit.

Springtails: These small insects feed on mycelium, causing it to disappear from the spawned substrate. They can also damage fruiting bodies.

Management: Proper hygiene, pasteurisation of the substrate, and proper disposal of spent compost are effective. Insecticides like malathion or dichlorvos can be sprayed on walls, floors, and surrounding areas.

3.8.5 General Management Strategies

Beyond targeting specific issues, a holistic approach is essential for preventing and managing problems:

Sanitation: Maintain strict hygiene throughout the growing house and surrounding area. This includes regular cleaning, disinfection of equipment, and proper disposal of spent substrate.

Environmental Control: Ensure optimal and consistent temperature, humidity, and ventilation. Poor control creates ideal conditions for many pests and diseases.

Substrate Preparation: Thorough pasteurisation of the substrate is critical for killing pathogens and competitor molds. Adding gypsum can help correct compost pH.

Source of Materials: Only use high-quality, disease-free spawn and fresh, clean straw for cultivation.

Worker Training: Educate workers on proper hygiene, movement patterns (e.g., from clean to dirty areas), and the importance of not moving equipment from old to new rooms.

3.9 Conclusion

Paddy straw mushroom (*Volvariella volvacea*) offers a sustainable and nutritious food source with notable medicinal properties. Cultivation of the mushroom has a rapid growth cycle and repurposes agricultural waste, though it can be low-yielding and sensitive to environmental factors. Research has focused on improving cultivation techniques to boost yield and stability, as well as on exploring its therapeutic benefits. Paddy straw mushroom is that it is a valuable crop with high nutritional and medicinal properties, easy to cultivate on readily available waste like paddy straw, and has the potential to improve farmer income and promote a circular economy. It offers health benefits like antioxidant effects and improved heart health, and its cultivation provides a sustainable way to manage agricultural waste and can be enhanced by using different substrates or improved growing systems like polyhouses, especially in regions with suitable climates.

OYSTER MUSHROOM CULTIVATION

Scientific name: *Pleurotus ostreatus*

Kingdom: Fungi

Family: Pleurotaceae

Class: Agaricomycetes

Genus: Pleurotus

Order: Agaricales

Division: Basidiomycota

Species: *P. ostreatus*



Oyster mushroom, commonly referred to as 'Dhingri' in India, as well as in Odisha. It is a basidiomycete and belongs to the genus 'Pleurotus'. It is a lignocellulolytic fungus that grows naturally in the temperate and tropical forests on dead, decaying wood logs, sometimes on drying trunks of deciduous or coniferous trees. It can also grow on decaying organic matter. The fruit bodies of this mushroom are distinctly shell, fan or spatula shaped with different shades of white, cream, grey, yellow, pink or light brown depending upon the species. However, the colour of the sporophores is an extremely variable character influenced by the temperature, light intensity and nutrients present in the substrate. Cultivation of a sp. of oyster mushroom (*Pleurotus ostreatus*) was initiated on an experimental basis in Germany by Flack during the year 1917 on tree stumps and wood logs. Growing technology was perfected in the USA by Block, Tsao and Hau. Commercial cultivation began in the mid-seventies.

The name Pleurotus has its origin from the Greek word 'Pleuro', which means formed laterally or lateral position of

the stalk or stem. The oyster mushroom is one of the most suitable fungal organisms for producing protein-rich food from various agro-wastes without composting. This mushroom is cultivated in about 25 countries of Far East Asia, Europe and America. It is the third-largest cultivated mushroom in the world. China alone contributes 88.00 percent of the total world production. The other major oyster-producing countries are South Korea, Japan, Italy, Taiwan, Thailand and the Philippines. At present, India produces annually about 10,000 tons of this mushroom. It is popularly grown in the states of Odisha, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh, West Bengal and in the North-Eastern States of Meghalaya, Tripura, Manipur, Mizoram and Assam.

Oyster mushroom cultivation in Odisha is feasible due to favourable local agro-climatic conditions and the availability of cheap, abundant paddy straw. The state government supports mushroom farming through programs like the Mushroom Mission and schemes from departments like the Odisha Horticulture Department and NABARD, offering training and subsidies for things like shed construction. To cultivate, chop and pasteurise paddy straw, mix it with spawn in polythene bags, make small holes for aeration, and incubate the bags in a well-ventilated room at around 25°C until the mycelial growth is complete.

More than 1000 species of the oyster mushroom have been described throughout the world under more than 25 related genera and about 50 species are recognised as the genus *Pleurotus*. The number of species of *Pleurotus* has been cultivated, as a result of which we get oyster mushrooms of all colours like white, grey, yellow, pink, etc. Some of the commonly

cultivated species are *Pleurotus oesteratus*, *P. sapidus*, *P. florida*, *P. sajor-caju*, *P. djamor*, *P. eous*, *P. citrinopileatus*, *P. flabellatus*, *P. eryngii*, etc.

It is lignicolous mushroom causes white rot disease in the trees. It is one of the most second important edible mushrooms after *Agaricus bisporus* for production and consumption worldwide and has broad adoptability among the mushroom growers. Reasons being: 1) to be grown on various organic wastes of agricultural, forest and industrial origin under a wide range of agro-climatic conditions from 10-30°C with 60-90 percent humidity; 2) easy to grow, easy to manage in crop room and easy to post-harvest; 3) it is nutritionally and medicinally rich with good taste.

4.1 Life Cycle of Oyster Mushroom

The basic life cycle of oyster mushroom cultivation involves spore germination, which develops into mycelium that colonises a prepared substrate, followed by fruiting, where the mycelium forms mushrooms, and finally, the mature mushrooms release spores to begin the cycle again.

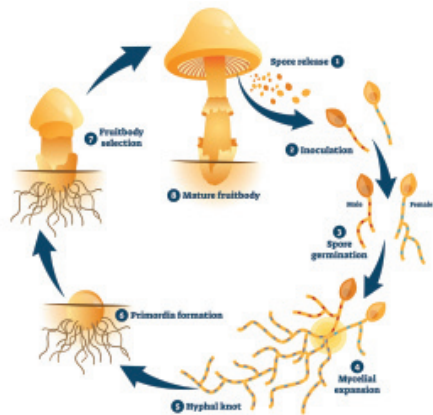


Fig 1, Life cycle of Oyster Mushroom

In a cultivation context, this translates to a process of: preparing a spawn, inoculating the substrate with it, incubating the substrate for mycelial colonisation, and managing the environment for fruiting and harvesting. Mushrooms are fascinating organisms that have

a unique lifecycle. Unlike most plants, which grow from seeds, mushrooms reproduce by spores. Spores are tiny, dust-like particles that contain the mushroom's genetic material. When conditions are right, the spore germinates and grows into a new mushroom.

4.2 Growing Species of Oyster Mushroom

The following species of *Pleurotus* are growing worldwide during the summer and winter months. The major types of oyster mushrooms are:

4.2.1 Pearl Oyster (*Pleurotus ostreatus*):

The pearl oyster mushroom is a common, edible fungus known for its delicate flavour and oyster-shell-like appearance. It is one of the most widely cultivated and consumed mushroom varieties in the world. The most common type with a mild, woody flavour.



Fig 2, Pearl Oyster Mushroom

4.2.2 Blue Oyster (*Pleurotus ostreatus* var. *columbinus*) :

Pleurotus ostreatus var. *columbinus*, or the blue oyster mushroom, is an edible variety of oyster mushroom known for its distinctive blue-gray cap, especially when young, which lightens as it matures. It is valued for its rich, earthy flavour and



Fig 3, Blue Oyster Mushroom

velvety texture, is easy to grow, and is often cultivated on straw or hardwood.

4.2.3 Golden Oyster (*Pleurotus citrinopileatus*):

Golden oysters (*Pleurotus citrinopileatus* mushrooms) are a relatively new species of oyster mushroom that have been showing up in all kinds of mushroom hunting boards in the Midwest lately, so I thought it would be good to take a close look at them today. I'll cover their history and identification, invasive status, as well as some tips



Fig 4, Golden Oyster

for harvesting and cooking. The mushroom is bright yellow and known for a more complex, aromatic flavour.

4.2.4 Pink Oyster: (*Pleurotus djamor*):

Pleurotus djamor known as “Pink Oyster Mushroom” due to the colour of the fruiting bodies, is pink. This is a unique *Pleurotus* mushroom species among all the members of the *Pleurotus* species. They are nutritionally very rich,



Fig 5, Pink Oyster Mushroom

composed of high-quality protein, high fibre, low fat, vitamins and essential minerals. These mushrooms have a very unique taste that can be considered as a good alternative to meat or non-veg. *P. djamor* can be grown on a wide range of growwastes like wheat straw, soyabean, coffee husk, rice husk

and paddy straw, etc. But the best results are only available on substrates which are having higher content of lignocellulose. In India, its cultivation can be popularised by working on its cultivation technology refinement, substrate availability and creating awareness among the people regarding the health benefits of *P. djamor*. Vibrant pink, with a more pungent, woody flavour.

4.2.5 King Oyster (*Pleurotus eryngii*):

The king oyster mushroom, or *Pleurotus eryngii*, is a large, edible mushroom known for its thick, meaty stem and rich umami flavour when cooked. Native to the Mediterranean and parts of



Fig 6, King Oyster Mushroom

Asia, it is widely cultivated and has a long shelf life. Its firm texture makes it versatile for cooking, allowing it to be sliced into scallops, grilled whole, or shredded, and it can be added to many dishes like stir-fries, curries, and soups. A larger variety with a thick stem and a rich, savoury flavour.

4.2.6 Phoenix Oyster: (*Pleurotus pulmonarius*):

The Phoenix Oyster, scientifically known as *Pleurotus pulmonarius*, is a type of oyster mushroom also called the lung oyster or Indian oyster. It is an edible mushroom with a sweet and



Fig 7, Phoenix Oyster Mushroom

meaty flavour that can grow on both hardwoods and conifers. This mushroom is distinct from the common pearl oyster mushroom (*Pleurotus ostreatus*) and prefers warmer temperatures for fruiting. Similar to the pearl oyster, but with paler, smaller caps and a longer stem.

4.2.7 Common Oyster: (*Pleurotus ostreatus*):

Pleurotus ostreatus is the scientific name for the common oyster mushroom, a widely cultivated and consumed edible mushroom with nutritional and medicinal properties. It is a popular food source known for its taste and is also used in



Fig 8, Common Oyster Mushroom

animal feed and environmental remediation due to its ability to degrade agricultural waste. The mushroom is rich in vitamins, minerals, and beneficial compounds like beta-glucans and has been studied for potential health benefits, including antioxidant, anti-inflammatory, and cholesterol-lowering effects.

4.2.8 White Oyster: (*Pleurotus florida*):

Pleurotus florida is an edible oyster mushroom species that can be cultivated on various agricultural waste products. It is a popular cultivated mushroom with



Fig 9, White Oyster Mushroom

nutritional benefits, including high protein content and vitamins, and potential medicinal properties like anthelmintic activity. While widely cultivated and available in grocery stores, caution is needed when identifying wild varieties, as some look-alike mushrooms can be poisonous.

4.2.9 Branching Oyster: (*Pleurotus cornucopiae*):

The Branching Oyster mushroom (*Pleurotus cornucopiae*) is an edible fungus known for its clusters of pale, funnel-shaped caps that often have fused stems. It is similar to the common oyster mushroom (*P.ostreatus*) but is distinguished by its highly decurrent gills, which run



Fig 10, Branching Oyster Mushroom

down the stem in a net-like pattern. This mushroom grows on dead deciduous trees and has a pleasant odour and mild taste. *Pleurotus cornucopiae* is a species of edible fungus in the genus *Pleurotus*, It is quite similar to the better-known *Pleurotus ostreatus*, and like that species is cultivated and sold in markets in Europe and China, but it is distinguished because its gills are very decurrently, forming a network on the stem.

4.2.10 Tree Oyster Mushroom: (*Pleurotus fossulatus*):

Pleurotus fossulatus is an oyster mushroom species that has been studied for its ability to produce the enzyme laccase and for its potential health benefits. Research shows that an aqueous extract from this mushroom has protective

effects on the liver and kidneys in diabetic models. It can be cultivated on various substrates, such as rice straw, and has a longer spore formation period compared to other oyster mushroom species.

Other species:

Mainly the Golden oyster, pink oyster, phoenix oyster, pearl oyster, and king trumpet are also commonly cultivated.

4.3 Cultivating a System of Oyster Mushrooms

The following cultivation systems are adopted in various locations across India. It can be divided into two categories based on the two different seasons, like winter and summer, which have different cultivation practices.

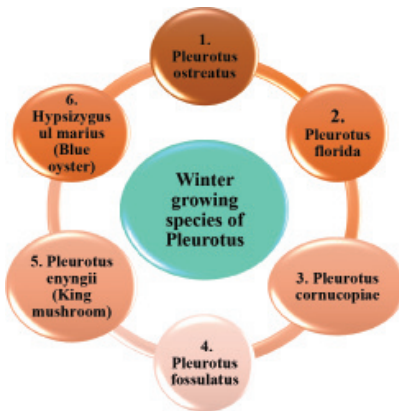


Fig 11, Winter Growing Species of Pleurotus



Fig 12, Summer Growing Species of Pleurotus

Bed cultivation system: In this system, the spawn mixed substrate is placed in the bed frame and or on the ridges. This system is mostly used with cotton waste/ straw substrate.

Plastic bag cultivation system: Spawned mixed substrate is filled in plastic bags. This system is mostly with cereal crop straw and is common in India and other Southeast Asian Countries.

Bottle or jar cultivation system: The suitable substrate is filled in bottles/jars and inoculated with a suitable strain. This system is mostly used with sawdust. It is used in Japan.

Modified bed cultivation system: This system is common in main mainland of China. In which trench are formed and covered by the plastic roof. The trench is about 2 meters deep, 2.5 meters wide and of variable length with 3 3-meter height from base to plastic roof.

6. Vertical tray system: The vertical tray system was described by Kurtzman in 1978 for growing oyster mushrooms. This system is practised in some places in Bihar and Eastern Uttar Pradesh. Substrate Preparation Pleurotus mushroom commonly cultivates on wheat straw worldwide. Although it can grow on almost all kinds of fresh, uncontaminated organic wastes like wood logs, sawdust, cereal straw, sugarcane bagasse, cotton wastes, jute, coir pith, cocoa pods, mango seed kernels, different oil cakes, rubber seed cake, sunflower straw, groundnut pod shell, tapioca starch, water hyacinth, banana wastes, etc. Various methods of substrate treatment are adopted for Pleurotus cultivation. The most commonly adopted substrate treatments are given below.

4.3.1 Categories of Substrate

1. **Highly suitable farm wastes:** Paddy straw and wheat straw (Productivity 80-150%)
2. **Moderately suitable farm wastes:** Sugarcane bagasse, maize ear head, cotton waste, oil palm fruit waste (productivity 50-80 %)
3. **Suitable farm waste:** Cotton stalk, sorghum stalk, sugarcane trash (productivity 40-50%)

4.3.2 Substrate Sterilisation

- 1. Unsterilized method:** In this method substrate, after soaking in water, is used for spawning. The chances of contamination are increased.
- 2. Hot water dip method:** It consists mainly of dipping of substrate in hot water for a variable duration depending upon the nature of the substrate used. Pre-soaked wheat straw is dipped in hot water at 60 °C for an hour, followed by drying in sunlight.
- 3. Pasteurisation method:** In this method, the wet substrate is exposed to live steam for a different duration (a few minutes to a few hours). This is the most common and widely adopted method throughout the world, especially with cereal straw.
- 4. Fermentation method:** It involves the application of thermophilic microorganisms in the fermentation of the substrate.
- 5. Chemical treatment method:** This method is commonly used in North India to sterilise the wheat and paddy straw substrate for *Pleurotus* mushrooms. Generally, formalin and fungicide (bavistine) are used to treat the substrate.
- 6. Sterile method:** In this method, the substrate is sterilised by live steam under pressure. This method is suitable under lab conditions.

3.3.3 Spawn

Commercial spawn is used for spawning purposes. It is a second-generation spawn prepared by first generation master spawn. About 15-25 spawned grains of master spawn are transferred in thermostatic polypropylene bags that contain

300-500g of sterilised wheat grain. Thus, one bottle of master spawn is sufficient to distribute in 30-40 polypropylene bags. Inoculated bags are incubated at $25\pm 1^{\circ}\text{C}$. Other grains like sorghum and pearl millet can also be used for spawn making. The boiling and sterilisation process of commercial spawn is the same as master spawn.

4.3.4 Climatic Condition

Climatic conditions, Oyster mushrooms can grow from cold to temperate but prefer humid climatic conditions. The various species below sustain a wide range of temperatures. Summer species of oyster mushrooms can grow from $25-30^{\circ}\text{C}$. However, winter species can better perform from $18-22^{\circ}\text{C}$ with 85-90 per cent humidity. However, a $20-25^{\circ}\text{C}$ temperature is most optimum for the cultivation of oyster mushrooms.

Table 1, Types of Oyster mushrooms with required optimum temperature

| Common Name | Scientific Name | Optimum Temperature Range |
|--------------|-----------------------------|---------------------------|
| Grey Oyster | <i>Pleurotus sajor-caju</i> | $20-28^{\circ}\text{C}$ |
| Black Oyster | <i>Pleurotus ostreatus</i> | $18-22^{\circ}\text{C}$ |
| White Oyster | <i>Pleurotus florida</i> | $20-28^{\circ}\text{C}$ |
| Pink Oyster | <i>Pleurotus djamor</i> | $20-26^{\circ}\text{C}$ |

4.3.5 Cultivation Process

- 1. Prepare substrate:** Chop paddy straw into 4-54 minus 54-5cm pieces. Soak them in fresh water for 6-8 hours.
- 2. Pasteurise:** Immerse the pre-wetted straw in hot water ($65-70^{\circ}\text{C}$) for one hour.

3. **Dry:** Spread the substrate in the shade to dry until it has a moisture content of 55-60%.
4. **Bagging:** Fill the polythene bags with the substrate, leaving some space at the top.
5. **Inoculate:** Add spawn and boiled wheat between layers of the substrate inside the bags.
6. **Seal:** Tie the open end of the bag securely.
7. **Create holes:** Make 15-20 small holes (0.5 cm diameter) on all sides of the bag for aeration and water removal.
8. **Incubate:** Place the bags in a well-ventilated room, ideally at a temperature of around 25°C. Do not open the bags during this phase.
9. **Fruiting:** After 12-15 days, when the mycelial growth is complete, you can open the bags to allow for mushroom formation.

4.3.6 Government support and Training

- The Agriculture and Farmers Empowerment Department of Odisha has a “Mushroom Mission” to increase production, especially through women SHGs.
- **Training:** KVKs (Krishi Vigyan Kendras) are offering free training and technical guidance to farmers and SHGs.
- **Subsidies:** The Odisha Horticulture Department offers subsidies (50–75%) under the MIDH scheme for certain aspects of mushroom farming, such as shed construction.
- **Marketing:** Local organisations like ORMAS/SHGs can assist with the marketing of dried mushrooms.

- **Financial Aid:** NABARD can also support shed construction and provide training.

4.4 Advantages of Growing Oyster Mushroom

1. Variety of substrates

Pleurotus mushroom can degrade and grow on any kind of agricultural or forest wastes, which contain lignin, cellulose and hemicellulose.

2. Choice of species

Among all the cultivated mushrooms, Pleurotus has the maximum number of commercially cultivated species suitable for round the year cultivation. Moreover, variation in shape, colour, texture, and aroma is also available as per the consumer's choice.

3. Simple cultivation technology

Pleurotus mycelium can grow on fresh or fermented straw, and it does not require composted substrate for growth. Substrate preparation for the oyster mushroom is very simple. Further, this mushroom does not require controlled environmental conditions like *A. bisporus*, as most of the species have very wide temperature, relative humidity and CO₂ tolerance.

4. Longer shelf life

Unlike the white button mushroom, the oyster mushroom fruit bodies can be easily dried and stored. Dried oyster mushrooms can be instantly used after soaking in hot water for 5 to 10 minutes, or they can be used in powdered form for several preparations. Fresh mushrooms have a shelf life of 24-48 hr even at room temperature.

5. Highest productivity

The productivity of oyster mushrooms per unit time is very high compared to all other cultivated mushrooms. One can harvest a minimum of about 500 to 700 kg of fresh oyster mushrooms from one ton of dry wheat or paddy straw in 45-60 days, while with the same quantity of straw, only about 400-500 kg of white button mushrooms are obtained in 80-100 days (including the period needed for compost preparation). The yield of this mushroom can further be increased by supplementing the substrate with a suitable nitrogen source viz., soybean and cotton-seed meal or by introducing high-yielding cultures/strains.

4.5 Growing Oyster Mushroom

The present-day cultivation technology of oyster mushrooms is a result of various successive steps evolved throughout the world during the 21st century. A very primitive form of growing *Pleurotus* spp. was adopted by Lumberman in Europe during the 19th century, which involved the collection of wood logs and stumps showing fructification in nature and keeping them in cool and moist places. The first successful experimental cultivation of *Pleurotus ostreatus* was achieved in Germany by Falck in 1917.

In India, cultivation of *P. flabellatus* on paddy straw was reported by Bano & Srivastava in 1962 at CFTRI, Mysore. Kaul and Janardhanan (1970) cultivated a white form of *P. ostreatus* on dried *Euphorbia royleana* (Thor) stems. Jandaik and Kapoor in 1974 could grow *P. sajor-caju* on various substrates, including wheat and banana pseudostems. Almost all the species *Pleurotus florida*, *P. cornucopiae*, *P. citrinopileatus*, *P. flabellatus*,

P. ostreatus, *P. sapidus*, *P. sajor-caju*, along with *H. ulmaris* can be successfully grown in the region. *P. sapidus* and *P. sajor-caju* do better during the warmer part of the year (May – August). *P. eous* with attractive pink coloured fruit bodies is most beautiful but has no commercial implications due to less yield potential and leathery texture.

Table 2, Required characteristics of different oyster mushroom species

| Characters | Oyster mushroom | Button mushroom | Milky mushroom | Paddy straw mushroom |
|-------------------------|-------------------------|-----------------------------|--------------------------|-----------------------------|
| Species | <i>Pleurotus spp.</i> | <i>Agaricus spp.</i> | <i>Calocybe indica</i> | <i>Volveriella spp</i> |
| Substrate use | Paddy straw | Compost | Paddy straw | Paddy straw |
| Growing Temperature | 20-25°C | 15-20°C | 30-35°C | 30-35°C |
| Relative humidity | 85% | 85-95% | 85% | 85-95% |
| Total life cycle | 35-45 days | 90 days | 45-50 days | 90 days |
| Days for first interval | 15-25 days | 60-70 days | 24-28 days | 10-15 days |
| Yield | 635g (500g paddy straw) | 800-900g/bed (4 kg compost) | 720g (500 g paddy straw) | 800-900g/bed (4 kg compost) |
| Shelf life (days) | | | | |
| a) Normal conditions | 2 | 2 | 3 | 1 |
| b) Refrigerated | 3 | 3 | 5-7 | 2 |
| Protein | 23.6% | 23.9% | 32% | 23.9% |
| Production cost/kg (Rs) | 60-75 | 90-120 | 60-80 | 45-55 |

4.6 Nutritional and Medicinal Value of Oyster Mushroom

Oyster mushrooms are 100% vegetarian, having their nutritive value of oyster mushrooms is as good as other edible mushrooms like white button mushroom (*A. bisporus*), shiitake (*Lentinula edodes*) or paddy straw mushroom (*Volvariella spp.*). They are rich in vitamin C and B complex. Protein content varies between 1.6 to 2.5% on a fresh weight basis. It has most of the mineral salts required by the human body, such as potassium, sodium, phosphorus, iron and calcium. The niacin content is about ten times higher than any other vegetable. A polycyclic aromatic compound pleurotin, has been isolated from *P. griseus*, which possesses antibiotic properties.

Table 3, Nutritive values of different mushrooms (dry weight basis g/100g)

| Mushroom | Carbo- hydrates | Fibre | Protein | Fat | Ash | Energy k cal |
|--|--------------------|-------|---------|------|------|-----------------|
| Oyster mushroom (<i>Pleurotus sajor-caju</i>) | 63.40 | 48.60 | 19.23 | 2.70 | 6.32 | 412 |
| Oyster mushroom (<i>Pleurotus ostreatus</i>) | 57.60 | 8.70 | 30.40 | 2.20 | 9.80 | 265 |
| White-button mushroom (<i>Agaricus bisporus</i>) | 46.17 | 20.90 | 33.48 | 3.10 | 5.70 | 499 |
| <i>Auricularia auricula</i> | 82.80 | 19.80 | 4.20 | 8.30 | 4.70 | 351 |
| Milky mushroom (<i>Calocybe indica</i>) | 64.26 | 3.40 | 17.69 | 4.10 | 7.43 | 391 |
| Shiitake mushroom (<i>Lentinula edodes</i>) | 47.60 | 28.80 | 32.93 | 3.73 | 5.20 | 387 |
| <i>Flammulina velutipes</i> | 73.10 | 3.70 | 17.60 | 1.90 | 7.40 | 378 |
| Paddystraw mushroom (<i>Volvariella volvaceae</i>) | 54.80 | 5.50 | 37.50 | 2.60 | 1.10 | 305 |

Table 4, Medicinal values of important mushrooms

| Mushroom | Compounds | Medicinal properties | Source |
|--|-------------------------------|---|---|
| <i>Ganoderma lucidum</i> | Ganoderic acid Beta-glucan | Augments immune system, liver protection, Antibiotic properties, inhibits cholesterol synthesis | Lin & Zhang,2004 Wang et al.,2007 Moradali et. al, 2006 Komoda et al, 1989 |
| White-button mushroom (<i>Agaricus bisporus</i>) | Lectins | Enhance insulin secretion | Ahmad, 1984 |
| Oyster mushroom (<i>Pleurotus sajor-caju</i>) | Lovastatin | Lower cholesterol | Gunde & Cimerman,1995 |
| Shiitake mushroom (<i>Lentinula edodes</i>) | Eritadenine Lentinan | Lower cholesterol, Anti cancer agent | Enman et al., 2007 |
| <i>Flammulina velutipes</i> | Ergothioneine Proflamin | Antioxidant Anticancer activity | Bao,2008, Ikekawa et al.,1985 |
| <i>Auricularia auricula</i> | Acidic polysaccharide | Decrease blood sucrose | Yuan et al.,1998 |

**Fig 13, Medicinal Species of Pleurotus**

4.7 Low-Cost Production of Oyster Mushroom

Cultivation technology of oyster mushroom is very simple, which does not require costly infrastructure facilities. The cultivation of oyster mushrooms in Odisha is mainly done in seasonal, low-cost growing rooms with very little expenditure. This simple cultivation technology, low production cost and adaptability attributes make this mushroom most widely cultivated throughout the country.

Site Selection

- For successful production and better returns of mushrooms, the site should be selected after consideration of the following points:
- Nearer to the residence of the grower for easy monitoring and supervision of the farm.
- Site should be easy to access by vehicle for transportation of critical inputs (Straws, construction materials) and farm products
- Availability of resources such as paddy straw, water, cheap labourers, power supply for installing motor-operated chaff cutter, exhaust fan, water pump, light, etc.
- Provision of a disposal site to convert spent mushroom substrate (SMS) to compost
- Sufficient areas should be available for storage of raw materials, chopping of raw materials, boiling and spawning areas and post-harvest handling.

Materials required

- (i) Paddy straw (ii) Trays (iii) Spawn (Mushroom seed)
- (iv) Water boiling drum (v) Chaff cutter/dao or Hachette

(vi) Sprayer/ hand spray (vii) Transparent poly bags (Size: 40- 45 cm X 20 cm) (viii) Single hole punch machine/Pointed stick (ix) Garlic extract (x) Jute thread/ Rubber band.

The method consists of the different steps, which are given below:

1. Preparation of substrate
2. Spawning
3. Spawn running
4. Cropping
5. Post-Harvest Management

1. Preparation of substrate

Oyster mushrooms are one of the most suitable fungal organisms for producing protein-rich food from various agro-wastes without composting. The best temperature for oyster mushrooms is 23°C to 25°C. *Pleurotus* mushrooms can degrade and grow on any kind of agricultural or forest waste. Paddy straw is the best substrate among all the cellulosic materials. The straw should be of good quality-golden yellow in colour, and free from diseases. It is chopped to a length of 5 cm and then boiled in hot water at 85°C for 30 minutes. Boiling makes the straw free from all contaminants and the cellulose is easily broken down by the mushroom fungus. About 2 kg of straw is needed for a polythene bag of 40-45×20 cm size.

2. Spawning

After draining excess water, spread the straw on a clean floor for cooling. We then squeeze the straw to remove excess water. We also need to maintain the moisture in the straw. The

moment when the straw is squeezed in the palm, no more water comes out. This indicates that the straw is ready for spawning and we stop further cooling. Spray garlic extract (stock solution) mixed with water (3-5 ml/ litre of water) on the boiled straw. One litre of garlic solution is sufficient for 5 kg of boiled straw.

Materials preparation is required during spawning

- i) **Garlic extract:** A Paste of 50 g (approx. 10 big-size cloves) of peeled garlic is made by adding 50ml of water (approx. 10 teaspoonfuls). The paste is squeezed through muslin cloth to get the stock solution. Spraying garlic extract prevents contamination of mushroom beds with green moulds, especially during the summer months. Spraying the soaked/boiled straw with garlic extract can be an optional practice during the winter months.
- ii) **Polybags:** Fold the poly bags (mushroom bags) lengthwise twice and perforate with a punch machine at a distance of about 10 cm between the holes. The sizes of the holes are about 5 mm in diameter. A polybag should have 15-20 no. of holes for proper ventilation. A polythene bag of 40×60 cm is used for spawn running.
- iii) **Spawn:** It is used at the rate of 2 % i.e.20g per kg of straw. The whole packet of 200g of spawn is used in making one bed with 2kg of straw. Break the lumps of planting spawn on a plate and divide into four equal parts of 50g each. Freshly prepared 20-30-day-old spawn is best for spawning.

Further, fill the bag with a layer of 10 cm of straw. Make the layer compact by pressing with the palm to a height of

about 4-5 cm. Spawn the straw layer with 50 gm of the spawn, sprinkle a larger amount of spawn towards the sides and a little less in the centre. Likewise, with a total of five layers of straw and four layers of spawn in between, fill up the polythene bag. Once the bag is filled up, tie the open end of the bag with a piece of jute thread. A label with the species name and date of spawning or preparing the bed should be attached to the bed for record.

3. Spawn Running

Bamboo racks or wooden shelves are built to accommodate the maximum number of beds. During mycelia growth, the bags are not to be opened and no ventilation is and light is required. Place the mushroom bag in a cool and dark place, safe from rodents and other insects, for the spawn run. The best temperature for spawn run is 25°C which is completed within 15-18 days. Once the mycelium has fully colonised the substrate, it forms a thick mycelia mat and is ready for fruiting and polythene can be removed with a white to cream coloured mycelium mat covering the entire straw.



Fig 14, Bamboo racks of Pleurotus

4. Cropping

Preparation of the cropping room: A cropping room of size 22 x 11 x 9 feet (length x breadth and height) can accommodate about 250 to 300 bags of 4kg each (wet basis). The spawning bags may be kept either by hanging or on shelves. Spawned bags are kept on a raised platform in shelves in a thatched shed with a minimum distance of 15-20 cm between each bag in the tier. The air ventilator or opening through which air is either blown in or out of the rooms should have at least a simple filter or cloth as a barrier. The wooden-made shelves can also be arranged in a 4 to 5-tier system and the length can be adjusted according to the size of the house. The distance between two tiers may be maintained at 45 cm, the tier height from the floor may be 4550 cm and the shelves should be placed preferably 45-50 cm away from the walls.



Fig 15, Iron racks with Oyster Mushroom

After completion of the spawn run, the bags are removed using a blade to allow space for fruiting. The beds after opening are kept inside the cropping room, having a minimum size of 22x11x9 ft. There should be diffused light and ventilation.



Fig 16, Low cost rope structure

Best temperature for fruiting is 23°C. The floors and walls are watered, usually twice a day, to maintain sufficient humidity. Water should not be sprayed on the beds for the first two days after removing the polythene. Mushroom fruit bodies come up after 5-7 days in clusters after the beds are placed in the cropping room. In the initial stage, these tiny fruit body clusters are known as pinheads. Pinheads grow into fully developed fruit bodies after 3-5 days of their appearance. These fruit bodies should be harvested just before they attain maturity, i.e. when the caps start to open outward.

5. Post-Harvest Management of mushroom

It is possible to obtain complete food value, medicinal values and taste by consuming mushroom in fresh condition and when harvested at the right stage. The right stage for picking can be judged by the shape and size of fruit body. Pileus margin when starts to curl upward or down ward indicates that the fruit bodies have become over maturity. Mushrooms should always be harvested before water spray. The margin of some fruit bodies starts curling upward and downward. This is the right stage for harvesting. Fruit bodies are harvested

by holding the stipe between the thumb and forefingers and twist it clockwise. Scoop out any portion of the stipe left in the bed to prevent saprophytic growth of other fungi and bacteria. Flushes of mushroom fruit bodies appear at 15-20 days interval and the harvest from first three flushes is considered as economic harvest in commercial cultivation in terms of time and space. Trim stipe/stalk of the fruit bodies to remove the adhering straw particles. Stipe is kept short or almost non-existent, as it is hard and not liked by many consumers. Fresh mushrooms should be packed in perforated polythene bags for marketing. They can also be sundried by spreading on a cotton cloth in bright sunlight or diffused light. In young mushrooms, the edge of the cap is thick and the cap margin is enrolled, while the cap of a mature mushroom is flat and inward curling starts. It is advisable to harvest all the mushrooms at one time from a bag so that the next crop of mushrooms starts early. The dried produce with 2-4% moisture can be stored for 3 to 4 months after proper sealing. Pack the fruit bodies in 250 gm or 500 gm packets as per requirement either in perforated poly bags or paper bags. Value addition can be done with attractive packaging, label and recipes.



Fig 17, Post-harvest management of oyster mushroom

6. Recycling of spent mushroom beds

Mushroom beds after the harvesting of the crop or continuation of cropping become uneconomic, the substrates

are considered 'spent' or 'used mushroom substrate'. If not handled properly, the 'spent mushroom substrate' creates various environmental problems, including groundwater contamination and nuisance, by being a safe home for pathogens. Diversified uses of 'spent mushroom substrate' in managing agriculture, environment and recycling energy have come to light

- (i) Used mushroom beds can be broken into pieces and applied in a vegetable or flower garden as organic manure.
- (ii) Spent mushroom substrate is a better substrate for vermicompost. Usually, 100kg of spent mushroom substrates yield 50 kg of vermicompost. The nutrient contents of the vermicomposting prepared from spent mushroom substrates are Nitrogen (1.85%), Phosphorus (0.90%) and Potash (1.12%).



Fig 18, Production to recycle of Oyster mushroom waste

- (iii) Spent oyster mushroom substrates serve as good livestock feed, especially for goats, cattle and pigs, because the oyster mushrooms have the capability of reducing the organic carbon and increasing the nitrogen content of plant residues. Cattle prefer these when the spent bed is broken into pieces, boiled with other feed and salt.

4.8 Disease and Insect Pests Management

Disease and insect pest management for oyster mushrooms involves integrated approaches focusing on prevention, sanitation, and targeted treatments. Key strategies include maintaining high hygiene standards, using sterile spawn, controlling environmental conditions to discourage pests, and applying chemical or biological controls when necessary. For specific issues like green mold, manually removing affected parts and discarding them is a primary solution. A few of the common disease and insect pests found in oyster mushrooms is discussed here with management controls to protect against the crop losses.

Disease Management

Preventative measures:

Hygiene: Maintain strict cleanliness in the growing area and use sterilised spawn to prevent contamination.

Spawn Quality: Avoid using spawn that shows signs of contamination, particularly green mold.

Environment: Ensure proper ventilation and temperature control, as high humidity and temperature can encourage disease.

Treatments:

Green mold:

Sometimes, during a spawn run, mushroom beds are seen covered with green coloured velvety growth, completely or in patches. This is because of the fungus, *Trichoderma harzianum*, that impairs mycelial run, causing a drastic reduction in yield. The contamination occurs due to improper boiling of the straw (sterilisation) or due to contaminated spawn. Green mould causes more problems during the warmer period of the year.

Management:

- (i) Spray garlic extract before spawning.
- (ii) Check the spawn packet for any fungal contamination before spawning.
- (iii) Discard contaminated spawn and remove contaminated beds away from the mushroom house.
- (iv) Wash mushroom bags properly before re-use.
- (v) Scooped out the green molds patches at the initial stage and sprayed the area with garlic extract

For minor cases, scrape off the affected area with a cotton swab dipped in formalin (4%) and discard the swab in a safe location.

Ink cap:

Ink cap fungus, *Coprinus spp.* is a weed mushroom. Affected beds turn black to deep blue colour due to excessive spore production of the weed fungus. Contamination of mushroom beds with this weed fungus is mainly due to excess moisture in the straw or decomposed straw used for mushroom bed preparation.

Management:

- (i) Use good quality and properly dried straw for bed preparation.
- (ii) Avoid decomposed straw or straw exposed to rain.
- (iii) Remove at young stage all the ink caps whenever seen on beds.

Browning:

Yellow to light brown colour may develop on the margin of the fruit bodies and the stalk, due to the bacterium *Pseudomonas spp.* Accumulation of water on the fruit bodies during watering of the beds leads to the growth of bacteria.

Management:

- (i) Avoid direct watering on the mushrooms.
- (ii) Shake the beds gently after watering to avoid water droplets from depositing on the mushrooms.

Bacterial diseases (e.g., yellow blotch): Use bactericides like oxytetracycline or streptomycin at a concentration of 400 ppm.

Fungal diseases: Some sources suggest spraying affected mushrooms with carbendazim or Chlorothalonil at 0.1%.

Discarding: If a significant portion of a substrate bag or tray is affected, discard the entire item to prevent the spread of infection.

Insect pest management

Preventative measures:

Environmental control: Use screens on vents to prevent flies and other pests from entering.

Sanitation: Keep the growing area clean, and dispose of old substrate properly by cooking it with steam or chemicals before disposal.

Monitoring: Employ light traps to monitor and control fungal gnats.

Treatments:

Flies and mites: Use sticky traps or apply chemical controls like malathion or deltamethrin to the walls of the grow room during specific stages of growth.

Other pests: Specific treatments exist for various pests, such as using quicklime for molluscs or boric acid-based baits for rodents.

4.9 Conclusion

Oyster mushrooms are a highly nutritious, versatile, and economically viable crop, recommended for both consumption and cultivation. They offer significant health benefits due to their rich protein, vitamin, and mineral content, while their rapid growth, adaptability to various substrates, and potential for generating income make them a valuable and profitable option for agriculture. Oyster mushrooms are a globally significant as well as an Odisha and versatile crop with a wide range of nutritional, economic, and environmental benefits. Their ease of cultivation on agricultural and industrial waste products makes them a cost-effective and sustainable food source, contributing to both local economies and Indian nutrition.



BUTTON MUSHROOM

Scientific name: *Agaricus bisporus*

Kingdom: Fungi

Family: Agaricaceae

Class: Agaricomycetes

Genus: *Agaricus*

Order: Agaricales

Division: Basidiomycota

A button mushroom is the most popular and widely consumed mushroom, characterised by its small, white, and mild-flavoured cap. Button Mushrooms (*Agaricus spp.*) are the most popular mushroom variety grown and consumed worldwide. In India, its production was limited earlier to the winter season. But based on the technology development, it is produced almost throughout the country round the year in small, medium and large scale in various farms adopting multifarious technology. It is a versatile and nutritious ingredient that can be used in a variety of dishes, including salads, soups, and stir-fries. It is known for being low in calories and fat while being a good source of B vitamins, potassium,

and antioxidants. The name “button mushroom” is often used interchangeably with cremini and portobello, as they are all the same species at different stages of maturity. A mature basidiocarp (fruit body) is whitish in colour and consists of a thick, short stipe with an annulus. The stipe supports the pileus, which appears as a hat-like expansion. On the underside of the pileus, many radiating gills or lamella are present, which are pink when young but purple-brown when mature.

Cultivation of button mushrooms (*A.bisporus*) started in the sixteenth century. However, on a commercial scale, the cultivation was initiated in Europe around the 17th Century. Many farms for the production of button mushrooms were established, and this variety still dominates the world production and consumption. India, with its diverse agro-climate conditions and abundance of agricultural wastes, has been producing mushrooms, mainly for the domestic market, for more than four decades. Commercial production picked up in the nineties, and several hi-tech export-oriented farms were set up with foreign technology collaborations. But a major share of mushroom production is still on small farms.

Button Mushroom (*Agaricus spp.*) is the most popular mushroom variety grown and consumed all over the world. The vegetative mycelium is composed of many interwoven, separate hyphae. The reproductive phase is initiated by the formation of small knob like swellings at different points of interwoven mycelial strands. These swellings increase in size and break through the surface of the substratum as small balls constituting the button stage. A mature basidiocarp (fruit body) is whitish in colour and consists of a thick, short stipe with an annulus. The stipe supports the pileus, which appears as a hat-

like expansion. On the underside of the pileus, several radiating gills or lamella are present, which are pink when young but purple-brown when mature.

India's current button mushroom production is estimated to be approximately 1.29 lakh tonnes, making up about 85% of the total mushroom production in the country. While total production is growing, India contributes only about 3% of the world's total button mushroom production. Major production hubs are located in the southern, western, and northern regions, with Punjab and Haryana being the leading states.

Button mushroom accounts for about 85% of India's total mushroom production. India is the sixth-largest producer of mushrooms in the world, contributing 3% of the global button mushroom output. Button mushroom cultivation has expanded beyond hilly, temperate regions to the entire country. While commercial units operate year-round with controlled environments, many small-scale growers cultivate the mushrooms seasonally in simple, low-cost houses, especially during the winter months. Utilising just 1% of the available agricultural residues could potentially increase India's mushroom output to 3.0 million tonnes, nearly equaling the current global production.

The white button mushroom (*Agaricus bisporus*) is the most popular variety, accounting for approximately 70–85% of India's total mushroom output. The Indian button mushroom market was valued at USD 1.46 million in 2024 and is projected to reach USD 2.48 million by 2030, growing at a compound annual growth rate (CAGR) of 11.1%.

5.1 Nutritive Value of Button Mushroom

Button mushrooms are low in calories, fat, and cholesterol, but rich in essential nutrients like vitamins B (riboflavin, niacin, and pantothenic acid), selenium, and copper. They also contain vitamin D and antioxidants like ergothioneine, making them a nutritious addition to a diet. The amino acid constituents of *Agaricus bisporus* button mushrooms are as follows:

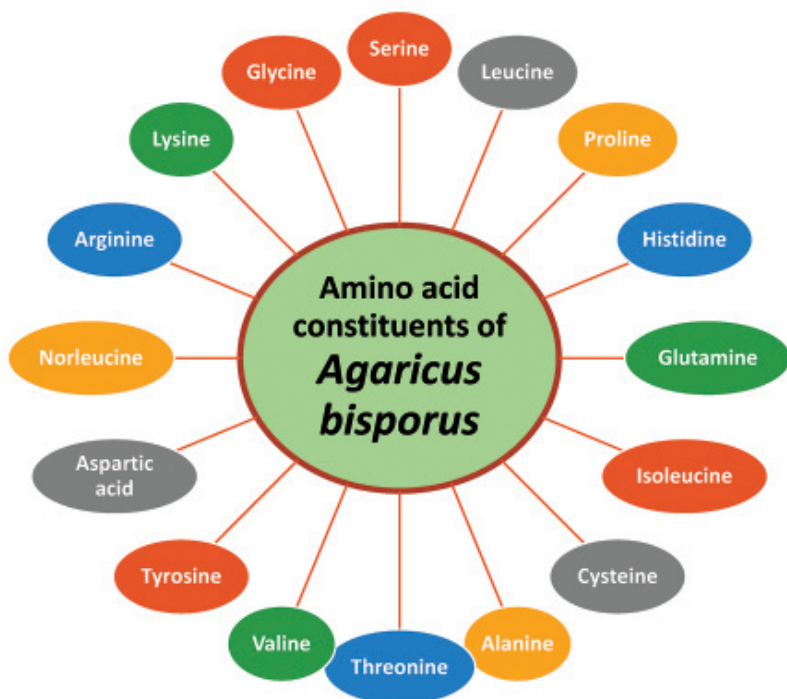


Fig 1, Samino acid constituents of *Agaricus bisporus*

Macronutrients and calories

Calories: Approximately 20-22 calories per 90-100 g serving.

Protein: About 3 grams per 90-100 gram serving.

Carbohydrates: Around 3 grams per 90-100 gram serving.

Fat: 0 grams per 90-100 gram serving.

Fiber: 1 gram per 90-100 gram serving.

Vitamins

Vitamin D: A good source of plant-based vitamin D2, especially if exposed to UV light.

B Vitamins: Rich in riboflavin (B2), niacin (B3), and pantothenic acid (B5), which are important for energy production and brain function.

Biotin (B7): A cup of raw button mushrooms can provide over 50% of the daily value.

Folate (B9): Contains folate, which is important for cell growth.

Minerals

Selenium: A good source that helps with immune function and acts as an antioxidant.

Copper: Another mineral found in good amounts, which is important for immunity and other bodily functions.

Potassium: A good source of potassium.

Phosphorus: Good source of phosphorus.

Other compounds

Antioxidants: Contain antioxidants like ergothioneine, which helps protect cells from damage.

Immune-modulating nutrients: Also contain nutrients that can help modulate the immune system.

5.2 Economic Importance

Button mushrooms (*Agaricus bisporus*) are economically significant due to their commercial cultivation, nutritional value, and versatility, which generate employment and income across various sectors. A global market valued at billions of dollars, with a steady growth rate, underscores the mushroom's

importance in both domestic and international markets. The economic importance of button mushrooms lies in their value as a food source, their profitability for farmers, and their potential in the pharmaceutical and cosmetic industries. They provide a significant income opportunity, especially for small and marginal farmers, and can be processed into value-added products, extending shelf life and creating new markets. Their cultivation requires minimal land, making it an eco-friendly venture.

For Farmers Perspectives

Income generation: Button mushroom cultivation is a profitable venture, particularly for small-scale farmers, as demonstrated by positive benefit-cost ratios.

Sustainable agriculture: Mushrooms are grown on substrates like straw and sawdust, helping to convert agricultural waste into a productive commodity.

Employment: The industry provides employment and supports rural development, from cultivation to processing and marketing.

Marketability: They are popular in both fresh and processed forms (e.g., canned, dried, soups), catering to a growing consumer demand.

Optimal resource use: Cultivation is space-efficient, requires minimal land, and repurposes agricultural by-products like wheat and paddy straw as compost. This sustainable practice provides a “wealth from waste” approach for farmers.

Support for small-scale growers: Small farms can thrive by leveraging simple, low-cost construction methods for

mushroom houses and utilising family labour. Local growers often have easier access to nearby markets, reducing transportation costs.

For the Food Industry

Nutritional value: They are a rich, low-calorie source of protein, vitamins, minerals, and dietary fiber, which makes them a valuable food product.

Value-added products: Processing mushrooms into products like pickles, soups, powders, and nutraceuticals extends their shelf life and creates new market opportunities.

Culinary use: They are a versatile ingredient, used in various cuisines and food products, including soups and sauces.

For the Health and Pharmaceutical Industries

Medicinal properties: Mushrooms have medicinal properties and are a source of bioactive compounds with antioxidant, anti-inflammatory, and potential anti-cancer effects.

Pharmaceutical applications: They are used in the pharmaceutical industry for developing medications and other health products.

Nutraceuticals: They serve as an important nutraceutical, a food that offers health benefits beyond basic nutrition.

“Health food” and nutraceutical market: The high nutritional value and potential health benefits of button mushrooms give them a premium status. They are rich in protein, B vitamins, minerals, and antioxidants, and are low in calories, fat, and sodium.

Potential therapeutic properties: Research into the medicinal properties of mushrooms, such as their anti-inflammatory, antioxidant, and anti-cancer effects, creates new value in the pharmaceutical and nutraceutical sectors.

Alternative protein source: With protein content higher than many vegetables, mushrooms offer a viable and affordable protein source, which can help address malnutrition, especially in lower-income populations.

For Environmental and Ecological value

Sustainable agriculture: The mushroom life cycle plays a vital role in decomposing organic waste, cleaning up the environment. The cultivation process repurposes agricultural waste, which would otherwise be burned, contributing to less air pollution.

Myco-remediation: Certain types of mushroom mycelia are used in bioremediation programs to break down contaminants like petroleum, contributing to ecological health. The spent mushroom substrate is also a valuable source of organic manure and animal feed.

5.2.1 Selection of location for the establishment of the Button mushroom unit

For a button mushroom unit, a successful location requires access to resources, a suitable climate (or capacity for climate control), and proximity to markets. The specific criteria will depend on whether you plan a low-investment seasonal operation or a high-tech, climate-controlled commercial farm. The ideal location for a button mushroom unit is near an all-season weather road, away from

municipal limits, and with good access to water, raw materials (like straw and poultry manure), and cheap labour. A site with an uninterrupted power supply is also crucial for cost-effective production.

Location selection criteria

Market access: Choose a site near a motorable road to reduce costs for transporting raw materials and finished products. Proximity to the market is essential for the disposal of the produce.

Distance from urban areas: The unit should preferably be located outside of municipal limits to avoid issues with the smell of the composting process.

Resource availability

Raw materials: Easy and cheap access to raw materials like straw and poultry manure is necessary.

Labour: The area should have an abundant supply of cheap and available labour.

Access to compost materials: Secure a reliable and affordable source of composting ingredients. For the widely used semi-synthetic compost, this includes agricultural by-products like wheat or paddy straw, as well as poultry manure.

Water supply: A plentiful and good-quality water supply, whether from a perennial source or underground, is essential for composting and maintaining humidity.

Spawn: You will need access to a supplier of high-quality, contamination-free spawn (mushroom seed), or you will need a facility to produce your own.

Infrastructure and Environment

Power supply: An uninterrupted power supply is highly desirable for managing the climate control systems in a modern unit. Power generation with diesel is expensive.

Space: You must acquire sufficient land to accommodate the various farm components, such as the composting yard, production rooms, and a potential future expansion.

Controlled environment: For year-round production, you will need to operate in insulated cropping rooms with air handling units to maintain the required temperature and humidity. Some producers repurpose existing structures like old tunnels or chicken houses.

Hygiene: Choose a site that can be kept clean and is away from potential contamination sources, such as garbage dumps or other farms with pest and disease issues.

Environmental factors: While modern technology allows for cultivation anywhere, classic button mushroom farming historically favoured hilly areas with cool climates like those found in the Nilgiris and Shimla. However, the key is to have controlled environmental conditions inside the growing house regardless of the external climate.

Waste disposal: The site should be suitable for the disposal of spent substrate (used compost), as its accumulation can lead to disease issues.

Labour and Support

Labour pool: Abundant and affordable labour is necessary for the manual processes involved in cultivation, harvesting, and packaging.

Support services: Access to technical expertise from government or research institutions can be beneficial. Local banks may offer financing for agricultural projects.

5.3 Types of Button Mushroom

The main types of button mushrooms are white button, cremini, and portobello, which are all the same species, *Agaricus bisporus*, at different stages of maturity. White button mushrooms are the youngest, with a mild flavour, while cremini mushrooms are a brown, slightly more mature stage, and portobellos are the fully mature, largest form with a robust, “meaty” flavour. The most common button mushrooms are all varieties of the same species, *Agaricus bisporus*, which are simply harvested at different stages of maturity.

5.3.1 White Button Mushrooms

Appearance: These are the least mature and smallest of the three types, with a firm, round shape and a pale white colour. They have a delicate, mild, and earthy flavour.

Culinary use: Their mild taste makes them extremely versatile. They can be cooked in many ways and are also a popular choice for eating raw in salads.

5.3.2 Cremini Mushrooms (or baby bellas)

Appearance: As the middle stage of maturity, cremini mushrooms are slightly larger and have a light to rich brown cap. They have a firmer texture and a deeper, more robust, earthy flavor than white button mushrooms.



Fig 2, White button mushroom

Culinary use: They are excellent for cooking because they hold their shape well and their flavor intensifies when cooked. They are often used in soups, stews, and sauces.



Fig 3, Cremini button mushroom

5.3.3 Portobello Mushrooms

Appearance: These are the fully grown and most mature version of the *Agaricus bisporus* mushroom. They are recognized by their large, flat, brown caps and deeply developed gills. Their size and colour give them a meaty texture and an intensely savoury, umami flavour.

Culinary use: Due to their rich flavour and steak-like texture, portobellos are a popular meat substitute. They are often grilled, stuffed, or used in sauces where their strong flavour can shine.

5.3.4 Other related varieties

Swiss brown mushrooms: This is another name for the brown variety of *Agaricus bisporus*, referring to cremini mushrooms or a slightly more mature stage.

Flat mushrooms: A common term, especially in Australia, for the large, open-capped portobello mushrooms.

5.4 Button Mushroom Cultivation Technology

The cultivation of button mushrooms involves a series of steps: preparing a compost substrate, mixing in spawn, allowing the compost to be colonised by the mycelium (spawn run), adding a casing layer, and finally, managing the crop for harvesting. Button mushroom cultivation involves precise, multi-stage technology that requires careful environmental control to achieve a high yield. The primary steps include compost preparation, spawning (inoculation), spawn running, casing, and cropping (fruiting).

1. Prepare the compost substrate

- The substrate is prepared from plant wastes like wheat straw or sugarcane bagasse, with supplements like urea, bran, and gypsum, and water.
- The initial wetting process can last 24-48 hours until the material reaches about 70-75% moisture content.
- For composting, heaps are made and turned periodically to ensure proper aeration and mixing, with a target carbon-to-nitrogen ratio.

Long method: This is a traditional, outdoor process that can take up to 28 days. Raw materials like chopped wheat straw, chicken manure, urea, and gypsum are mixed, moistened, and stacked in piles. The stack is turned regularly to ensure uniform decomposition. The final compost should be dark brown, have a sweet smell (with no ammonia), and a moisture content of around 65-70%.

Short method: A more modern and efficient approach that takes 16-22 days and involves two phases.

- **Phase I (outdoor):** Raw materials are composted for 8–12 days. This is often done in aerated bunkers to accelerate decomposition and build up heat.
- **Phase II (indoor):** The compost is pasteurised in a special tunnel at 58–60°C for several hours to kill pests and competitor organisms, and then cooled.

2. Spawn and spawn run

- After the compost is prepared, spawn is mixed into it at a rate of 600"750 grams per kg of compost. This is called spawning.
- The spawned compost is filled into containers like polythene bags or trays.
- During the spawn run, the mycelium colonises the compost. This phase takes about 12"14 days at a temperature of 23-28°C and 90% relative humidity.
- The bags or trays are typically covered with a newspaper for this period, which is kept moist by spraying water.

Spawn quality: The quality and genetic vigour of the spawn are critical for a successful crop. Spawn is typically produced under sterile conditions in specialised laboratories.

Techniques: Spawn is mixed into the cooled compost in various ways.

- **Through spawning:** Mixing the spawn evenly throughout the compost.
- **Layer spawning:** Creating layers of spawn within the compost.
- **Spot spawning:** Planting small lumps of spawn into holes in the compost.

3. Casing and case run

- Once the spawn has completely colonised the compost, a 2.5"3.0 cm layer of casing material is applied on top.
- Common casing mixtures include spent compost, sand, and lime, or loam soil and sand. The casing material should be porous, have a high water-holding capacity, and be pasteurised or sterilised before use.
- The surface is kept moist by sprinkling water and maintaining 70"80% humidity and the same temperature as the spawn run phase, until the casing soil is fully colonised by the mycelium.

4. Fruiting and harvesting

- After the case run, the temperature is lowered to 2-18 °C to induce the formation of mushrooms.
- Pinheads will form on the surface of the casing layer.
- As mushrooms grow, they are harvested when they reach the desired size. Repeated harvesting can continue for several weeks.

Pinhead formation: After the mycelium has colonised the casing layer, the room's conditions are changed to induce "pinning"-the formation of tiny mushroom heads. The temperature is lowered to 15-18°C, fresh air is introduced, and the humidity is maintained above 85%.

Harvesting: The first harvest usually occurs about three weeks after casing. Mushrooms are harvested while their caps are still closed by twisting and gently pulling them from the soil.

Yield: Multiple "flushes" or crops can be harvested from a single batch of compost over several weeks. An average

yield is 10–14 kg of mushrooms per 100 kg of compost using the long method, and 15–20 kg with the short method.

5.5 Diseases and Pests

Button mushrooms are susceptible to fungal, bacterial, and viral diseases, as well as various pests. Common fungal diseases include dry bubble (*Verticillium fungicola*) green mould (*Trichoderma*), and cobweb (*Cladobotryum*). Bacterial blotch (*Pseudomonastolaasii*) is a prevalent bacterial disease, while viral diseases like dieback are also common. Major pests include mushroom flies (sciarid, phorid, and cecid), mites, springtails, and nematodes.

5.5.1 Diseases

Fungal Diseases:

1. **Dry Bubble:** Causes muddy brown spots and gray-white mold.
2. **Wet Bubble:** Results in malformed mushrooms with wet rot and amber liquid.
3. **Cobweb:** Appears as a white, silky, or cottony growth.
4. **Green Mould:** Dark green patches on the mushrooms, often caused by *Trichoderma* species.
5. **False Truffle:** Manifests as cottony wefts on the mushrooms.
6. **Internal Stipe Necrosis:** A disorder affecting the stem.

Dry Bubble

Verticillium fungicola

- Muddy brown, often sunken spots on the cap of the mushrooms

- Greyish-white moldy growth seen on the pileus
- Later stage mushroom becomes dry and leathery
- Initially infected ones do not develop or remain small
- Main source of infection
- Debris
- Dust on the floors of the growing house
- Spread
- Water splashes on a healthy mushroom
- Sciarid and phorid flies over long distances
- Favourable temperature 28° c
- Poor ventilation
- High humidity



Fig 6, Dry Bubble of button mushroom

Management of Dry Bubble

- Pick and destroy infected mushrooms to prevent spread
- Sanitary conditions in the growth house
- Lower the temperature to 14°c when disease noticed
- Use clean equipment
- Control flies and mites
- Bubble can be destroyed with salt

Management by using salt

- Use of clean pasteurised casing media
- Properly maintained air filtering system.

- Water early infection centers with formaldehyde
- For protective measures, use zineb
- Apply chlorothalonil to the casing or mix it into casing material

Dry bubble in Oyster

False Truffle

- *Diehliomyces microsporus*
- Competitor than a pathogen
- Appears as cottony weft of mycelium on bed surface
- Wefts turn to dense small reddish brown, wrinkled, stromatic bodies resemble a truffle
- Infected bed have peculiar disagreeable odour
- Reduced yield at mycelia exist
- Introduced through soil



Management

- Good sanitation
- Proper Pasteurisation of casing material
- Low temperature during the spawn run

Wet Bubble

Mycogone pernicioso

- Malformed mushrooms with swollen stipes
- Reduced or deformed caps
- Undifferentiated tissue becomes necrotic and a wet, soft rot emits a bad odour
- An amber liquid appears on infected mushrooms.
- Mushrooms become brown in colour

- Bubbles may be as large as a grapefruit.
- The fungus is spread via airborne dust and contaminated casing.
- It is also a parasite of wild mushrooms.
- It produces two spore types,
- one which is small and water-dispersed like *Verticillium*,
- second which is a large resting spore capable of persisting for a long time in the environment

Control

- Sanitation in the growth house
- Clean environment around the cultivation area
- Incorporating benzimidazoles in the casing.
- Benomyl at the rate of 0.95 g/m²,
- Carbendazim and thiabendazole at the rate of 0.62 g/m²

Cobweb

- *Cladobotryum dendroides*
- White silky growth grows over the surface of the casing soil
- It climbs up and covers mushrooms that come in its path
- Infected mushrooms become soft
- Later engulfed by a cottony ball of mycelia
- Serious problem where year-round growing is practised
- Cobweb mold is darker than mycelium... almost grey as compared to white.



Fig 6, Dry Bubble of button mushroom

- The main source of infection is casing soil
- A cottony mycelium grows over the casing
- The mycelium soon envelopes the mushroom with a soft, mildewy mycelium and causes a soft rot
- It is also a parasite of wild mushrooms.
- Cobweb mold is favoured by high humidity.

Management of Cobweb

- Identify disease symptoms early, not only the web but also cap spotting.
- Treat spotty infections with an alcohol drenched paper towel
- Cover infected areas with salt
- Change from light peats to heavy peat casing may encourage disease development, but heavy black peats are not responsible for initial infections.
- Heavier casing may require increased water applications, therefore, may encourage the spread and development of the disease.
- Heavily infected 2nd or early 3rd breaks should be steamed off to reduce the spore load on the farm.
- Control strategies include lowering humidity and /or increasing air circulation
- Increase the hygiene of the harvesting and watering department.
- Judicious applications of Benzimidazole fungicides should be made
- Chlorothalonil should be included in the fungicide application program

Common chemicals used to control diseases in mushroom

| Fungicide | Against Pathogen | Doze |
|-------------------------|--|---|
| Benomyl and Carbendazim | Dactylium, Mycogone, Trichoderma, Verticillium | Mix 240 g/100m ² With casing or in water @ 240g/200 l /100m ² |
| Chlorothalonil | Mycogone, Verticillium | 200 ml/200 l/100m ² 1 st spary 1 week after casing & 2 nd after 2 week |
| Prochloroz manganese | Dactylium, Mycogone, Verticillium | 300g/ 100 l/ 100 m ² for single spary or 113g /100 l/100 m ² if 2 spray |
| Thiabendazole | Dactylium, Mycogone, Verticillium | Mix 240 g/100m ² with casing or in water @ 240g /200 l/100m ² |
| Zineb | Dactylium, Mycogone, Verticillium | 350 g/ 100m ² , (dust) every week after casing.1 kg/ 1000 l @ of 5 l/10m ² after casing & between flushes |

Bacterial Diseases

Bacterial Spot/Pit /Brown Blotch

- *Pseudomonas tolaasii*.
- Pale yellow spots on the surface of the piles later it turns to yellow
- In Sevier case mushrooms are radially streaked
- Damage at storage and transit

- Source of contamination may be soil or water
- High humidity and watery conditions are favourable for disease
- Vector: Tryoglyphid mite
- Lesions on tissue that are pale yellow initially, later become a golden yellow or rich chocolate brown.
- Discoloration is superficial (not more than 2 to 3 mm)
- Underlying tissue may appear to be water soaked and grey.
- Blotches appear in early button stage,
- Appear on any age - even on harvested refrigerated mushrooms
- At favourable moisture conditions spots enlarge and coalesce, sometimes covering entire cap
- Mushroom stems can also be blemished similarly
- Typical spotting is observed at or near the edge of mushroom caps wherever caps remain wet for a period of 4 to 6 hours or longer after water has been applied
- If very dry conditions occur after blotch has developed, infected caps may crack radially as the mushroom expands
- Casing and air-borne dust are the primary sources.
- The bacterial pathogen is probably present in most casing material, even after pasteurisation.
- Occurrence of disease is associated with the size of the bacterial population on the mushroom cap, rather than on the population in the casing, which explains why a prolonged wet period on the cap precedes disease occurrence.

- Spread by splash, tools, flies and nematodes.
- Moisture content of less than 62 percent at spawning preconditions mushrooms to blotch infection.



Fig 7, Bacterial Spot/Pit /Brown Blotch

Management

- Sanitation
- Lowering humidity
- Watering with a 150 ppm chlorine solution (calcium hypochlorite products are used since sodium hypochlorite products may burn caps).
- If the mushroom stays wet, however, chlorine has little effect since the bacterial population reproduces at a rate that neutralises the effect of the oxidising agent

Mummy disease

- The disease was first described in 1942 by CM Tucker and JB Routien in the United States
- Fruit bodies have tilted caps,
- Early veil breaking,
- Base of the stem enlarged
- Curved stalk
- Tissue of the mushroom becomes



- Spongy,
- Dry and Brown
- Mummified appearance.
- Rapid rate of spread through the bed, up to 30cm (12 inches) daily.
- Infected mushroom is tough and dry texture
- Gritty texture appeared when cut
- Water-soaked appearance and cavities in the mushroom tissue

Management

- Dig a trench to separate the diseased area from the healthy.
- Dug around 2m (6-8ft) ahead of the advancing disease and the trench itself to be several inches wide.
- All compost and casing has to be removed from the trench
- Gap thoroughly disinfected.
- If the crop is growing in separate containers, the usual advice is to isolate or dispose of them.
- Good hygiene is strongly recommended.

Viral Disease

- Virus (several)
- Double-stranded RNA
- Reduced cropping,
- bare patches on the beds,
- long-bent stalks with small caps,
- Premature opening of mushrooms,
- Stalks tapering towards the base of the stalk,

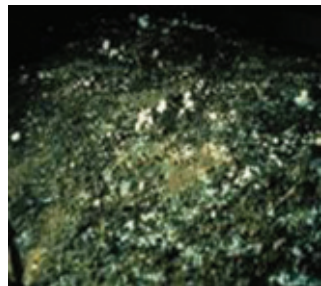
- Dying pinheads
- Infected mycelium grows slowly in the beds and fruiting bodies are not produced.
- Infection of the crop at spawning leads to a higher level of disease

Spread and source of infection of the virus

- Infected mushroom spores
- Mycelium from previous crops also survives in the trays
- Mushroom sheds can also release infected spores
- Dust from around the farm may introduce infected spores
- Only 10 infected spores are required for a disease outbreak.
- Farm hygiene
- Maintain 60 °C temperature throughout the compost
- Filter air and seal rooms properly to prevent spores from entering during cool cool-down phase of compost
- Clean equipment's
- Ensure workers have clean spare clothes
- Ensure absolute filters are fitted to spawn-run buildings
- Clean trays to prevent infection from old-infected mycelia

Green molds

- *Trichoderma koningii*
- *T.viride*
- *T.aggressivum f.sp.aggressivum*
- Dark green mould patches on casing spreading to lesions on stems.



Control of green mould

- Sanitation and hygiene programme, especially targeting post-crop
- Cover spots with sodium hypochlorite solution, salt, lime or gypsum and lime mix.
- Good insect and mite control
- Personnel movement patterns further reduce the spread of the disease.
- chlorothalonil at casing or mix into casing material 254 mL formulation per 100 m² of production
- Chlorothalonil is not effective against an established infection, but lowering the infection

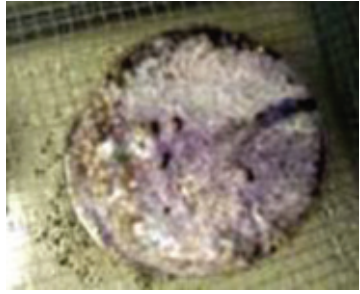
Cinnamon Mould

- *Chromelosporium fulva* (*Peziza ostrachoderma*)
- The colour of this mold ranges from yellow gold to golden brown to cinnamon brown.
- It grows rapidly in circular patches.
- It is very common in soil and flourishes on damp wood.
- Areas in compost overheated during the spawn run may be colonised.
- Improperly conditioned compost will also support growth,
- It often occurs on sterilised soil.
- Sexual fruiting bodies may appear several weeks after the first appearance of the mold.
- Spores are airborne

Pink Mold

- *Neurospora* spp.
- Commonly to occasionally seen on agar and grain.

- It is ubiquitous in nature, occurring on dung, in soils and on decaying plant matter.
- *Neurospora* spores germinate more readily at elevated temperatures.
- The pink mold seen in mushroom culture is most frequently *Neurospora sitophila*, a pernicious contaminant that is difficult to eliminate.
- All infected cultures should be removed as soon as possible from the laboratory and destroyed.
- A thorough cleaning of the laboratory is necessary.
- If contamination persists, remove all spawn and start anew



Inky Cap

- *Coprinus* spp.
- These are evidence of free ammonia in the compost.
- Their delicate gray caps autodigest quickly.
- Inky caps are indicators of nitrogen over supplementation or a poorly managed Phase II compost.
- If there is too much residual ammonia, Phase II thermophilic microflora may be unable to convert all the ammonia into microbial protein.
- fungus is strongly cellulolytic.

Other Management and Prevention

Hygiene and Sanitation: Proper pasteurization of compost and casing soil is crucial, as is good hygiene throughout the growing area.



Environmental Control: Proper air circulation and humidity management can help control many diseases.

Integrated Pest Management: This approach is considered the most effective long-term strategy for managing both pests and diseases.

Chemical Control: Fungicides and other chemicals can be used, but resistant strains and environmental impact are concerns.

5.6 Conclusion

A staple of global cuisine, the button mushroom (*Agaricus bisporus*) is a versatile ingredient prized for its mild, earthy flavour and tender texture. Beyond its culinary uses, it is a low-calorie, nutrient-dense food that provides significant health benefits and is produced through sustainable agricultural practices. Button mushrooms are a highly nutritious, versatile food with potential medicinal properties, and their cultivation requires careful attention to compost preparation and growing conditions. They are a valuable food source, rich in protein and minerals, and can be cultivated to produce value-added products like enriched powders, offering economic benefits and a sustainable food option.

MILKY MUSHROOM

Scientific name: *Calocybe indica*

Kingdom: Fungi

Family: Lyophyllaceae

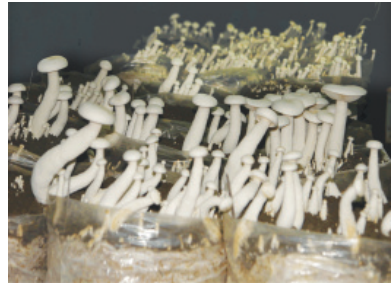
Class: Agaricomycetes

Genus: Calocybe

Order: Agaricales

Division: Basidiomycota

Species: indica



Milky mushroom (*Calocybe indica*) cultivation is a straightforward process suited for warm, humid climates, making it an excellent alternative to more infrastructure-intensive varieties like button mushrooms. Milky mushroom cultivation in India involves preparing a substrate like straw, mixing it with spawn, and incubating the bags for mycelial growth. After the spawn run, a casing layer is applied, and the bags are kept in a well-ventilated area with proper moisture and light to encourage fruiting. The best temperature range is 25-35°C and 80-85% humidity, making it suitable for cultivation from March to October, especially in the southern parts of the country. milky mushrooms grow on humus-rich soil in agricultural fields or along the roadside in tropical and

subtropical parts of India, especially in the plains of Tamil Nadu and in Rajasthan.

Milky mushroom cultivation is suitable for Odisha's hot and humid climate and can be done from March to October. The cultivation process involves preparing a substrate of chopped paddy straw, which is then spawned, incubated in bags or beds, and grown in a humid environment with regular watering. Odisha has the potential for commercial cultivation, with government support and training programs available through initiatives like the Mushroom Mission.

Milky mushroom cultivation involves preparing a substrate like paddy straw, inoculating it with spawn, and incubating it under specific conditions before fruiting. Key steps include substrate preparation by chopping and soaking straw, followed by pasteurisation to eliminate competitors. After inoculation, the beds are incubated in a dark room for 10-20 days at 25-35°C and 80-90% relative humidity. Once the mycelium fully colonises the substrate, fruiting is initiated by introducing fresh air and light, and a casing layer of sterilised soil is often applied to trigger pinhead formation. The cultivation process involves six key stages: substrate preparation, spawning, spawn run, casing, cropping, and harvesting.

6.1 Nutritive Value of Milky Mushroom

Milky mushrooms are a nutritious food source, providing roughly 47-50 kcal per 100 g, with a good amount of protein (around 3.1-4.3g), and low fat (around 0.7g). They are rich in essential amino acids, minerals like calcium, phosphorus, potassium, iron, and zinc, and various vitamins,

including B vitamins, C, and E. They are also a good source of dietary fiber, which is beneficial for digestion.

It has a dense, meaty consistency that enhances its unique taste, along with its smooth, firm caps and long, thick stems. Milky mushrooms have a chewy texture and taste similar to radishes, with a mild, oily flavour. These mushrooms are a good source of Vitamin D for vegetarians and are renowned for their nutrient-rich properties, long shelf life, and versatility in cooking. Milky mushrooms have been known to be used for specific disease conditions, viz., hyperglycaemia and hypertension. Milky mushrooms are an excellent source of vitamins B2, E, and A, phosphorus, potassium, and selenium, and also contain calcium, vitamin C, iron, and zinc. It is particularly known for vitamin E (tocopherol), an antioxidant that protects membranes, lipids and lipoproteins. Now use



technology to specifically enhance Woodberry Mushrooms with Vitamin D. Ideal for any Indian cuisine, it can be used in curries, stews, soups, toppings for pizza, omelettes, stir fry, East Asian, and Southeast Asian cuisine.

Macronutrients (per 100g, fresh weight)

- **Calories:** 46.56"50.03 kcal
- **Protein:** 3.1"4.3 g
- **Carbohydrates:** 6.7g
- **Fat:** 0.68"1.05g
- **Fiber:** 1.11"2 g



Key vitamins and minerals (per 100g)

- **Vitamins:** Thiamin, riboflavin, niacin, vitamin C, vitamin E, and vitamin A
- **Minerals:** Calcium, sodium, potassium, phosphorus, iron, zinc, copper, and magnesium

Other notable nutritional aspects

- **Amino acids:** Milky mushrooms contain all essential amino acids, with high levels of threonine, isoleucine, methionine, and valine.
- **Health benefits:** Their low-calorie and low-fat profile makes them suitable for weight management, while their protein and fiber content can help you feel full. The high fiber content and alkaline ash are also beneficial for those with hyperacidity and constipation.

6.2 Suitability for Odisha

- **Climate:** The tropical and humid climate of Odisha is ideal for milky mushrooms, which thrive in temperatures between 25-35°C.

- **Timing:** Cultivation is feasible from March to October.
- **Government support:** The state government's Mushroom Mission aims to increase production, especially through women farmers, and provide training and capacity building.

6.3 Types of Milky Mushroom

The main type of milky mushroom cultivated is *Calocybe indica*, with specific strains like Bheema, APK2, and IIHR Ca-1 being popular for cultivation due to their performance. Other related species, sometimes referred to as milky mushrooms, include those from the genus *Lactarius*, but these can be toxic and are distinct from the edible *C. indica*.



- **Bheema:** A high-yielding strain with a biological efficiency of 157% on paddy straw, as reported in one study. “Bheema Milky Mushroom” is likely a typo for a high-yielding strain of the Milky Mushroom (*Calocybe indica*) called Bheema. This Indian native mushroom is known for its suitability to hot, humid climates and has a longer shelf life than many other mushrooms. The Bheema strain is noted for its high yield compared to other strains.

- **APK2:** A strain that performed well in cultivation, achieving a yield of 1010g per kg of dry substrate in one study. APK2 is a specific variety of the tropical milky mushroom (*Calocybe indica*) released by Tamil Nadu Agricultural University in 1998, known for its high yield and suitability for warm climates. This variety is a popular choice for commercial cultivation, thrives in temperatures of 30–35°C, and can be grown on a variety of substrates like paddy straw.
- **IHT Ca-1:** Another cultivated strain, with a study showing it yielded 1040g per kg of dry substrate.
- **DMR-Milky 334:** A variety developed and released by ICAR-DMR Solan, with a fruit body weight of 33-38g and a yield of 74-82 kg/100 kg of dry straw.
- **DMR-Macrocybe-1:** A related strain, also released by ICAR-DMR Solan, similar to *Calocybe indica*.

Some other species, sometimes called “milky mushrooms” are

- **Lactarius:** species: This genus includes many species that exude a milky latex when cut, but many are toxic. Examples include *Lactarius deliciosus* and *Lactarius piperatus*. It is important to distinguish *C. indica* from these other milky-latex-producing mushrooms to avoid consuming toxic varieties.

6.4 Milky Mushroom Cultivation Process

6.4.1 Climatic Requirement

Temperature: Milky Mushroom can be grown in the temperature range of 25⁰-40⁰C. However, for the best yields,

Mushroom Spawn: Three weeks to one month old, 100 grams of good-quality seeds (10 % of the dry weight of straw) is necessary for raising a bag. The spawn should be procured from a recognised spawn laboratory.

Organic Supplement: For improving productivity, one may use pasteurised maize meal, wheat bran, paddy husk or boiled wheat grain at 100-150 gm per bag during spawning.

Polythene Bag: A Polythene tube of dimensions 60 cm x 40 cm with 100-gauge thickness and open at both sides is required for milky mushroom cultivation.

6.4.3 Cultivation Procedure

Substrate Processing: Good quality paddy straw is chopped to a 4-5 cm size with a chaff cutter. The chopped straw is soaked in clean and cold water for six hours. However, the soaking period varies with the nature of the substrate. Excess water is drained from the straw, and it is subjected to physical and chemical means of pasteurisation, as in the case of the oyster mushroom. Straw should contain 50-55% moisture at the end to give better productivity.

Raising of Bags: One end of the polythene tube is tied with a rubber band and the moistened and pasteurised substrate is put inside to a height of 7.5 cm. Substrate is then gently pressed and one third each of the spawn and supplement (35 gm) is spread at the periphery close to the polythene. Likewise, three such layers are made and the bag is closed at the upper end after pressing the substrate. 15 to 20 small holes (0.5 cm to 1.0 cm dia) should be made on all sides to facilitate gas exchange. Instead of layer spawning, mixed spawning may also be followed,

where the required quantity of spawn is mixed with the prepared substrate (soaked and pasteurised straw) and incorporated into the bag. The bags are then incubated in a dark room where a temperature of 25-35°C and a relative humidity of 80% are maintained. It takes about 20 days when the substrate is fully colonised and the bags are ready for casing. Bags are shifted to the cropping room for casing and cropping.

Casing and after care: Casing means covering the top surface of bags after the spawn run is over, with pasteurised casing material in about 2-3 cm thickness. Casing provides physical support, moisture and allows gases to escape from the substrate. Casing material (soil 50% + Compost 50%) with pH adjusted to 7.8 to 7.9 with chalk powder is pasteurised in an autoclave at 15 psi for one hour or chemically treated with 4 % formaldehyde solution about a week in advance of casing. It is covered with a polythene sheet to avoid the escape of chemicals and turned at 2 2-day intervals so that at the time of casing, the soil is free from formalin smell. The top of the bag is opened, the polythene is folded and the casing material is uniformly spread in a 2-3 cm thickness.

Cropping: It takes about 10 days for the mycelium to reach the top of the casing layer when fresh air is introduced along with appropriate temperature and humidity. The changes thus made in the environment result in the initiation of fruit bodies within 3-5 days, which may mature in about a week.

Mushrooms of 7-10 cm diameter are harvested by twisting, cleaned and packed in perforated polythene/polypropylene bags for marketing. In a 40-day duration crop, around 800-

1000 g of mushrooms may be harvested per bag. Hence, the biological efficiency of milk mushroom is 80-100%.

1. Substrate preparation

Choose substrate: Use cereal straws such as paddy, wheat, or ragi, or other agricultural wastes like sugarcane bagasse.

Chop: Cut the straw into small pieces, ideally 2-4 cm long.

Soak: Soak the chopped straw in fresh water for 8-16 hours to hydrate it. For pasteurisation, you can use chemically treated water with a mixture of formalin and bavistin.

Drain: After soaking, drain the excess water. The straw should be air-dried to a moisture content of about 20-35% before packing.

2. Inoculation and bed preparation

Layering: Prepare beds by layering the prepared straw and spawn. A common method is to place a layer of straw and then a layer of spawn, repeating this process until the bag or bed is filled, with at least five spawn layers.

Packing: Pack the straw tightly to remove air pockets and ensure good contact between the straw and spawn.

Bags: Use polyethene bags to hold the substrate. You can arrange these bags in a hanging system to save space.

3. Incubation

Dark room: Place the bags in a dark room for the spawn run.

Temperature and humidity: Maintain an optimal temperature of 25-35°C and relative humidity of 80-90%.

Duration: Spawn will fully colonise the substrate in 10-15 days.

4. Fruiting

Casing: After the spawn run, a thin layer of sterilised casing soil (garden soil mixed with calcium carbonate is ideal) is applied to the top of the bed.

Initiation: Introduce fresh air and light (2500-3000 lux) for about 10 hours a day to initiate fruiting.

Fruiting bodies: Within 3-5 days, the first “pinheads” or baby mushrooms will appear, which will mature in about a week.



5. Harvesting and post-harvest

Harvest: Harvest the mushrooms when they reach full development by gently twisting and pulling them from the substrate.



Subsequent flushes: After the first harvest, stir the soil and mist the bed to encourage a second flush of mushrooms, which can be harvested about 10 days later.

Storage: Milky mushrooms have a long shelf life, making them easy to handle and transport.

6.5 Diseases and Pests of Milky Mushrooms

Diseases and pests that affect milky mushrooms (*Calocybe indica*) often originate from unhygienic conditions or contaminated materials. Proper sanitation and environmental control are the most critical factors in preventing infestations and disease outbreaks. Common diseases of milky mushrooms include fungal infections like cobweb disease and green mold, while major pests include sciarid and phorid flies, mites, and nematodes. These can be managed through integrated pest management strategies focusing on hygiene, proper substrate moisture, and ventilation.



6.5.1 Fungal Diseases

Green mold (*Trichoderma* spp.):

This is one of the most common and destructive diseases in mushroom cultivation.

Symptoms: Greenish mycelial patches appear in the compost, casing, or on the fruiting bodies. It can quickly spread and compete with the mushroom mycelium, leading to significant crop loss.

Causes: Improper sterilisation of the substrate, contaminated equipment, and high humidity.

Wet bubble disease (*Mycogone perniciosa*):

This disease infects the fruiting bodies, causing malformed, swollen mushrooms that rot and emit a foul odour.

Symptoms: Infected tissue becomes necrotic and soft. An amber-coloured liquid may appear on the surface, and the mushroom tissue can turn brown.

Causes: The fungus spreads through airborne dust and contaminated casing material. It thrives in high humidity.

Cobweb disease (*Cladobotryum dendroides*):

A fast-spreading, silky white or grayish fungal growth that covers the casing soil and mushrooms, causing a soft rot.

Symptoms: The mycelial mat can turn pink or red with age. The infected mushrooms become soft and eventually decompose.

Causes: High humidity and contaminated soil are major contributing factors.

Dry bubble disease (*Verticillium fungicola*):

Causes brown sunken spots and deformed, dry, leathery mushrooms, especially if infection occurs early.

Causes: Spread by dust, flies, and water splashes in humid conditions.

Ink caps (*Coprinus spp.*):

This is considered a competitor weed rather than a pathogen.

Symptoms: Long, slender mushrooms with small caps that quickly dissolve into an inky black liquid. They can overtake the bed and arrest the growth of the milky mushroom mycelium.

Causes: High moisture content, poor ventilation, and high ammonia levels in the compost.

6.5.2 Bacterial Diseases

Bacterial blotch (*Pseudomonas spp.*):

One of the most serious bacterial diseases, causing superficial yellow or brown lesions on the mushroom caps.

Symptoms: Pale yellow spots on the cap that enlarge and darken to golden yellow or chocolate brown. In severe cases, the cap may crack.

Causes: High humidity and standing water on the mushroom caps. The bacteria are often present in casing material and spread by splash, tools, and mites.

Mummy disease (*Pseudomonas spp.*):

Causes fruit bodies to become spongy, tough, and dry.

Symptoms: Curled or tilted caps, enlarged stems, and cavities in the mushroom tissue.

Causes: Poor hygiene and pasteurization are often responsible.

6.5.3 Pests

Mushroom flies (Sciariid, Phorid, and Cecid flies):

These are the most significant pests in mushroom cultivation.

Damage: Larvae feed on mycelium, pinheads, and bore into mature mushrooms, causing rot. Adult flies can spread disease pathogens.

Cause: Unhygienic conditions attract flies, which lay eggs in the compost.

Mites: Several species of mites can infest mushroom crops.

Damage: Mites feed on mycelium and fruiting bodies. Some species also spread pathogens like bacterial blotch.

Cause: Infestations often begin from raw materials or are transported by flies.

Nematodes:

These microscopic worms feed on mycelium, leading to blank areas in the casing soil and potential crop failure.

Cause: Improper compost pasteurisation is a major source of nematode infestations.

Springtails:

Small, greyish insects that feed on the mushroom mycelium and can cause minor damage to fruiting bodies.

Cause: Poor hygiene, inadequate pasteurisation, and improper disposal of compost.

Rodents (Rats): These pests can eat the spawn and create holes in the growing bags.

Management strategies: An Integrated Pest and Disease Management (IPDM) approach is the most effective way to protect your milky mushroom crop.

Strict hygiene: Clean and disinfect growing rooms, tools, and equipment before each crop. A bleach solution or formalin can be used for disinfection.

Substrate pasteurisation: Ensure that all growing materials are properly pasteurised to kill molds, pests, and competing organisms. Maintaining temperature control is critical.

1. Environmental control:

- Maintain optimal temperature and humidity for mushroom growth, but adjust to lower humidity when diseases are present
- Ensure proper air circulation to prevent stagnant, moist air buildup.
- Use 40-mesh nets on doors and windows to exclude insect pests.

2. Biological controls:

Introduce beneficial microorganisms, such as *Trichoderma harzianum*, to outcompete harmful molds. Predatory nematodes and mites can also help control pest insects.

3. Sanitary practices:

Immediately remove and destroy any contaminated beds or infected mushrooms. Dispose of spent compost far

away from the cultivation area.

Chemical controls (use with caution):

Fungicides like carbendazim or benomyl can be used to control fungal diseases. Insecticides like malathion can be sprayed on walls, but never on the mushroom beds directly. Use chlorine solution (150 ppm) to control bacterial blotch, but only on dry mushroom caps to prevent bacterial growth

6.6 Conclusion

Milky mushrooms are a nutritious, versatile, and relatively easy-to-cultivate edible fungus, popular in tropical climates for their high protein, fiber, and vitamin content. Their firm texture and mild flavour make them a great meat substitute, and their cultivation benefits from high temperatures and humidity. Overall, they are a valuable food source with significant nutritional and potential health benefits, and a commercially viable crop in many regions. The milky mushroom (*Calocybe indica*) is a nutritious and functional food that offers significant health benefits and a promising opportunity for sustainable, profitable cultivation, particularly in warm, humid climates.

WAY FORWARD

Mushroom cultivation in Odisha is a thriving and high-potential sector that plays a significant role in the state’s agricultural landscape and rural economy. Odisha contributes over 10% to India’s total mushroom production and is the leading state for cultivating paddy straw mushrooms, which account for the majority of its output. Mushroom cultivation in Odisha is a dynamic and emerging sector with immense potential for driving rural economic growth, enhancing nutritional security, and empowering women farmers. The state is a leading producer of paddy straw mushrooms in India, leveraging its abundant agricultural waste and favourable climate for this crop.



MUSHROOM MARKET



INDUSTRY DEVELOPMENT

Applied Food Sciences, Inc., an American supplementary product manufacturer, launched its new organic functional mushroom line, including Lion’s Mane, Cordyceps, Reishi, and Chaga mushroom varieties sourced from Finland.

TRENDS

Growing Investments in Smart Automation for Mushroom Production

DRIVERS

- Increasing Investments in R&D to Improve Commercial Cultivation
- Rising Health Consciousness to Propel Consumption of High Nutritional Value Food



ASIA PACIFIC

\$12.95 Million
2022

\$13.77 Million
2023

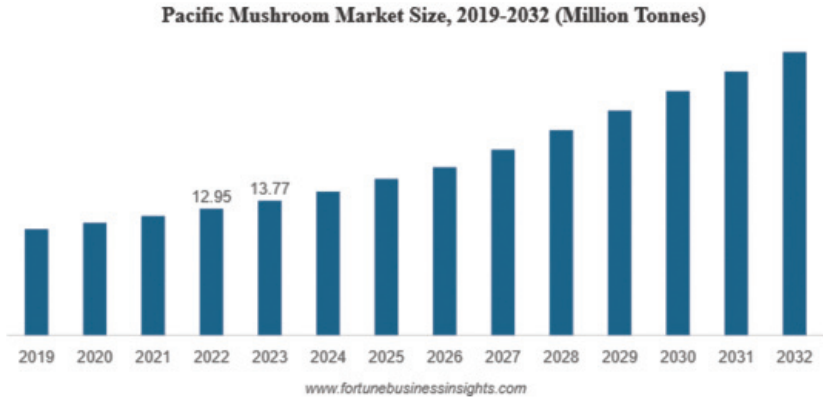


North America | South America
Europe | Middle East & Africa

Key Strengths and Opportunities

- **Economic and Social Impact:** Mushroom farming serves as a viable, low-cost, and additional source of income, particularly for small, marginal, and landless farmers and women's Self-Help Groups (SHGs). It helps in converting agro-waste (paddy straw) into a valuable, protein-rich food source. It offers low-cost, short-duration enterprise opportunities with high returns, thus improving socio-economic standards and promoting women's entrepreneurship.
- **Resource Efficiency:** The practice effectively recycles abundant local agro-wastes, primarily paddy straw, into a nutritious food source and valuable organic manure (spent mushroom substrate), contributing to environmental sustainability.
- **Growing Demand:** There is a growing local and urban demand for fresh mushrooms, driven by increasing awareness of their nutritional and medicinal benefits and a diversifying food culture.
- **Institutional Support:** The government, research institutions like the Centre of Tropical Mushroom Research and Training (CTMRT) at OUAT, Krishi Vigyan Kendras (KVKs), Horticulture Department and leading NGOs are actively involved in promotion, technical assistance, and training programs, with initiatives like the Mushroom & Floriculture Mission aiming to further boost the sector.
- **Favourable Climate and Growing Demand:** Odisha's hot and humid climate is ideal for tropical varieties like

paddy straw and oyster mushrooms for a significant part of the year. There is a growing domestic demand for fresh mushrooms, driven by their nutritional benefits and diversifying food habits.



Major Challenges and Needed Interventions

Despite the significant progress, the sector faces several bottlenecks:

- **Post-Harvest Management:** High perishability and a lack of proper cold chain and storage facilities are major issues, leading to post-harvest losses and unstable market prices.
- **Input and Financial Access:** Limited access to finance and an inconsistent supply of quality spawn (mushroom seed) are key constraints for farmers looking to scale up to commercial production.
- **Technology Adoption:** There is a need to promote year-round production through controlled environment cultivation and diversification into higher-yielding

varieties like button and milky mushrooms, which currently have limited production.

- **Market Linkages and Value Addition:** The market is often unorganised, with middlemen a common feature. There is a need to streamline the marketing system and encourage value-added products like pickles, cookies, and dried mushrooms to increase shelf life and profitability.

The future prospects are promising, provided that these challenges are addressed through targeted government policies, improved market linkages, value addition (e.g., canning, pickles), and continued technical support and training. By leveraging its potential, Odisha's mushroom industry can achieve substantial growth, enhance food security, and significantly boost the rural economy.

To realise its full potential, a coordinated effort from all stakeholders is required to address the existing challenges. By focusing on improved post-harvest infrastructure, ensuring the availability of quality inputs, facilitating financial access, and promoting value addition and better market linkages, Odisha can transform mushroom cultivation from a supplementary "subsistence enterprise" into a more robust and highly remunerative full-fledged horticultural industry in the near future.



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