

Mushrooms

Cultivation, Marketing and Consumption



Editors

Manjit Singh
Bhuvnesh Vijay
Shwet Kamal
G.C. Wakchaure



Directorate of Mushroom Research

(Indian Council of Agricultural Research)

Chambaghat, Solan –173213 (HP)





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शरद पवार
SHARAD PAWAR



कृषि एवं खाद्य प्रसंस्करण उद्योग मंत्री
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MINISTER OF AGRICULTURE & FOOD
PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

09 February, 2011

MESSAGE

Quality food, health and environment are the major concerns facing our country. Mushroom cultivation helps to address the issue of nutritional security and also provides solution for proper recycling of agro-wastes. In addition to good quality protein, no cholesterol, high fibre, low sodium, good quantity of vitamins and minerals, the mushrooms also have bioactive compounds like b-glucans, protein-polysaccharide complexes that impart unique medicinal values like anti-cancer and anti-viral properties. With ever increasing demand for quality food, mushroom cultivation is emerging as an important activity in different parts of our country. This activities requires very little land and can be good source of employment for small and lanless farmers, educated youth and women. The two primary inputs for mushroom cultivation i.e. agro-wastes and labour, are easily available in our country. Integrating mushroom cultivation in existing farming systems will supplement the income of rural masses, provide gainful employment and will lead to inclusive growth as all sections of society can adopt this venture. I am sure that the present book will help in disseminating the knowledge about the production technologies, economics, marketing and consumption of different edible mushrooms.

(SHARAD PAWAR)

Foreword

The global food and nutritional security of growing population is a great challenge, which looks for new crop as source of food and nutrition. In this context, mushrooms find a favour which can be grown even by landless people, that too on waste material and could be a source for proteineous food. Use of mushrooms as food and nutraceutical have been known since time immemorial, as is evident from the description in old epics Vedas and Bible. Earlier civilizations had also valued mushrooms for delicacy and therapeutic value. In the present time, it is well recognized that mushroom is not only rich in protein, but also contains vitamins and minerals, whereas, it lacks cholesterol and has low calories. Furthermore, it also has high medicinal attributes like immunomodulating, antiviral, antitumour, antioxidants and hepatoprotective properties.

With the growing awareness for nutritive and quality food by growing health conscious population, the demand for food including mushrooms is quickly rising and will continue to rise with increase in global population which will be 8.3 million by 2025 and expandable income. The mushroom cultivation has grown up in almost all the parts of the world and during last three decades, the world mushroom production achieved the growth rate of about 10%. Globally, China is the leading producer of mushrooms with more than 70% of the total global production, which is attributed to community based farming as well as diversification of mushrooms. In India, owing to varied agro-climate and abundance of farm waste, different types of temperate, tropical and subtropical mushrooms are cultivated throughout the country. It is estimated that India is generating 600 million MT of agricultural waste besides, fruit and vegetable residue, coir dust, husk, dried leaves, prunnings, coffee husk, tea waste which has potential to be recycled as substrate for mushroom production leading to nutritious food as well as organic manure for crops.

Mushroom production being an indoor activity, labour intensive and high profit venture provides ample opportunities for gainful employment of small, farmers, landless labourers, women and unemployed youth. Therefore, promotion of mushroom cultivation shall a step to meet nutritional needs to reduce malnutrition and providing livelihood to landless poor.

I appreciate the efforts of editors in bringing out this valuable publication on "Mushroom cultivation, marketing and consumption" and hope that this book will be of immense use to the growers, students, extension workers and researchers.



(H.P. Singh)

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Preface

Mushrooms are the plant of immortality - that's what ancient Egyptians believed according to the Hieroglyphics of 4600 BC. The delicious flavor of mushrooms intrigued the pharaohs of Egypt so much that they decreed mushrooms as food for royalty. In various other civilizations throughout the world, including Russia, China, Greece, Mexico and Latin America, mushroom rituals were practiced. Many believed that mushrooms had properties that could produce super-human strength; help in finding lost objects and lead the soul to the realm of the gods. The oldest representation, which suggests the possibility that mushrooms may have been used ritualistically are the Tasili Cave paintings in Northern Algeria where zoomorphic figures whose bodies are adorned with drawings of what macroscopically appear to be mushrooms are found. These drawings have been dated from at least 9000 BP.

The Chinese were the first to artificially cultivate the tropical and subtropical mushrooms about thousands year back (*Auricularia polytricha* in 600 AD; *Flammulina velutipes* in 800 AD; and *Lentinula edodes* in 1000 AD) but real commercial ventures started when Europeans started cultivation of button mushroom in caves during 16th and 17th centuries. In the late 19th century, mushroom production made its way across the Atlantic to the United States where curious home gardeners in the East tried their luck at growing this new and unknown crop. The first producer of pure culture virgin spawn was the American Spawn Company of St. Paul Minnesota, headed by Louis F. Lambert, a French mycologist at the beginning of 20th Century. By 1914, mushroom marketing began to play a much greater role in the industry. In the beginning button mushroom dominated the world scenario and even upto 1979 it contributed 70 percent of the world mushroom production. Since then number of other mushrooms have been commercialized and by 1997 the share of button mushroom fell down to 32 percent and mushrooms like shiitake, oyster mushroom, paddy straw mushroom, wood ear mushroom, etc started gaining popularity.

Mushroom cultivation in India is of recent origin and it was in the 1961 when ICAR funded a scheme on button mushroom cultivation technology at Solan which led to the establishment of a UNDP project with FAO experts. The pioneering research work of the HPKVV at their Agriculture College campus at Chambaghat, Solan laid a firm foundation for mushroom research in the country. National Centre for Mushroom Research & Training was established in 1983 at the same place under the aegis of ICAR that was later renamed as National Research Centre in 1997 and upgraded to Directorate of Mushroom Research in December 2008. Number of other institutions and State Agricultural Universities have since undertaken R&D activities in button and various other mushrooms and the mushroom production in the Country has progressed from mere 5000 tons in 1990 to more than 1 lakh ton in 2010.

Diversification in any farming system imparts sustainability. Mushrooms are one such component that not only impart diversification but also help in addressing the problems of quality food, health and environmental related issues. Commercial production of edible mushrooms represents unique exploitation of the microbial technology for the bioconversion of the agricultural, industrial, forestry and household

wastes into nutritious food (mushrooms). Indoor cultivation of mushrooms, utilizing the vertical space, is regarded as the highest protein producer per unit area and time. This hi-tech horticulture venture has a promising scope to meet the food shortages, without undue pressure on land. For the people of a developing country like India, the two main issues are the quality food and unemployment besides the environmental issues and these issues can be resolved by popularizing mushroom cultivation amongst the rural masses and the young generation.

The present book is an effort to pool the information of cultivation, marketing and utilization of commonly grown mushrooms and present in simple form that would serve the requirement of the people who would like to join the field of mushroom cultivation and research. The book encompasses all the aspects of various commercial mushrooms from culture maintenance to processing and marketing. The aspect of diversification in mushroom production, so important for India, has been adequately addressed. Engineering aspects of farm-design, machinery, etc in mushroom production, economics, cooking have also found due importance. The editors are thankful to the authors, who have taken pains in sharing their experiences in the field of mushroom cultivation and hope that the book will be useful to all those who wish to learn, teach and undertake mushroom cultivation, i.e. to the mushroom growers/entrepreneurs, students, trainers, teachers and all those who wish to adopt or integrate mushroom cultivation in the existing farming systems.

Editors

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Mushroom Production: An Agribusiness Activity

Manjit Singh

Indian agriculture will continue to be a main strength of Indian economy. With the variety of agricultural crops grown today, we have achieved food security by producing over 200 million tonnes of food grain. However, our struggle to achieve nutritional security is still on. Though we have significant achievements in milk, vegetables and fruit production still we have to do more. In future, the ever-increasing population, depleting agricultural land, changes in environment, water shortage and need for quality food products at competitive rates are going to be important issues. To meet these challenges and to provide food and nutritional security to our people, it is important to diversify the agricultural activities in areas like horticulture.

Diversification in any farming system imparts sustainability. Mushrooms are one such component that not only impart diversification but also help in addressing the problems of quality food, health and environment related issues. One of the major areas that can contribute towards goal of conservation of natural resources as well as increased productivity is recycling of agro-wastes including agro-industrial waste. Utilising these wastes for growing mushrooms can enhance income and impart higher level of sustainability.

Commercial production of edible mushrooms bioconverts the agricultural, industrial, forestry and household wastes into nutritious food (mushrooms). Indoor cultivation of mushrooms utilizes the vertical space and is regarded as the highest protein producer per unit area and time-almost 100 times more than the conventional agriculture and animal husbandry. This hi-tech horticulture venture has a promising scope to meet the food shortages without undue pressure on land.

Mushroom farming today is being practiced in more than 100 countries and its production is increasing at an annual rate of 6-7%. In some developed countries of Europe and America, mushroom farming has attained the status of a high-tech industry with very high levels of mechanization and automation. Present world production of mushrooms is around 3.5 million tonnes as per FAO Stat and is over 25 million tonnes (estimated) as per claims of Chinese Association of Edible Fungi. The wide variation in world production data in FAO Stat and CAEF is partly due to the fact that in FAO Stat, mushroom means button mushroom (*Agaricus* spp.) along with the boletes, morels and tuber, whereas CAEF data covers all types of mushrooms. China alone is reported to grow more than 20 different types of mushroom at commercial scale and mushroom cultivation has become China's sixth largest industry.

Presently, three geographical regions– Europe, America and East Asia contribute to about 96% of world mushroom production. With the rise in the income level, the demand for mushrooms is bound to increase in other parts of the world as well. China has been producing mushrooms at very low costs with the help of seasonal growing, state subsidies and capturing the potential markets in the world with processed mushrooms at costs not remunerative to the growers in other mushroom producing countries.

In India the mushroom production systems are mixed type i.e. both seasonal farming as well as high-tech industry (Fig. 1.1 and 1.2). Mushroom production in the country started in the 70s but growth rate, both in terms of productivity as well as production has been phenomenal. In seventies and eighties button mushroom was grown as a seasonal crop in hills, but with the development of the technologies for environmental controls and increased understanding of the cropping systems, mushroom production shot up from mere 5000 tonnes in 1990 to over 1,00,000 tonnes in 2010. Today, commercially grown species are button and oyster mushrooms, followed by other tropical mushrooms like paddy straw mushroom, milky mushroom, etc. The concentrated areas of production in India are the temperate regions for the button mushroom, tropical and sub-tropical regions for oyster, milky, paddy straw and other tropical mushrooms. Two to three crops of button mushroom are grown seasonally in temperate regions with minor adjustments of temperature in the growing rooms; while one crop of button mushroom is raised in North Western plains of India seasonally. Oyster, paddy straw and milky mushrooms are grown seasonally in the tropical/sub-tropical areas from April to October. The areas where these mushrooms are popularly grown are Orissa, Maharashtra, Tamil Nadu, Kerala, Andhra Pradesh, Karnataka and North Eastern region of India. Some commercial units are already in operation located in different regions of our country and producing the quality mushrooms for export. The present production of white button mushroom is about 85% of the total production of mushrooms in the country.



Fig. 1.1. A commercial mushroom production unit



Fig. 1.2. Seasonal cultivation of mushroom

India produces about 600 million tonnes of agricultural waste per annum and a major part of it is left out to decompose naturally or burnt *in situ*. This can effectively be utilized to produce highly nutritive food such as mushrooms and spent mushroom substrate can be converted into organic manure/vermi-compost. Mushrooms are grown seasonally as well as in state-of-art environment controlled cropping rooms all the year round in the commercial units. Mushroom growing is a highly labour-oriented venture and labour availability is no constraint in the country and two factors, that is, availabilities of raw

materials and labour make mushroom growing economically profitable in India. Moreover, scope for intense diversification by cultivation of other edible mushrooms like oyster, shiitake, milky and medicinal mushrooms are additional opportunities for Indian growers.

On the export front also, till 1993, Indian contribution to the world trade was almost negligible, but it was heartening to note that for the first time, during 1994, India not only figured in the US imports, but emerged as the second largest exporter of canned mushrooms replacing Taiwan. Now a big Export Oriented Unit (rated as one of the biggest in the world) and few medium size commercial units are exporting mushrooms to the American, European and other countries regularly. Although India is endowed with favorable natural agro-climate and a rich source of agro-wastes that could be exploited for cultivation of diverse mushroom species, yet our country does not have any significant status either as a mushroom producer or as a consumer. The per capita consumption of mushroom in India is a dismal 30-40 g as compared to 2-3 kg in USA and Europe. India itself is a big market and increase of per capita consumption even up to 100 g from present figure will help growers to market over 1.00 lakh ton mushroom within the country. People in India have become health conscious and economic conditions are good enough to permit majority of Indians to consume mushrooms as a regular vegetable on daily basis. Presently fresh/canned mushrooms are available in all major towns/cities.

By just diverting 1% of agro-wastes towards mushroom production, India can produce 3 million tonnes of mushroom and about 15 million tonnes of compost. Being an indoor crop, the commodity provides immense opportunities for empowerment of rural and urban women through cultivation and also the production of value-added products. Mushrooms possess significant health benefits and medicinal properties including anti-cancer effect. India can enter into a big and lucrative international trade in the medicinal mushrooms, presently monopolized by some East Asian countries and America. There is tremendous scope for diversifying mushroom export by including other mushroom species. With the current growth rate of the Indian economy, the domestic market too for the mushrooms is likely to enlarge sooner than later. India

endowed with varied climate and thus has the inherent advantage for the diversification of mushroom in different regions and seasons of the country (Fig. 1.3). Scientific and technical manpower on mushrooms in the country coupled with the skill-upgradation will cater to the technological needs of the industry. Mushroom industry is getting its due support both from the public as well as private funding agencies and is making rapid strides under the Govt.'s policy of liberalization and globalization.

Major issues which are confronting and are likely to continue to do so in foreseeable future are: i) population growth, ii) income growth and iii) urbanization. During the next 18-

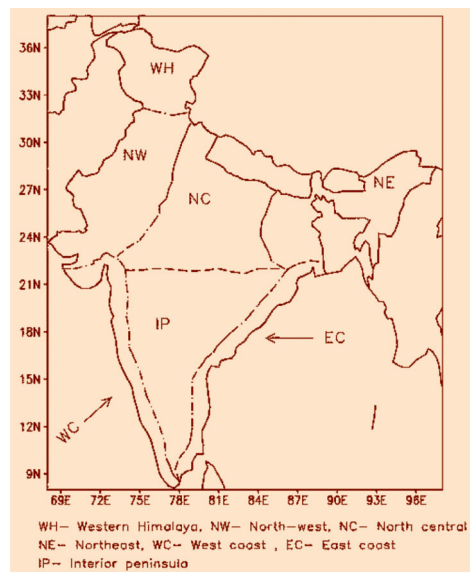


Fig. 1.3. Temperature homogeneous regions of India
(Source: www.tropmet.res.in)

20 years these factors will determine the demand for food in general and mushrooms in particular throughout the world, especially in the developing countries. The rate of population growth is still high in developing countries as compared to developed countries.

Income growth is another factor, which will not only determine the quantity but also the composition of food demand. Currently, the growth in the per capita income of developing countries is a universal phenomenon. This means that there will be increase in food consumption in most developing countries as also there will be shift in diet-pattern: from staple grains to live-stock products and vegetables including mushrooms.

Urbanization will also play a major role in the composition of food demand. In urban areas, the diet mostly comprises of high value cereals, livestock products and vegetables, a large proportion of which is in the processed form. There is a considerable migration towards urban areas in most of the developing countries and it is expected that the urban population may rise from the level of 31% in 2005 to 57% by 2025. In the rural areas of developing world the problems of malnutrition and poverty are alarming. Presently nearly 1.1 billion people live in poverty in the developing countries out of which about 800 million are in Asia.

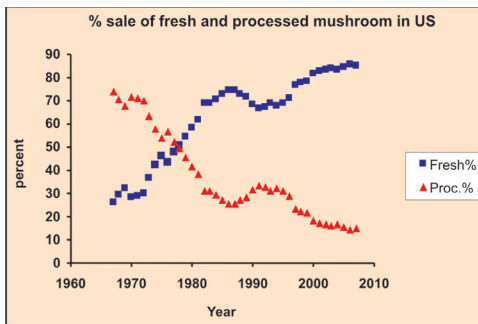


Fig. 1.4. Per cent sale of fresh and processed mushroom in US

It is evident from the above that the yields of major market crops of the world will have to be more than doubled, simply to maintain the current consumption pattern. In case of mushrooms, for which vast markets (like India) still remain to be trapped, the production at global level may have to be more than doubled in the next 18-20 years. Meeting the challenge of producing so much food will exert enormous pressure on the natural resource base.

In spite of predominantly tropical and subtropical climates in India, it is the temperate button mushroom that has ruled and is still dominant in the mushroom scenario of the country. Taking a clue from China, it is the tropical and sub-tropical mushrooms, which should be promoted in a big way, both with the producers and consumers. A beginning has already been made with the popularization of the oyster and milky mushrooms in South India. People do develop the taste as per the available commodity-it is a universal phenomenon. At times, we take the shelter of no demand to justify almost negligible diversification in the mushroom production in India.

However, the challenges and opportunities thrown by this unconventional crop, are a bit different particularly with reference to India. Today India is not only self-sufficient in the production of food grains, but is also in a position to export several agricultural commodities. But mushroom scenario in India is not that rosy. The cultivation of white button mushroom - *Agaricus bisporus* has come a long way of evolution and advancement in technology. Still all stages of evolution of cultivation technology can be seen. There are farmers still growing mushroom on compost prepared by long method and there are commercial units that have shifted to bunkers or almost indoor composting technology.

Even though the consumption of mushrooms has increased, but there is increasing preference for fresh mushrooms. This is evident from the fact that four decades ago three-fourth of the mushrooms consumed in US were in the processed form. In 2008-09 only 15% of the total mushrooms consumed were contributed by processed mushroom (Fig. 1.4). In fact, the consumption of processed mushrooms remain more or less static in the 2four decades and there was about 15 times increase in the consumption of fresh mushrooms.

Regular supply of energy at affordable costs is one of the constraints in commercial production of mushrooms. An important strategy to cut down the energy cost is to diversify and grow different mushrooms as per the natural conditions. No strategy for growing mushrooms can succeed if proper cultural practices are not followed. The three important Hs for mushroom cultivation are: Homogeneity, Hygiene and Humidity. For example in button mushroom homogeneity in wetting of substrate, Phase-I, filling of the tunnels, temperature in different corners of the tunnel, distribution of carbon-dioxide and temperature in cropping rooms is important. The lack of uniformity at any of these steps results in decrease in yield. Hygiene is perhaps the single most important issue to ensure adequate production of quality mushrooms. The disease once appears can be managed only partially and the damage can seldom be restored. It is always proper to follow the dictum of "Prevention is better than cure". Thirdly, management of humidity (and uniformity in humidity over time and space) plays an important role to get good yields and avoid various biotic and abiotic symptoms. Of course, along with humidity other environmental parameters like CO₂ and temperature are very important. There is need to monitor these parameters by making use of IT (agronics) at different steps of pasteurization of substrates and cultivation. The production becomes meaningful when there is increase in consumption/demand. To enhance local consumption there is need for popularising the cooking methods and health benefits of mushrooms.

There have been rapid changes and fluctuations in prices and demand due to global recession. The important lesson to be learnt from this scenario is that it will be appropriate to diversify in terms of different types of mushrooms, the mushroom products as well as the regions for supply of different mushrooms and products. This will provide buffering to counter the ill effects of fluctuations in prices and demand. It is possible to cultivate mushrooms under varied climatic conditions. Some of the important mushrooms for temperate, sub-tropical and tropical conditions are briefly described below:

A. Temperate Mushrooms

1. Button mushroom

The button mushroom is most popular variety both for domestic and export market (Fig. 1.5). At global level it ranks first. The major production is from Hitech Projects. However, Hitech projects faced several problems in successful production resulting in high cost of production. The main problems are quality of raw materials particularly, wheat/paddy straw, chicken manure and some times gypsum resulting



Fig. 1.5. Button mushroom

in poor quality of compost and poor yield. Besides, high cost of imported cultures/spawn, machineries and casing material are other impediments. In recent years even increasing cost of electricity has given severe blow to the mushroom industry. Several medium scale projects have started growing mushroom targeting big city markets utilizing indigenous machinery and equipment. However, during winter season hundreds of seasonal growers undertake button mushroom production particularly in Northern States targeting big cities like Delhi, Chandigarh, etc.

Advantages

There are good opportunities in India both for domestic and export market for button mushroom.

- i. Seasonal production is possible in big way in Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Uttaranchal, Bihar, West Bengal, North Eastern Region, Madhya Pradesh and other areas where temperature remains below 20°C during winter season. In this situation cost of production is low.
- ii. Raw materials are easily and cheaply available for compost and casing material.
- iii. Awareness about food and medicinal values is increasing in the country thus creating better domestic market.
- iv. Transport facilities are available both by land and air.
- v. There is increasing market for postharvest products like pickle and soup powder.

Limitations

- i. High cost of energy for year round production.
- ii. Un-organized production and sale particularly by seasonal farmers.
- iii. Lack of facilities to produce quality compost, casing material, spawn and processed products.

2. Oyster mushroom

This mushroom has species suitable for both temperate and sub-tropical regions (Fig. 1.6). For temperate region *Pleurotus ostreatus*, *P. florida* (winter strain) and *P. fossulatus* (Kabul dhingri), *P. eryngii* (King oyster) are ideal. The areas suitable for button mushroom are equally suitable for the cultivation of these species. Oyster mushroom in dried form can be exported.

Advantages

- i. It grows on wide range of agricultural wastes.
- ii. It can grow in wide range of temperatures.
- iii. Its conversion rate i.e. fresh mushroom production from the dry substrate is high (BE upto 100%).
- iv. It is less prone to diseases and competitor moulds than other mushrooms.
- v. Faster growth rate and easy cropping.
- vi. Low cost of production.



Fig. 1.6. Winter oyster mushroom

- vii. Most suitable for rural areas and can create self employment.
- viii. Easy post harvest processing particularly dehydration/sun drying.

Limitations

- i. Spore allergy to certain people.
- ii. Lack of sporeless commercial strain.
- iii. Limited consumer demand in some parts of the country.

3. Shiitake

This is one of the most popular mushrooms both as food and medicine (Fig. 1.7). At global level it has second position and contributes 24% to total mushroom production. In India, its cultivation is negligible. However, experiments show that this variety can be successfully grown on saw dust when temperature is about 20°C. There is good scope for the cultivation in the country. This may become a popular variety in domestic market and has good potential for export.



Fig. 1.7. Shiitake mushroom



Fig. 1.8. *Flammulina velutipes*

4. *Flammulina velutipes*

Flammulina velutipes, commonly referred as winter mushroom, is popular in East Asian countries and is known for its nutritional and medicinal value (Fig. 1.8). It can be cultivated on saw dust of broad leaves supplemented with 10% wheat bran. This is a temperate mushroom fruiting in the temperature range of 10-14°C. This mushroom can be grown in variety of containers. The complete technology for its cultivation has been standardized at the Directorate.

B. Subtropical Mushrooms

1. Summer white button mushroom

This variety also belongs to genus *Agaricus* - *A.bitorquis*. Since it grows well in temperature upto 24°C it is suitable for cultivation in subtropical region. However it is sensitive to false truffle due to its production at higher temperature and thus the perfect pasteurization of compost and casing material is a must.

2. Oyster mushroom

Most of the oyster mushroom species are subtropical in nature and grow well in temperature range of 20-32°C. The most popular ones are *P. sajor-caju* (Fig. 1.9), *P. florida*, *P. flabellatus*, *P. eous* (Fig. 1.10). These varieties particularly *P. florida* and *P.sajor-caju* are most popular in the country.

Fig. 1.9. *Pleurotus sajor-caju*Fig. 1.10. *Pleurotus eous*

3. Shiitake

There are strains of *Lentinula edodes* which can be grown in temperature range upto 24-25°C. Hence ideal in subtropical areas.

4. Black ear mushroom

This mushroom (*Auricularia* spp.) is fourth most popular mushroom in the world (Fig. 1.11). Unfortunately not a single farm has been noticed growing this mushrooms in India even though cultivation technology for this mushroom was standardized at this Directorate in 1986. At present, this mushroom is collected and consumed in many North East states of our country and thus demand is already there. There is tremendous scope for its cultivation in temperature range of 20-32°C. It needs high RH (90-95%).



Fig. 1.11. Wood ear mushroom

- i. It grows on wide range of temperature and substrates
- ii. High biological efficiency (100-150%)
- iii. Very good keeping quality
- iv. Good for health particularly for stomach and used as medicine in China

5. *Agrocybe aegerita*

Agrocybe aegerita, commonly called as black poplar mushroom, grows on willow wood. Its cultivation on wheat straw has been standardized at the Directorate. It fruits at temperature around 25°C.

C. Tropical Mushrooms

1. Paddy straw mushroom (*Volvariella* spp.)

This variety is most popular for its taste and flavour in South East and far East Asian countries (Fig. 1.12). Its flavour is excellent and cropping cycle is short. However, this variety has low yield and poor keeping quality. In India, its cultivation is restricted to



Fig. 1.12. Paddy straw mushroom



Fig. 1.13. Outdoor cultivation of paddy straw mushroom

Orissa (Fig. 1.13). It can be grown in temperature range of 25-40°C. Pasteurized paddy straw substrate supplemented with cotton seed hulls gives better productivity.

2. Milky mushroom (*Calocybe indica*)

This is indigenous tropical mushroom most suitable for tropical regions (Fig. 1.14). At present this variety is being commercially cultivated in South India (Tamil Nadu, A.P. and Karnataka) (Fig. 1.15). Recently its production has started in North India.

- i. It can be grown on wide range of agricultural wastes.
- ii. It grows on higher temperature range hence suitable for tropical region.
- iii. Attractive white mushroom with excellent keeping quality.
- iv. Its conversion rate (BE) is very high (about 100%).
- v. It is suitable for pickling and chutney.



Fig. 1.14. Milky mushroom



Fig. 1.15. Low cost structure for milky mushroom

3. Reishi mushroom (*Ganoderma lucidum*)

This is also a tropical mushroom growing in temperature range of 30-35°C with high humid climate (Fig. 1.16). The world production is estimated to be 6000 tonnes and share of China is 4000 tonnes/annum. Its cultivation technology has been standardized at the Directorate. There is good scope of this mushroom both in domestic and export market. Caution, however, is required in disposal of spent substrate as the fungus is a phytoparasite. It may be ensured that filters are in place in cropping rooms and substrate is disposed after heat kill or is burnt after drying.



Fig. 1.16. Reishi mushroom

D. Future Prospects

India has tremendous potential for mushroom production and all commercial edible and medicinal mushrooms can be grown. There is increasing demand for quality products at competitive rate both in domestic and export market. Though growth of mushroom will depend on increasing and widening domestic market in coming years, export market will be equally attractive. To be successful in both domestic and export market it is essential to produce quality fresh

mushrooms and processed products devoid of pesticide residues and at competitive rate. It is also important to commercially utilise the compost left after cultivation for making manure, vermi compost, briquettes, etc. for additional income and total recycling of agro-wastes.

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Nutritional and Medicinal Values of Mushrooms

K. Manikandan

Meeting the food demand for the increasing population from the limited land resource is a big challenge for our Indian democracy in this vulnerable climate change era. In addition to this, wide spread malnutrition and associated diseases are more common among the economically poor population. This compels us to search for cheap alternative quality nutritional sources for our huge population. Non green revolution otherwise referred as mushroom farming is one among the apt ways to meet this challenge because mushrooms grow on wastes without requiring additional land besides its exceptional nutritional and medicinal properties.

A. Nutritional Values of Mushrooms

Indian diet is primarily based on cereals (wheat, rice and maize), which is deficient in protein. Supplementation of mushroom recipe in Indian diet will bridge protein gap and improve the general health of socio-economically backward communities. Earlier mushrooms were considered as an expensive vegetable and were preferred by affluent peoples for culinary purposes. Currently common populace also considers mushroom as a quality food due to its health benefits.

Mushroom is considered to be a complete, health food and suitable for all age groups, child to aged people. The nutritional value of mushroom is affected by numerous factors such as species, stage of development and environmental conditions. Mushrooms are rich in protein, dietary fiber, vitamins and minerals. The digestible carbohydrate profile of mushroom includes starches, pentoses, hexoses, disaccharides, amino sugars, sugar alcohols and sugar acids. The total carbohydrate content in mushroom varied from 26-82% on dry weight basis in different mushrooms. The crude fibre composition of the mushroom consists of partially digestible polysaccharides and chitin.

Edible mushrooms commonly have insignificant lipid level with higher proportion of polyunsaturated fatty acids. All these result in low calorific yield from mushroom foods. Mushrooms do not have cholesterol. Instead, they have ergosterol that acts as a precursor for Vitamin D synthesis in human body. Similarly, ergosterol in button mushroom is converted in to vitamin D₂ when exposed to UV radiation or sunlight. The protein content of edible mushrooms is usually high, but varies greatly. The crude protein content of mushrooms varied from 12-35% depending upon the species. The free amino acids composition differs widely but in general they are rich in threonine and valine but deficient in sulphur containing aminoacids (ethionine and cysteine). Nutritive values of different mushroom are given in Table 2.1.

Table 2.1. Nutritive values of different mushrooms (dry weight basis g/100g)

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

Courtesy: Stamets, 2005 (*A.bisporous*, *P. sajor-caju*, *Lentinula edodes*), FAO, 1972 (*Pleurotus ostreatus*, *V. volvaceae*), Doshi and Sharma, 1995 (*Calocybe indica*), Crison and Sand, 1978 (*Flammulina velutipes* and *Auricularia spp*).

Mushrooms comprise about 80-90% of water, and 8-10% of fiber. In addition to these, mushroom is an excellent source of vitamins especially C and B (Folic acid, Thiamine, Riboflavin and Niacin). Minerals viz., potassium, sodium and phosphorous are higher in fruit bodies of the mushroom. It also contains other essential minerals (Cu, Zn, Mg) in traces but deficient in iron and calcium.

B. Medicinal Values

Since thousands of years, edible fungi have been revered for their immense health benefits and extensively used in folk medicine. Specific biochemical compounds in mushrooms are responsible for improving human health in many ways. These bioactive compounds include polysaccharides, tri-terpenoids, low molecular weight proteins, glycoproteins and immunomodulating compounds. Hence mushrooms have been shown to promote immune function; boost health; lower the risk of cancer; inhibit tumor growth; help balancing blood sugar; ward off viruses, bacteria, and fungi; reduce inflammation; and support the body's detoxification mechanisms. Increasing recognition of mushrooms in complementing conventional medicines is also well known for fighting many diseases. Medicinal values of the some important mushroom are given in Table 2.2.

1. Good for heart

The edible mushrooms have little fat with higher proportion of unsaturated fatty acids and absence of cholesterol and consequently it is the relevant choice for heart patients and treating cardiovascular diseases. Minimal sodium with rich potassium in mushroom enhances salt balance and maintaining blood circulation in human being. Hence, mushrooms are suitable for people suffering from high blood pressure. Regular consumption of mushrooms like *Lentinula*, *Pleurotus* spp. decreases cholesterol levels. The lovastatin obtained from *Pleurotus ostreatus* and eritadenine obtained from shiitake has the ability to reduce blood cholesterol levels.

2. Low calorie food

The diabetic patients choose mushroom as an ideal food due to its low calorific value, no starch, little fat and sugars. The lean proteins present in mushrooms help to

Table 2.2. Medicinal values of some important mushrooms

Mushroom	Compounds	Medicinal properties	Courtesy
<i>Ganoderma lucidum</i>	Ganoderic acid Beta-glucan	Augments immune system Liver protection Antibiotic properties Inhibits cholesterol synthesis	Lin and Zhang, 2004 Wang et al., 2007 Moradali et al., 2006 Komoda et al., 1989
<i>Lentinula edodes</i>	Eritadenine Lentinan	Lower cholesterol Anti-cancer agent	Enman et al., 2007
<i>A. bisporous</i>	Lectins	Enhance insulin secretion	Ahmad, 1984
<i>P. sajor-caju</i>	Lovastatin	Lower cholesterol	Gunde and Cimerman, 1995
<i>G. frondosa</i>	Polysaccharide Lectins	Increases insulin secretion Decrease blood glucose	Horio and Ohtsuru, 2001
<i>Auricularia auricula</i>	Acidic polysaccharides	Decrease blood glucose	Yuan et al., 1998
<i>Flammulina velutipes</i>	Ergothioneine Proflamin	Antioxidant Anti cancer activity	Bao, 2008, Ikekawa et al., 1985
<i>Trametes versicolor</i>	Polysaccharide-K (Kresin)	Decrease immune system depression	Coles and Toth, 2005
<i>Cordyceps sinensis</i>	Cordycepin	Cure lung infections Hypoglycemic activity Cellular health properties Anti-depressant activity	Li et al., 2006 Ko et al., 2009 Nishizawa et al., 2007

burn cholesterol in the body. Thus it is most preferable food for people striving to shed their extra weight.

3. Prevents cancer

Compounds restricting tumor activities are found in some mushrooms but only a limited number have undergone clinical trials. All forms of edible mushrooms, and white button mushrooms in particular, can prevent prostate and breast cancer. Fresh mushrooms are capable of arresting the action of 5-alpha-reductase and aromatase, chemicals responsible for growth of cancerous tumors. The drug known as Polysaccharide-K (Kresin), is isolated from *Trametes versicolor* (*Coriolus versicolor*), which is used as a leading cancer drug. Some mushroom-derived polysaccharides have ability to reduce the side effects of radiotherapy and chemotherapy too. Such effects have been clinically validated in mushrooms like *Lentinula edodes*, *Trametes versicolor*, *Agaricus bisporus* and others. Selenium in the form of selenoproteins found in mushrooms has anticancer properties. According to the International Copper Association, the mushroom's high copper levels help to reduce colon cancer besides osteoporosis.

4. Anti-aging property

The polysaccharides from mushrooms are potent scavengers of super oxide free radicals. These antioxidants prevent the action of free radicals in the body, consequently reducing the aging process. Ergothioneine is a specific antioxidant found in *Flammulina velutipes* and *Agaricus bisporus* which is necessary for healthy eyes, kidney, bone marrow, liver and skin.

5. *Regulates digestive system*

The fermentable fiber as well as oligosaccharide from mushrooms acts as a prebiotics in intestine and therefore they anchor useful bacteria in the colon. This dietary fibre assists the digestion process and healthy functioning of bowel system.

6. *Strengthens immunity*

Mushrooms are capable of strengthening the immune system. A diverse collection of polysaccharides (beta-glucans) and minerals, isolated from mushroom is responsible for up-regulating the immune system. These compounds potentiate the host's innate (non-specific) and acquired (specific) immune responses and activate all kinds of immune cells.

Mushrooms, akin to plants, have a great potential for the production of quality food. These are the source of bioactive metabolites and are a prolific resource for drugs. Knowledge advancement in biochemistry, biotechnology and molecular biology boosts application of mushrooms in medical sciences. From a holistic consideration, the edible mushrooms and its by-products may offer highly palatable, nutritious and healthy food besides its pharmacological benefits.

Still there are enough challenges ahead. Until now, how these products work is elusive and vast number of potential wild mushrooms are not explored. The utility of mycelia is paid little attention but it has tremendous potential, as it can be produced year around with defined standards. Knowledge on dose requirement, route and timing of administration, mechanism of action and site of activity is also lacking. Work is under progress in various laboratories across the world to validate these medicinal properties and to isolate new compounds. If these challenges are met out in the coming days, mushroom industries will play a lead role in nutraceutical and pharmaceutical industries. The increasing awareness about high nutritional value accompanied by medicinal properties means that mushrooms are going to be important food item in coming days and at places may emerge as a substitute to non-vegetarian foods. Growing mushroom is economically and ecologically beneficial. Consuming mushroom is beneficial in every respect. Thus mushrooms are truly health food, a promising nutraceutical.

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Production and Marketing of Mushrooms: Global and National Scenario

G.C. Wakchaure

Marketing is getting the right product, to the right people, at the right price, at the right time and in the right way. Marketing of fresh mushrooms all over the world is not very organised except the auction system in Netherlands. Producers make direct efforts to bring the produce to the super markets and 'wholesale distributor' element is mostly missing. However, trade in the processed (canned and dried) is sizeable and organised.

A. Global Scenario

About the mushroom marketing, Stan Hughes said “Mushroom growers have mystified me for years. They put so much effort into growing and so little into selling”. For effective and efficient marketing, especially export, it is necessary to understand the global trade vis-à-vis the sources of supply, potential regions of demand and consumption patterns. The global mushroom production as per FAO Statistics was estimated at about 2.18 to 3.41 million tons over period of last ten years (1997-2007). Mushrooms in FAO database have been classified as FAOStat code 0449 and have been defined as those inter alia: *Boletus edulis*; *Agaricus campestris*, *Morchella spp.* and *Tuber magatum*. Since there was an increase of about 56% world mushroom production in last decades and guesstimates can be put on current production to be around 3.5 million tons. China, USA, Netherlands, Poland, Spain, France, Italy, Ireland, Canada and UK are the leading producers (Table 3.1).

Table 3.1. World production of mushrooms (metric tons)

Countries	1997	2007
China	5,62,194	15,68,523
United States of America	3,66,810	3,59,630
Netherlands	2,40,000	2,40,000
Poland	1,00,000	1,60,000
Spain	81,304	1,40,000
France	1,73,000	1,25,000
Italy	57,646	85,900
Ireland	57,800	75,000
Canada	68,020	73,257
United Kingdom	1,07,359	72,000
Japan	74,782	67,000

Countries	1997	2007
Germany	60,000	55,000
Indonesia	19,000	48,247
India	9,000	48,000
Belgium	NA	43,000
Australia	35,485	42,739
Korea	13,181	28,764
Iran	10,000	28,000
Hungary	13,559	21,200
Viet Nam	10,000	18,000
Denmark	8,766	11,000
Thailand	9,000	10,000
Israel	1,260	9,500
South Africa	7,406	9,395
New Zealand	7,500	8,500
Switzerland	7,239	7,440
Other countries	85911	59297
Total World Production	21,86,222	34,14,392

Source: Table 50, World mushroom & truffles: Production, 1961-2007; United Nations, FAO, FAOStat (8/28/2009)

The three major mushroom producing countries as FAO data viz., China, USA, and Netherlands account for more than 60% of the world production; however share of China itself is 46% which is about half of the world mushroom production (Fig. 3.1). According to current Indian estimates, mushroom production of India is about 1 lakh metric tons, which is about 3% of the world mushroom production.

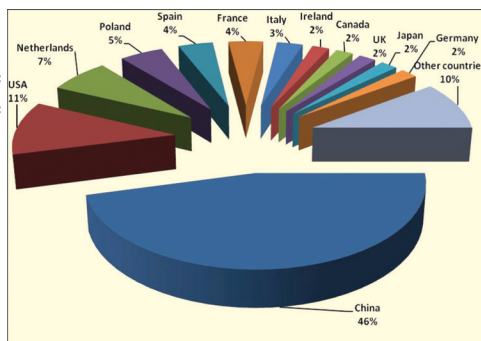


Fig. 3.1. World mushroom production in per cent (countries wise), 2007

Source: Table 50, World mushroom & truffles: Production, 1961-2007; United Nations, FAO, FAO Stat (8/28/2009)

In USA and Europe major contribution towards mushroom production is by white button mushroom. In Asian countries the scenario is different and other species are also cultivated for commercial production.

Data by Chinese Association of Edible Fungi possibly includes all these mushrooms. Consequently the mushroom production figures quoted by Chinese are at much higher scale. The gap between FAOStat and Chinese Association of Edible Fungi data is enormous. This does bring out the contribution of other edible mushrooms/ medicinal mushrooms, even if the figures may seem exaggerated (Table 3.2). The mushroom export in China accounts for less than 5% of its total domestic production and about half of it is to Asian Countries.

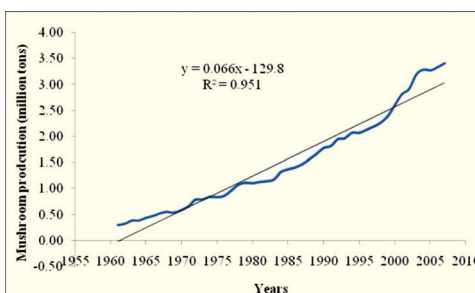
Table 3.2. Mushroom production in China and in the World (metric tons)

Year	World	China	China/World (%)
1978	1,060	60	5.7
1986	2,176	585	26.9
1990	3,763	1,000	26.6
1994	4,909	2,640	53.8
1997	6,158	3,415	55.5
2000	-	6,630	-
2002	12,250	8,650	70.6
2006	-	14,000	-
2008	26,000*	18,200	70.0

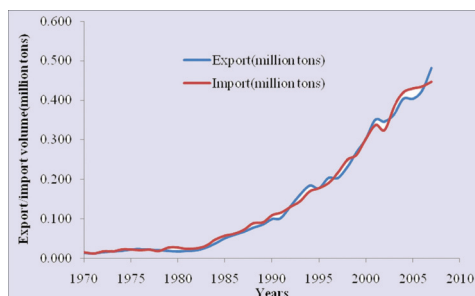
Source: Table 1. Mushroom Production in China and World (Chinese Association of Edible Fungi), Mushroom Economics in China, Mushroom Business Information Centre- Mushroom Business (1/5/2010); *Qi Tan and Hui Cao. 2010.

Considering that 95% of mushroom production in China is consumed locally, the consumption per capita is likely to be over 10 kg/person/year. This is drastically higher than in US and many European countries where it is around 3 kg/person/year. In India the consumption is miserably low. Considering that we produce over 1 lakh tons and export about 60-70% of it, our per capita consumption is around 30-40 g/person/year.

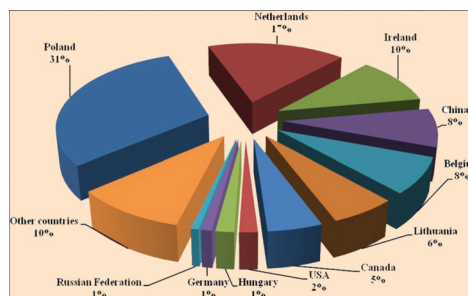
World mushroom production (FAOStat) is continuously increasing from 0.30 to 3.41 million tons over period of about last 50 years from 1961 to 2010 (Fig. 3.2). Also the export and import trend lines shows that the mushroom export/import has continuously increased in last 40 years, but marginally upto 1985 and beyond it there is tremendous increase in mushroom export/import upto 2010 (Fig. 3.3). Poland, Netherlands, Ireland, China, Belgium, Lithuania, Canada and USA are the major mushroom exporting countries while countries like UK, Germany, France,

**Fig. 3.2.** General trend of world mushroom production (million tons)

Source: Table 50, World mushroom & truffles: Production, 1961-2007; United Nations, FAO, FAO Stat (8/28/2009)

**Fig. 3.3.** World mushroom export and import (million tons)

Source: Table 51a-World mushrooms and truffles: Export volume, 1970-2007, Table 54a-World mushrooms and truffles: Import volume, 1970-2007, United Nations, Food and Agriculture Organization, FAOStat (08/31/2009)

**Fig. 3.4.** Major leading exporters of mushrooms

Source: Table 51a-World mushrooms and truffles: Export volume, 1970-2007, United Nations, Food and Agriculture Organization, FAOStat (08/31/2009)

Netherland, Belgium, Russian Federation and Japan import the mushroom from above said exporting countries (Fig. 3.4).

World processed (canned and dried) mushroom export is continuously increasing from 0.049 to 0.683 million tons over the period of last four decades (1970-2010) as compared to the fresh mushroom export (0.014 to 0.482 million tons) but fluctuations in export is higher in case of the processed mushroom (Fig. 3.5). In USA, five decades ago, 75% of the mushroom consumption was in the form of canned mushroom. Today, canned mushroom contributes only 15% of total mushroom consumption. As can be seen in Fig. 3.6, the consumption of canned mushroom is static and that of fresh mushroom has increased continuously. This clearly shows that consumer's interest is shifting towards fresh mushroom consumption.

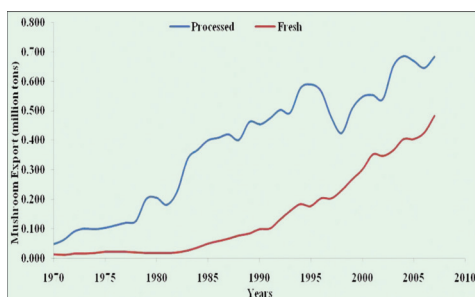


Fig. 3.5. World processed (canned and dried) and fresh mushroom export

Source: Table 52a-World mushrooms: Canned export volume, 1970-2007, Table 53a-World mushrooms: Dried export volume, 1970-2007, Table 51a-World mushrooms and truffles: Export volume, 1970-2007, United Nations, Food and Agriculture Organization, FAOStat (08/31/2009)

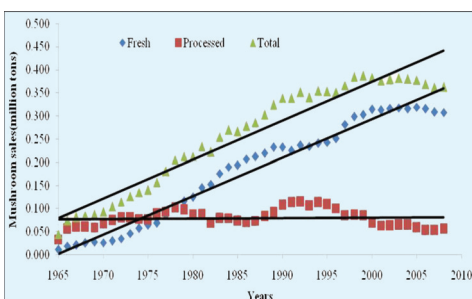


Fig. 3.6. Fresh and processed *Agaricus* mushroom sale in US

Source: Table 6-Agaricus mushrooms: Production by type of sale, 1965/66-2008/09; USDA, National Agricultural Statistics Service, Mushrooms

Largest importer of preserved mushrooms (canned) is Germany with about 1,05,186 tons in 2007 (FAO) followed by Russian Federation (69,726 metric tons), USA (67,058 metric tons) and Japan (32,757 metric tons). Most of these supplies are made by China (4,05,112 metric tons), Netherland (1,15,349 metric tons), Spain (20,623 metric tons), France (18,496 metric tons) and Indonesia (18,392 metric tons).

China is the largest producer and consumer of mushrooms in the world (15,68,523 metric tons production + 17,732 metric tons imports) followed by USA (3, 59,630 metric tons production + 68,123 metric tons imports) and Netherland (2,40,000 metric tons production + 7,884 metric tons imports) respectively.

Trade of mushrooms in European Union is significant and is reflected in Table 3.3. The European Union mushroom production is about 27% of the world production (2007, FAO). Netherlands is the largest producer and consumer, Poland is largest exporter, UK largest importer, France and Spain are also the larger producers as well as consumers. From outside, China is largest exporter of processed mushroom. Per capita consumption is very high (about 3.5 kg) in these countries (Table 3.4). Highest per capita consumption of mushroom is in Netherland (11.62 kg) followed by Ireland (6.10 kg) and Belgium (4.46 kg). Per capita consumption of mushroom in India has increased from 25 g to 40 g in last 10 years (1996-2007). However as per Indian estimates per capita consumption in India

Table 3.3. Mushroom trade in European Union (2007)

County	Production (metric tons)	Export (metric tons)	Import (metric tons)	Consumption (metric tons)
UK	72,000	384	99,552	1,71,168
Belgium	43,000	36,918	33,876	39,958
Netherlands	2,40,000	83,592	34,161	1,90,569
Germany	55,000	4,553	54,168	1,04,615
Italy	85,900	3,135	9,835	92,600
France	1,25,000	3,013	37,158	1,59,145
Spain	1,40,000	848	1,688	1,40,840
Poland	1,60,000	1,47,817	1,213	13,396

Source: Table 50-World mushroom and truffles: Production, 1961-2007, Table 51a-World mushrooms and truffles: Export volume, 1970-2007, Table 54a-World mushrooms and truffles: Import volume, 1970-2007, United Nations, Food and Agriculture Organization, FAOStat (08/31/2009).

Table 3.4. Per capita consumption of mushrooms (kg)

Country	1996		2007	
	Total	Fresh	Canned	Total
European Union				
UK	3.35	2.81	0.20	3.01
Belgium	3.90	3.77	0.69	4.46
Netherlands	2.80	11.62	0.00	11.62
Germany	3.83	1.27	1.20	2.47
Italy	2.60	1.56	0.06	1.62
France	3.03	2.58	0.14	2.72
Spain		3.11	0.00	3.11
Denmark	2.90	3.22	0.66	3.89
Ireland	-	6.05	0.05	6.10
Poland	-	0.35	0.00	0.35
USA	-	1.27	0.22	1.49
Canada	-	1.71	0.59	2.30
Japan	-	0.60	0.26	0.86
China	-	1.16	0.00	1.16
India	0.03	0.04	0.00	0.04

Source: 2007 World population data sheet, Population Reference Bureau, 1975 Connecticut Ave., NW, Washington, DC-20009, USA; Table 50-World mushroom and truffles: Production, 1961-2007, Table 51a-World mushrooms and truffles: Export volume, 1970-2007, Table 52a- World mushroom: Canned export volume, 1970-2007, Table 54a-World mushrooms and truffles: Import volume, 1970-2007, Table 55a-World canned mushroom import volume, 1975-2007, United Nations, Food and Agriculture Organization, FAOStat (08/31/2009).

is about 90 g, which very less compared to other countries including USA (1.49 kg) and China (1.16 kg).

It is clear from the above that European Union and USA are the biggest markets and Poland and China are the biggest competitors, for mushrooms from India.

B. National Scenario

There is no denying the fact that production of mushrooms, especially of the white button mushroom, in India has gone up in the last few years (Fig. 3.7) but it has also exacerbated its marketing problems. There have been frequent reports of gluts in north Indian States during the winter months forcing the distress sale of the mushrooms. It should be borne in mind that efforts to increase the production without solving its marketing problems, would be counter-productive. The marketing of fresh mushrooms would determine the future of mushroom industry in India. The appropriate production based on the information prescribed by State Department of Agriculture/Horticulture or as reported in websites of commercial units are as given in Table 3.5.

Table 3.5. Present state-wise mushroom production in India (tons) (2010)

Sr. No.	State	Button	Oyster	Milky	Other Mushroom	Total production
1.	Andhra Pradesh	2,992	15	15	0	3,022
2.	Arunachal Pradesh	20	5	0	1	26
3.	Assam	20	100	5	0	125
4.	Bihar	400	80	0	0	480
5.	Chattisgarh	0	50	0	0	50
6.	Goa	500	20	0	0	520
7.	Gujarat	0	5	0	0	5
8.	Haryana	7,175	0	3	0	7,178
9.	Himachal Pradesh	5,864	110	17	2	5,993
10.	J&K	565	15	0	0	580
11.	Jharkhand	200	20	0	0	220
12.	Karnataka	0	15	10	0	25
13.	Kerala	0	500	300	0	800
14.	Maharashtra	2,725	200	50	0	2,975
15.	Madhya Pradesh	10	5	0	0	15
16.	Manipur	0	10	0	50	60
17.	Meghalaya	25	2	0	0	27
18.	Mizoram	0	50	0	0	50
19.	Nagaland	0	75	0	250	325
20.	Orissa	36	810	0	5,000	5,846
21.	Punjab	58,000	2,000	0	0	60,000
22.	Rajasthan	100	10	0	10	120
23.	Sikkim	1	2	0	0	3
24.	Tamil Nadu	4,000	2,000	500	0	6,500
25.	Tripura	0	100	0	0	100
26.	Uttarakhand	8,000	0	0	0	8,000
27.	Uttar Pradesh	7,000	0	0	0	7,000
28.	West Bengal	50	50	0	0	100
Union Territories						
1.	A&N Islands	0	100	0	0	100
2.	Chandigarh	0	0	0	0	0
3.	Dadar & Nagar Haveli	0	0	0	0	0
4.	Daman & Diu	0	0	0	0	0
5.	Delhi	3,000	50	20	0	3,070
6.	Lakshadweep	0	0	0	0	0
7.	Puducherry	0	0	0	0	0
Total		1,00,683	6,399	920	5,313	1,13,315

Source: RMCU, DMR, Solan, 2010

Despite the changing currents, there is not yet much market for the processed foods and basically fresh vegetables and fruits are preferred in this country. Fresh mushrooms have very short shelf-life, cannot be transported to long distances without refrigerated transport facility and are sold in localised markets in and around production areas. The cultivation of white button mushrooms throughout the year under controlled condition is restricted to few commercial units and 30-40% of the production is being done under natural conditions during the winters. All the problems of marketing is experienced in 2-3 winter months (Dec-Feb) when more than 75% of the annual production comes in market for sale in limited duration and market area. Farmers face the consequences of over-saturated market and are forced to sell their produce at highly unremunerative prices. Private processors, rather than coming for rescue, get tempted to avail of the situation for their benefit.

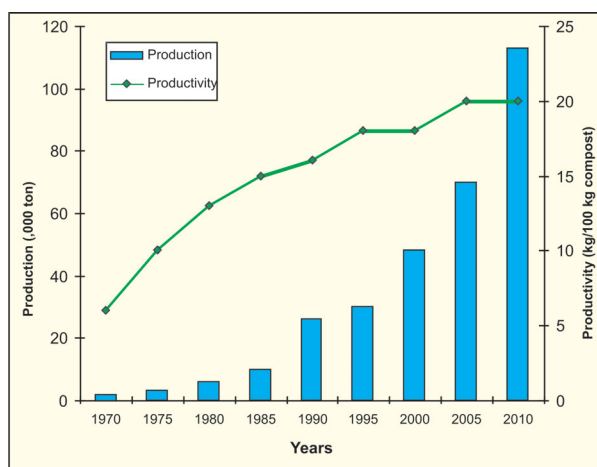


Fig. 3.7. Mushroom production and productivity in India

Marketing of mushrooms in India is not yet organised. It is the simple system of producers selling directly to retailer or even to consumer, which has its own limitations. Unlike the other countries where 10% of the total cost is earmarked for marketing, we have not given marketing sufficient thought and investment. Per capita consumption of mushrooms in India is less than 50 g as against over a kg in various countries. There has not been any serious effort to promote the product, to strengthen and expand the market in order to increase its consumption. Mushroom is a novel food item for this country and what to ask of its flavour, texture, nutritive value, many are not aware of 'what is mushroom and whether vegetarian or non-vegetarian item?'

In the coming years, there is going to be good demand for processed and fast foods. Mushrooms may be canned to meet the demand in the off-season and in the non-producing areas. Product diversification should also be tried. Regarding the problems of sale/export of canned mushrooms, serious thought has to be given to bring down the cost of production of mushrooms and its processing in order to compete in the international market.

There is not much problem in the sale of fresh *Pleurotus* due to very low production but there have been problems in selling dried 'Dhingri' particularly its export where middlemen take lion's share. Generally, the export orders are too big to be met by a single grower. *Pleurotus* growers may form a cooperative where they may pool their product and trade. APIDA and other Central as well as State agencies would be too willing to help them once they are assured of sufficient consignment for export, for 2-3 years.

Some of the suggestions to solve the marketing problems of mushrooms especially of white button mushrooms in India are given below:

1. Expand the market area and strengthen the demand:
 - a. Popularize mushrooms using ICT as delicacy with nutritive and medicinal value, on mass media like Doordarshan, also ads. and posters.
 - b. Break consumer resistance by creating awareness in new areas. Demonstration of recipes and free samples in new areas. Free recipe booklet.
2. Form cooperatives for sale:
 - a. Create cold storage facility
 - b. Create refrigerated transport facility
 - c. Create processing facility
 - d. Create distributor function for big cities.
3. Decrease the cost of production and bring down the sale price to boost the demand.
4. Good prepacks for eye appeal.
5. Train retailers about handling, storage, food value and recipes.
6. Approach supermarkets, chain vegetable stores, mother dairy retail counters for retail sale.
7. States should fix minimum support price.
8. Public sector marketing, processing and export organisations should come forward.
9. Assured supply throughout the year at a reasonable constant price is key to good marketing. Efforts should be made to diversify and cultivate different mushrooms throughout the year along with cultivating some of the important mushroom during off-season under controlled condition.
10. In a limited area, say a village or a cooperative, the crops should be time-scheduled to get a daily reasonably uniform production to avoid glut on a day, this is required to meet the commensurate demand. One cannot ask consumer to purchase more because all have got a peak flush during a week. The marketing system has to be viewed as a value chain where all components are taken care of. The increased production should get translated into economic gain for mushroom producers. This is possible only when marketing is organised and demand is ensured. Considering that awareness about consumption and health benefits of mushrooms is limited, their demand is also less. Hence, multipronged strategy is required that means needs to Expand market, Increase demand, Organise marketing and Form cooperatives.

Further Readings

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3. <http://www.mushroombusiness.com>
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Mushroom Culture Preparation and Preservation Techniques

R.C. Upadhyay

Successful mushroom production depends upon proper maintenance of pure culture and spawn capable of providing higher yield of quality mushrooms. Maintenance of vigour and genetic characteristics of a pure strain in form of culture is the main objective of strain preservation. The isolation, purification and maintenance of mushroom cultures require technical expertise and aseptic laboratory facilities. Therefore, most of the small mushroom growers rely entirely on commercial spawn producers, governmental or non-governmental organizations that play a vital role in supplying reliable spawn of the desired mushroom strain or variety.

There are various methods of maintenance and preservation of mushroom culture and a good culture collection centre adopt more than one method to preserve them. Since there is no satisfactory method to check and evaluate the quality of spawn by rapid on-the-spot examination, an appropriate method of preserving selected strains is of primary importance. It is important to understand that under certain conditions strains tend to degenerate as indicated by change in their growth pattern and decline in yields. Hence proper maintenance on different media and evaluation is a continuous process.

In laboratory, the edible mushroom strains are cultured on various culture media like Potato Dextrose Agar (Peeled potato 200 g, Dextrose 20 g, Agar agar 20 g, Distilled water 1 lit.), Oat meal agar (Oat meal flakes 30 g, Agar agar 20 g, Distilled water 1 lit.), compost agar (Pasteurized and conditioned compost 150 g, Agar agar powder 20 g, Distilled water 1 lit.), wheat extract agar (wheat grain 32 g, Agar agar powder 20 g, Distilled water 1 lit.), and rice bran decoction medium (Rice bran 200 g, Agar agar 20 g, Distilled water 1



Fig. 4.1. Culture media

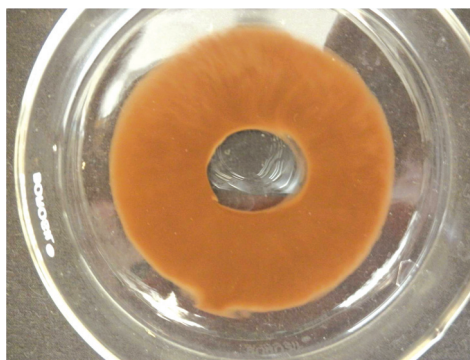


Fig. 4.2. Spore print

lit.) (Fig. 4.1). Wheat grain and compost extract are most suitable culture media for maintaining *A.bisporus* and *A.bitorquis* cultures. Cultures of *Volvariella* spp. and *Pleurotus* spp. can be maintained on PDA or Malt extract agar medium. It is desirable that cultures are not maintained on the same type of culture medium in each subculturing. Fresh and healthy mushroom fruit body (basidiocarp) showing all the desirable attributes of that species/strain or their spores (Fig. 4.2) are used to raise mycelial cultures by the scientists using following methods:

A. Culture Isolation

1. Vegetative mycelium culture (tissue culture)

Under aseptic conditions using laminar flow, young basidiocarp is cleaned with sterilized distilled water and dipped into 0.1% mercuric chloride or 2.5% sodium hypochlorite solution for 1 min. In case of button mushroom, the basidiocarp is air dried and split open longitudinally from centre and vegetative mycelial bits are cut from the collar region (junction of pileus and stipe). Whereas, in black ear mushroom, the ear is cut along the edge with a sterilized scissor and inner tissues are scrapped and small bits of tissues are taken. These bits are then washed in sterilized water to remove $HgCl_2$ and placed in oven sterilized petriplates having culture media. Inoculated plates are incubated at $25^\circ \pm 2^\circ C$ in a BOD incubator. In general, tissue from inside the fruiting body of mushroom is taken from the region of active growth.

Within 4-5 days the new mycelium growing over the media is observed. The pure cultures are made by carefully transferring young mycelium from growing edge of the colony from petriplate to test tubes and again incubating at $25^\circ \pm 2^\circ C$ for 10-14 days ($35^\circ C$ for *Volvariella* spp.) (Fig. 4.3 and Fig. 4.4).



Fig. 4.3. Tissue culture



Fig. 4.4. Inoculation of tissue culture in tube

2. Multisporous culture

Under aseptic conditions, spore mass is scraped from a fresh spore print or basidiocarp and suspended in 100 ml of sterilized distilled water in flasks and shaken to obtain uniform spore suspension. A few drops of this suspension is added to lukewarm culture medium and poured into oven sterilized petriplates. Petriplates are rotated to homogenize the spore suspension into culture medium. The culture medium is allowed to solidify and then petriplates are incubated at $25^\circ \pm 2^\circ C$ for 3-4 days ($35^\circ C$ for *Volvariella volvacea*). The spore germination is observed under microscope and germinating spores are transferred carefully to culture tubes along with a piece of agar containing a culture medium recommended for the mushroom species isolated. The culture tubes are then incubated at $25^\circ C$ for 10-14 days in case of *Agaricus bisporus* and *A.bitorquis* and at $32^\circ C$ for *Volvariella volvacea* for 7 to 10 days (Fig. 4.2).

3. Single spore culture

A. bitorquis and *Pleurotus* spp. are heterothallic with tetraspored basidia, therefore, single spores are self-sterile and this technique is used for breeding new strains. *A. bisporus* being secondary homothallic with bispored basidia and majority of its spores being self fertile the spores can be used to raise fertile cultures also. Single spore cultures are procured in the same way as that in multispore cultures. Nevertheless, for single spore culture isolation, the spore suspension is serially diluted to obtain 10-12 spores/petriplate. Individual germinating spore is marked and lifted under aseptic conditions, transferred to culture tubes and incubated at 25°C for 10-14 days. After pure mycelial cultures are obtained, variety of methods are available for the conservation of mushroom cultures suitable for a particular need e.g., preservation for a relatively shorter period, or for a longer period. The choice of preservation method depends upon many factors but the availability of necessary equipments and funds is commonly a determining factor in such decision. The commercial mushroom growers who produce their own spawn normally procure high yielding strains and work related to strain isolation and development is left to scientists in government or private sector.

B. Culture Maintenance and Storage

1. Frequent subculturing

Under recommended temperature and pH conditions, most mushroom mycelium continues to grow till the nutrients of a suitable culture medium are exhausted. Therefore, these cultures remain viable only for few months depending upon the growth rate, substrate, method of storage, etc. Using a system of periodic transfer at reasonable intervals, stock cultures are often maintained in an actively growing state. After obtaining optimum mycelial growth, mushroom cultures are stored until sub-culturing is necessary. For storage purposes, cultures are prepared on agar slants in culture bottles and /or test tubes (Fig. 4.5). These cultures can be stored in racks at room temperatures for one to few weeks. The periods between sub culturing can be extended up to 4-6 months by storage at cooler temperatures, i.e., at 4 to 7°C in a refrigerator or cold room. However, all mushroom species cannot be stored at low temperatures. For example *Ganoderma*, *Calocybe* and *Volvariella* sp. should not be kept at temperature less than 15°C. Similarly growth pattern varies in different mushrooms.

In laboratory, the edible mushroom strains are subcultured on suitable culture media. *Volvariella volvacea* is incubated at 32°C for 7 to 10 days. The other mushroom strains are incubated at 25°C for 2-3 weeks until the slants are fully covered with mycelium. Once fully-grown culture of *V.volvacea* has been obtained, they are to be kept at room temperature. *V. volvacea* should be subcultured every 2 months. Species of *Lentinula*, *Pleurotus* and *Agaricus* strains can be kept in refrigerator at 4°C, and they should be subcultured every 6 months. Deviation from the original characteristics of the cultures can be detected visually in mycelial cultures. The most common degenerative symptoms are sectors of slow growth, mycelium that is thin and



Fig. 4.5. Growth of culture in slants

weak in appearance, or matted or fluffy but has normal growth rate. A slow growing mycelium needs more time for colonization and may carry virus particles. A fluffy mycelium causes the grain to stick together and is harder to spread in compost than normal grains. It tends to form stroma and gives lower yields. Mycelia of this type should be discarded. *Volvariella* spp. form clamydospores in culture tubes, which are brownish in colour. Culture tubes showing more clamydospores indicate that the culture has a good vigour and will be high yielding type. Nevertheless, partial loss of mushroom forming capacity and the desired qualities because of degeneration and mutation during prolonged vegetative propagation of stock cultures can occur. Hence continuous observation of culture characteristics and yield pattern is important. Repeated subculturing may in fact result in preserving a culture different from the original one. To avoid frequent subculturing, proper storage is important. Some of the commonly used methods for storing cultures are described here.

2. Storage under mineral oil

The mineral oil (Liquid Paraffin or Medical Paraffin specific gravity 0.830 - 0.890) is sterilized in an autoclave at 121°C for 15 minutes for two consecutive days. Actively growing mycelial cultures are covered upto 1 cm above the slant level. Short slants require less oil to cover them. Coverage must be complete as strands of mycelium left exposed may act as wicks to dry out the culture. Alternatively, 0.5 cm mycelial discs are suspended in 1-2 ml of sterilized liquid paraffin. Covering cultures on agar slants with mineral oil prevents dehydration, slows down metabolic activity and growth through reduced oxygen tension. The mineral oil blocks the exchange of oxygen between the mycelial surface and the atmosphere in the container thus retards metabolism and also prevents dessiccation of the agar medium. In conjunction with maintenance of the culture in a refrigerator at 4°C, this is an effective method of preserving fungal cultures. Retrieval is done by removing a small piece of the fungal colony or disc with a sterile needle, hook or loop, draining off excess oil and streaking the inoculum onto culture medium in plates or tubes. Tilting the plate or bottle may facilitate drainage. The first subculture often has a reduced growth rate and a second sub-culture is usually required before a good culture is obtained.



Fig. 4.6. Storage of culture under mineral oil

Two disadvantages of oil storage are contamination by airborne spore and retarded growth on retrieval. Nevertheless, in our laboratory, this method is working very well for conservation of most mushroom cultures satisfactorily for several years. The method was described by Sathe and Dighe in 1987 using *Pleurotus pulmonarius* taking 3 mm diameter discs from agar cultures of fungus and storing the discs at room temperature in glass tubes (9 x 75 mm) containing 1 ml of sterilized liquid paraffin. The culture stored in this way remained viable for 8 years (Fig. 4.6).

3. Water storage

The cultures are grown on a suitable culture medium. 4-5 bits of 0.5 mm diameter are transferred aseptically to glass vials containing simple water and the lids are tightly screwed. The bottles are stored at room temperature. Revival of culture is by taking of block and placing on a suitable growth medium. Survival of fungal cultures stored this

way is reported for 2 to 5 years satisfactorily. Growth may sometimes occur during storage in water. This can be reduced if the spores or hyphae are removed from the surface of agar without medium and transferred in water blanks. All mushroom cultures except *V. volvacea* can be stored by this method. Demineralized water proved better.

4. Lyophilization

Lyophilization, also known as freeze-drying, is a method of choice for long-term preservation of spore-bearing fungi. Mycelial mushroom cultures are not well preserved in this way. However, spore collected from a young and healthy mushroom aseptically can be stored for several years by this method. In freeze-drying, spore are frozen and water is removed by sublimation. The drying of the spores is accomplished by freezing under reduced pressure in vacuum. Stability and long storage periods have been shown to be the main advantages of freeze-drying.

Most commonly used suspending media for freeze-drying are skimmed milk (10%), or trypticase soybroth (0.75 g) with sucrose (10 g) and Bovine-serum albumin (5.0 g in 100 ml distilled water), and are used with equal volume of culture suspension. Freeze-drying of basidiospores of mushroom can be done by adopting following procedure of freeze-drying. The glass ampoules are first sterilized in a hot air oven at 130°C for 2-3 hours and are plugged with cotton. These ampoules are autoclaved for 15-20 min. at 121°C at 15 p.s.i. Culture suspension in case of mushroom or spore suspension in other fungi is prepared in skimmed milk or suitable medium. Each sterilized ampoule is then filled with 0.2 ml of culture suspension. A few aliquots are serially diluted to determine pre-freezing viable count. Rest all the ampoules with spore suspension are placed in a freezer (-70°C) for 1 to 2 hours. When shelf temperature of the freeze chamber reaches -40°C, ampoules with frozen samples are placed inside the chamber of freeze-dryer (Lyophilizer) and vacuum is created. Primary drying is achieved at -40°C for 4 hours. Temperature is then raised in 10°C increments keeping at each temperature for at least half an hour and at -20°C for one hour. Vacuum is released and ampoules are stored at -20°C (or -70°C). Next morning samples are dried atleast for 2 hours and vacuum released. Cotton plugs are then pushed inside down and constrictions are made in the ampoules above the cotton plug. The ampoules are then attached to the freeze-dryer for secondary drying under vacuum at -20°C for 2 hours and sealed while attached to the lyophilizer itself with the help of a gas-air torch. The ampoules are then stored at 4° to 6°C for longer shelf life inside a refrigerator. A representative ampoule can be cut from the top to check post-freezing count before finally storing the ampoules for longer duration. Viability of most organisms does not change much upon freeze-drying of viable spores. Rehydration of the fungi with sterile distilled water should be carried out slowly for 30 min for



Fig. 4.7. Lyophilized culture

absorption of moisture before plating on a suitable culture medium. At the Directorate technique for storing culture in lyophilized form has been developed where instead of mycelial bits, spawn grains are lyophilized (Fig. 4.7).

5. Preservation at -70°C

Glycerol (10%) in aqueous solution is sterilized by autoclaving at 121°C for 15 minutes. Alternatively Dimethyl sulfoxide (DMSO) is sterilized by filtration using 0.22 micron Teflon filter. Usually 10% glycerol suspensions of cultures are made (0.5 ml to 1 ml) and the aliquots are distributed in small vials or tubes. The vials/tubes are placed at -70°C. DMSO penetrates more rapidly and is often more satisfactory and may also be used as cryoprotectant in place of glycerol. Many culture banks are maintaining mushroom cultures by this method satisfactorily for several years (Microbial Type Culture Collection, Chandigarh).

6. Cryopreservation in liquid nitrogen



Fig. 8. Storage of culture under liquid nitrogen

The storage of microorganism at ultra low temperatures (-196°C in liquid nitrogen) is at present regarded as the best method of cryopreservation. Lowering the temperature of living cells reduces the rate of metabolism until, when all internal water is frozen, no further biochemical reaction occurs and metabolism is suspended. Although little metabolic activity takes places below -70°C, recrystallization of ice or ice crystal growth can occur at temperature above -139°C, and this can cause damage during storage. The volume occupied by water increases by 10% when water crystallizes and form ice. This puts the cell

under mechanical stress. At -196°C dormancy is induced, and the organism does not undergo and change either phenotypically or genotypically, provided adequate care is taken during freezing and thawing. This method can be applied to both sporulating and non-sporulating cultures. The technique has been evaluated at the Directorate (Fig. 4.8).

The temperature of liquid phase of nitrogen remains at -196°C and average temperature of the vapour phase is around -140°C. Glycerol (10%) suspension of young mushroom mycelium is prepared and distributed in aliquots of 0.5 ml to 1 ml in plastic screw cap cryo-vials, which can withstand ultra cold temperature. At some culture banks 0.5 mm disc are suspended in 10% glycerol solution. Programmed cooling at 1°C to 10°C per minute is ideal. In case where programmable freezer is not available, vials are first placed in a mechanical freezer (-70°C) for an hour and then to check viability of a culture before and after freezing. Glycerol may be replaced by 5% DMSO. Cultures may be recovered by rapid thawing at 37°C. Presence of liquid nitrogen in storage vials may cause explosion while thawing.

Cultures remain viable for years and no apparent change in morphological or physiological characters. This technique is suitable for species like *Agaricus*, *Lentinula*, *Pleurotus*, *Schizophyllum commune*, *Tremella* and *Polyporus* but not suitable for *Volvariella volvacea*.

7. Granular structure medium

A granular structure culture medium (saw dust or mixed straw powder (72%), wheat powder (20%), soybean powder (5.5%), complex additives (2%) and adhesive (0.5%)) can be prepared and sterilized in 500 ml jars and used as an economic substitute for the traditional cereal grain medium used in spawn manufacture and as medium for the

preservation of mushroom strains. The mycelial viability and the economic properties of mushroom strains can be retained for at least five years, if the mycelium is preserved at 2-4°C on granular structure medium. This method was claimed to be superior, practical and helps in rejuvenation of mushroom strain.

8. Cryopreservation in mechanical freezers

Because viability of stored cells increases dramatically with lower temperature, the ultra low temperature mechanical freezers are recently designed by leading multinational companies to operate efficiently at -140°C or -150°C. Cells may be stored indefinitely at sufficiently low temperatures, safely below -130°C, which is glass transition temperature of water. Below this temperature enzyme activity is completely suspended and thermally driven reaction cannot occur. The cultures are prepared in the same way as for liquid nitrogen preservation and placed first at -20°C and then at -70°C and finally in freezers maintained below -130°C. The culture preservation by this method is as good as in liquid nitrogen. It is cost effective when compared to the cost of per litre refill charges of liquid nitrogen, thus reducing operating expenses. Nevertheless, ultra low temperature freezers are run on electricity and therefore need continuous electricity supply.

The choice of methods will depend on the requirements of the collection, the equipment and facilities available. Table 1 compares different methods of preservation with regard to costs of materials, labour, longevity and genetic stability. It is recommended that each mushroom strain/isolate should be maintained by at least two different methods. In general, storage in liquid nitrogen and mineral oil preservation technique are best suited for preservation of edible mushrooms. The handling techniques, freezing protocols, cryopreservation and thawing rates can be optimized for a particular strain to obtain maximum survival. Once the mushroom has been successfully frozen and stored in liquid nitrogen, the storage period appears to be indefinite, because no chemical and or physical changes can occur at such low temperatures. The flow chart of mushroom culture preparation and conservation is given in the Fig. 4.9.

C. Mushroom Repositories

The maintenance and production of reliable pure culture spawn with desirable qualities is a key operation and the first critical stage in the success of mushroom cultivation. Mushroom culture repositories/banks play a vital role in supply of pure and

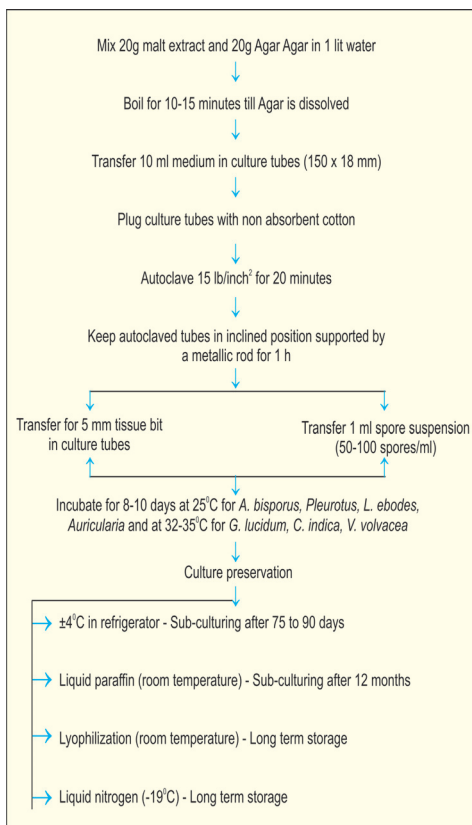


Fig. 4.9. Flow chart of mushroom culture preparation and conservation

Table 1. Comparison of mushroom culture preservation methods

Method of preservation	Cost		Longevity	Genetic stability
	Material	Labour		
Storage at room temperature	Low	High	4-6 weeks	Variable
Storage in refrigerator	Medium	High	4-6 months	Variable
Storage under oil	Low	Low/medium	4-5 years	Moderate
Storage in water	Low	Low/medium	2-3 years	Moderate
Storage in deep freezer (-70°C)	Medium	Low/medium	4-5 years	Moderate
Freeze-drying of Basidiospore	High	Initially high	20 years	Good/medium
Liquid nitrogen	High	Low	Indefinite	Good*
Ultra-low mechanical freezers (-150°C)	High	Low	(-)	(-)

1= Not a regular practice with mushroom culture bank, (-) = Ultra low temperature freezers are new. Longevity & genetic stability yet to be proved superior to other methods of preservation.

authentic culture to most of the mushroom spawn producing units. One can obtain pure cultures for making spawn from any of the National or International repositories listed below:

National

- Directorate of Mushroom Research (ICAR), Chambaghat, Solan (HP).
- Division of Mycology and Plant Pathology, IARI, Pusa, New Delhi.
- Indian Institute of Horticulture Research (ICAR), Bangalore.
- Institute of Microbial Technology, Chandigarh.
- Department of Microbiology, PAU, Ludhiana.
- Department of Plant Pathology, Rajasthan College of Agriculture, Udaipur.

International

- American Type Culture Collection (ATCC), Rockville, Maryland, USA.
- International Mycological Institute, Kew, Surrey, UK.
- National Regional Research Laboratory (NRRL), USDA, Peoria, Illinois, USA.
- Fermentation Research Institute (FRI), Japan.
- Canadian Collection of Fungus Culture (CCFC), Canada.
- College of Agricultural Sciences, Pennsylvania State University, USA.
- Dutch Mushroom Experimental Station, The Netherlands.

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Spawn Production Technology

V.P. Sharma and Satish Kumar

Spawn, i.e. seed required for growing mushroom, is the vegetative mycelium from a selected mushroom cultured on a convenient medium like wheat, pearl millet, sorghum grains, etc. In simple words spawn is grains covered with mushroom mycelium. It essentially involves preparation of pure culture of mushroom from tissue/spores, evaluation of selected cultures for yield, quality and other desirable traits, maintenance of selected cultures on suitable agar medium, followed by culturing on sterilized grains and further multiplication on grains. From 1652 to 1894 A.D. spawn was gathered from the wild rather than made and was referred as Natural or Virgin spawn (from pastures & meadows) and Flake spawn (breaking of beds through which mushroom mycelium has run), Mill-track spawn (bricks dried and made from mixture of horse dung, cow dung and loam soil). In the beginning of 20th century pure mycelial culture were made and used for making manure spawn on sterilized horse manure or compost manure.

The process of making grain spawn was first introduced by the Pennsylvania State University in 1932. Grain spawn had an advantage over manure spawn as it could be mixed easily and provided many inoculum points. The grain spawn was further perfected by Stoller in 1962. Today most of the traditional spawn laboratories world over are using wheat, rye and millet grains as substrate for spawn production and are following the standard technique of mother spawn from pure culture mycelium grown on synthetic medium. The spawn production technology is divided into following steps (Fig. 5.1 and 5. 2).

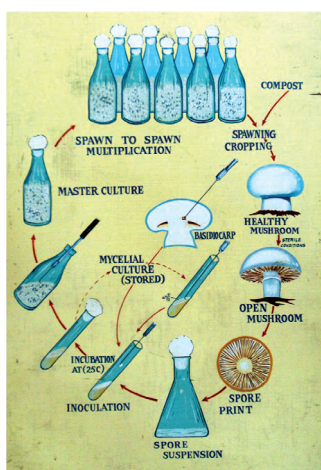


Fig. 5.1. Spawn production technology

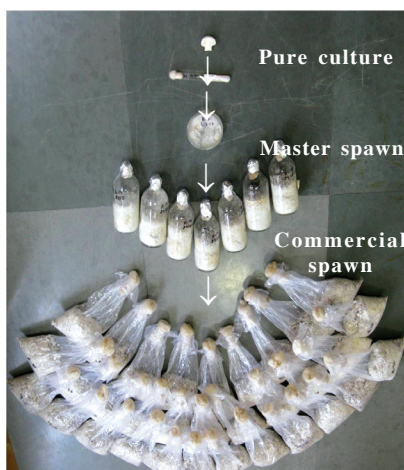


Fig. 5.2. Steps in spawn production

A. Pure Culture Preparation

Pure culture of mushrooms can be prepared either by multi-spore or by tissue culture. Multi-spore culture is made from spore print that can be obtained by hanging a alcohol sterilized fresh fruit body on a loop of wire above a petriplate/sterilized paper. Spores are serially diluted and transferred to sterile potato-dextrose-agar (PDA) or malt-extract-agar (MEA) culture slants. These slants are then incubated at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for 2 weeks to obtain pure culture. For tissue culture, mushroom after alcohol sterilization is cut longitudinally into 2 halves and bits from collar region (i.e. junction of cap and stalk) are transferred to pre-sterilized PDA or MEA culture medium, which is, incubated at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ in BOD incubator for one week. Mycelium from growing edges is carefully transferred to MEA/PDA slants and again incubated for 2-3 weeks to obtain pure cultures. Basic materials and equipment required for obtaining pure culture is given in Fig. 5.3.



Fig. 5.3. Preparation of pure culture

B. Substrate Preparation

Mushroom spawn can be prepared on any kind of cereal grains like wheat, jowar, bajra or rye and on agricultural wastes like corn cobs, wooden sticks, rice straw, saw dust and used tea leaves, etc. Spawn substrate i.e. cereal grains should be free from diseases and should not be broken, old and damaged by insect pests. Most of the cereal grains are good substrate for spawn production of white button mushroom (*Agaricus bisporus* and *A. bitorquis*), oyster mushroom (*Pleurotus* spp.) and paddy straw mushroom (*Volvariella volvacea*), but wood rotting fungi like shiitake (*Lentinula edodes*) and black

ear mushroom (*Auricularia* spp.) grow better on saw dust based substrates over cereal grains. The grains are thoroughly washed in sufficient water three to four times to remove soil debris, straw particles and undesirable seed of grasses, weeds, etc. Washed grains are then soaked in sufficient water for 20-30 minutes and boiled in a container for 15-20 minutes. It should be ensured that grains get boiled but do not burst and same can be tested by pressing the grains. Normally for soaking and boiling 20 kg of wheat grain, 35 liters of water is required. Excess water from the boiled grains is removed by spreading boiled grains on sieve made of fine wire mesh or muslin cloth. The grains are left as such for few hours on the sieve so that the water on surface gets evaporates. Now the grains are mixed with gypsum (Calcium sulphate) and chalk powder (Calcium carbonate) so that the pH of the grains is around 7 to 7.8 and they do not form clumps. Different people have given different ratios of Gypsum and Calcium carbonate. The best results



(a) Boiling, sieving, autoclaving and inoculation



(b) Method of inserting ring, folding bag and plugging



(c) Preparation of master spawn and commercial spawn

Fig. 5.4 (a-c). Steps of substrate preparation

are however, obtained by using 200 g gypsum and 50 g chalk powder for 10 kg grains (dry weight basis). First gypsum and chalk powder are separately mixed and then they are thoroughly mixed with the grains. This mixing should be done on a smooth surface after wearing gloves. For commercial spawn production rotating drums can be used for uniform mixing. Different steps of substrate preparation are given in the Fig. 5.4.

C. Mother Spawn Preparation



Fig. 5.5. Mature master culture

About 300 g prepared substrate (boiled grains mixed with gypsum and chalk) is filled in glucose/milk/glass bottles upto 2/3 volume and plugged with non-absorbent cotton. The plugs are covered with aluminum foil. These bottles are then autoclaved at 22 p.s.i. pressure for 1.5 to 2 h. Autoclaved bottles are left in the room for 24 hours for cooling and are kept on laminar flow under U.V. tube for 20-30 minutes before inoculation. A piece of mycelium (pure culture) grown in Petri plates is aseptically transferred to these bottles and inoculated bottles are

incubated (for incubation temperature refer Table 5.1). These bottles are gently shaken on 5th and 10th day for distributing the inoculum evenly in the bottles. This spawn prepared using pure culture mycelium as inoculant is referred as mother spawn (Fig. 5.5). Fully colonized mother spawn bottles can be used for inoculating commercial spawn bags after two to three weeks.

D. Commercial Spawn Preparation

Commercial spawn can be prepared in polypropylene bags (heat resistant). Normally for half and one kg spawn, the bags should be of 35 x 17.5 cm and 40 x 20 cm in size, respectively. Polypropylene bags should have double sealing at the bottom. After filling the grains a polypropylene neck (height 2 cm, dia. 4 cm) is placed near top by passing polypropylene bag through PP ring and folding back the bag (Fig. 5.6). The bags are plugged with non-absorbent cotton. These are then sterilized at 22 p.s.i. pressure for 1.5 to 2 hours. Autoclaved bags are shaken well before inoculation so that the grains absorb the water droplets accumulated inside the bags. The sterilized bags are kept on the laminar flow under U.V. tube for 20-30 minutes. The bags are incubated under aseptic conditions using master spawn as inoculum. Ten to fifteen grams of grains of master spawn are used for inoculating one bag and one bottle of master spawn is sufficient for inoculating 25 to 30 commercial spawn bags.

Inoculated bags are again shaken so that the inoculum is well mixed with the grains. The bags are then kept in incubation room for mycelial spread. During incubation, the bags are regularly examined



Fig. 5.6. Polypropylene neck

for mould infestation. Contaminated bags should be immediately removed to avoid build-up of contamination in the incubation room. Normally it takes around 15-20 days for complete mycelial run on the grains. Fully colonized bags should thereafter be kept in cold room (4°C) for future use (Fig. 5.7). The spawn of button mushroom, *Pleurotus* can be stored at this temperature. However, neither the culture nor spawn of *Volvariella*, *Ganoderma* and *Calocybe* is stored below 15°C (Table 1). The contaminated bottles/bags/tubes etc. are autoclaved before emptying and discarding.



Fig. 5.7. Mature spawn

Table 5.1. Temperature requirement for storage and incubation of different mushrooms

	Agaricus	Pleurotus	Lentinula	Volvariella	Calocybe
Days for complete coloni- zation of mother spawn	20-21	8-12	20-22	6-7	15-17
Days for complete coloni- zation in commercial spawn	12-14	8-10	15-16	5-6	12-14
Incubation temperature (°C) during colonization	25	25	25	32	25
Storage temperature (°C)	4	4	4	15	15-16
Shelf life of spawn	Two months	One month	Three months	< 15 days	15 days

E. Spawn Storage and Its Transport

Whereever possible, freshly prepared spawn should be used since the mycelium is in the state of active growth. The spawn bags after completion of growth can be stored for 2-3 months at low temperature in some cases.

Earlier spawn was prepared in milk or glucose bottles, which was difficult to transport from one place to another. Heat resistant polypropylene bags have revolutionized the spawn industry. High-tech multinational spawn labs now use polypropylene bags with microfilm windows for aeration. Though polypropylene translucent bottles of 5-10 litres capacity are also used in Europe and USA for spawn production, but it has not been introduced in India due to high cost of the material. The mature spawn bags, that is polypropylene bags with grains fully colonized by mycelium should be packed in well ventilated cardboard cartons and stored at 2-4°C. The spawn is transported from one place to another in refrigerated vans or during night when temperature does not rise above 32°C. It is important that spawn bags are not exposed to heat and dust during transport.

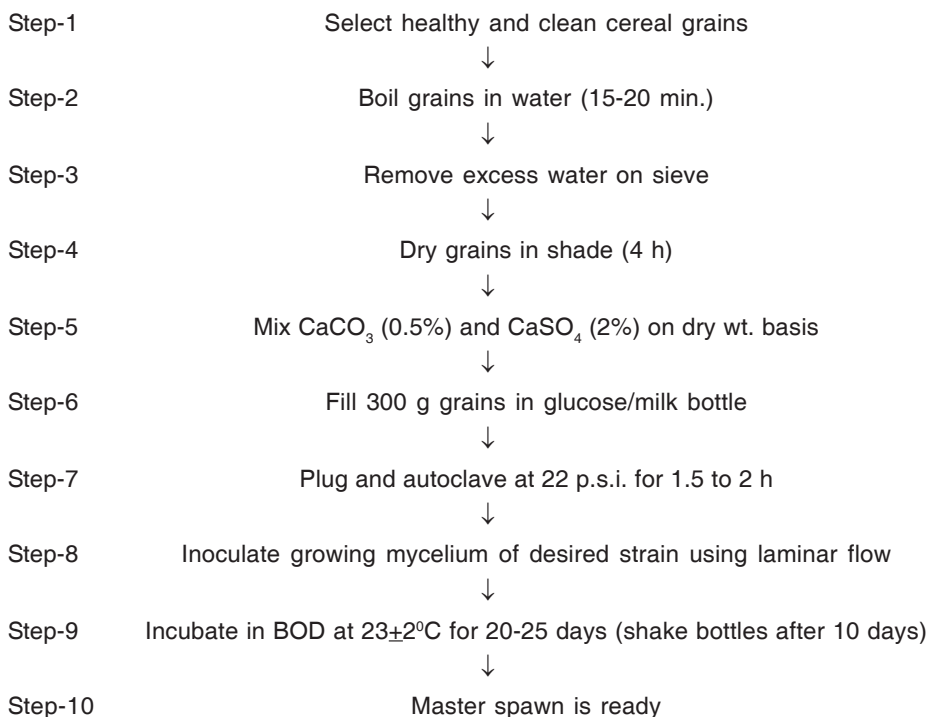
F. Liquid Spawn

Mycelium cultured in liquid medium followed by maceration/ homogenization can also be used for spawning. This is commonly referred as liquid spawn. It can be used for mechanizing inoculation process of spawn multiplication or can be used for inoculating substrates. In one of our experiments shiitake (*Lentinula edodes*) cultured in liquid medium was used as a liquid spawn for its cultivation on synthetic sawdust substrate. Normal fruit-bodies were harvested from the colonized substrate in 90 days on substrate inoculated with the liquid spawn as compared to 120 days when solid spawn was used.

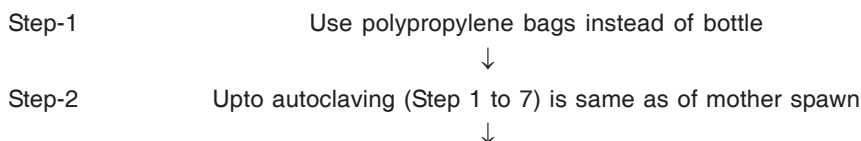
Strandy cultures showing good growth and not showing fluffy growth, sectoring or slow growth are desirable. During cropping bare patches on bed, deformed fruit bodies with no or few gills, weeping mushrooms indicate degeneration. Multispore cultures degenerate faster than single spore cultures. Hence, it is important to properly maintain the culture at desired temperature and rejuvenate them by change of media and replace them in case of any sign of degeneration.

Spawn production cycle

1. Preparation of mother spawn



2. Preparation of commercial spawn



- Step-8 Inoculate with 10-15 grams of mother spawn per PP bags
- ↓
- Step-9 Incubate at $23 \pm 2^{\circ}\text{C}$ in incubation room (Shake bags after 7-8 days)
- ↓
- Step-10 Commercial spawn is ready in 2-3 weeks

Problems faced during pure culture/ spawn preparation and their solutions are given in Table 5.2.

Table 5.2. Problems, causes and solution during pure culture/ spawn preparation

Problem	Cause	Solution
Agar medium very soft or hardly solidifies	Quantity of agar insufficient i.e. too low or agar is of inferior quality	Use branded and proper quantity of agar in medium
Agar surface in the plates not smooth or lumpy	Agar medium partially solid when poured	Pour agar medium when it is still hot
Contaminants appear after 2-3 days on the surface of the medium after sterilization and before inoculation	Medium not sufficiently sterilized Medium not aseptically poured	Sterilization should be carried for the recommended period and at recommended temperature pressure Medium should be poured aseptically
Transferred mycelial bit/ tissue resume no growth	Non-viable inoculum/ culture Wrong type of medium Incorrect formulation or pH Needle or scalpel used to transfer the culture bit too hot or culture exposed to flame for prolonged period during transfer	Use viable culture/ actively growing culture Use correct medium Properly check the formulation and pH of the medium Cool the flamed needle before picking the inoculum and carefully transfer it
Contamination develops on the plugs after 2-3 days	Cotton too moist or not of non-absorbent quality Filters of the laminar flow damaged Incubation room too much loaded with air born inoculum	Properly cover plugs before autoclaving and use quality non absorbent cotton Filters should be checked or replaced as per recommendation Sterilize incubation rooms from time to time
Resulting mycelial growth slow and fluffy	Strain degenerated	Obtain another culture or retrieve stock culture
Grains contaminated after sterilization and before inoculation	Highly infected seeds Grains not fully sterilized Sealing of PP bags improper or plugs too loose	Use fresh and clean seed Prolong sterilization period Use quality PP bags (may use double bags) and properly plug the bottles/bags
Mycelial growth very thin and hardly penetrates the grains	Grains too dry	Boil the grains sufficiently and adjust proper moisture levels

Problem	Cause	Solution
Mycelial growth does not continue upto the bottom of the bag	Excessive grain moisture	Adjust proper moisture level
Mycelia do not grow thoroughly on the substrate or patchy growth	Grains contaminated with bacteria / yeast due to improper sterilization Less vigorous strain	Use recommended sterilization time Use vigorous strain
Contamination appears on the surface of the inoculum (grain or mycelia bit)	Contamination occurred during inoculation	Inoculation should be performed in a more aseptic way and observe complete cleanliness
Mycelia growing very slowly	Unsuitable substrate or processing improper, pH not correct, poor quality of gypsum or chalk Incubation temperature not suitable	Use recommended substrate Check the temperature requirement Use vigorous culture

G. Design of a Spawn Laboratory (Production Capacity 100 TPA)

The medium size spawn laboratory (production capacity at least 100 TPA) should have a total built up area of 19 x 8 x 3.6 m (L x B x H). This area will be divided into different work areas like cooking/autoclaving room, inoculation room, and incubation room, washing area, store, office and one cold storage (Fig. 5.8). Cold storage room of 3 x 3 x 3.6 m (L x B x H) is enough to store the spawn at 4-5°C. The walls, roof floor as well as door is provided with heavy insulation (7.5-10 cm thickness) and two air conditioner (each of 1.5 tonnes capacity) are required to maintain temperature inside the room. Two incubation rooms of 3 x 6.0 x 3.6 m (L x B x H) with entire surface area (wall, floor, ceiling, doors) insulated with 5-7.5 cm thick insulation. Two air conditioners (each 1.5 tonnes capacity) are required to maintain temperature (25°C) in the incubation room.

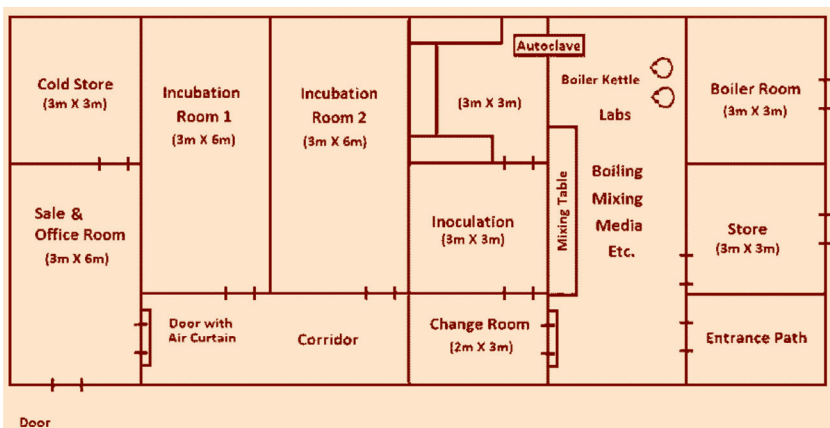


Fig. 5.8. Layout of Spawn Lab

H. Equipments Required

The equipment required in a spawn laboratory (Fig. 5.9) are:

1. Boiling pans/boiling kettle (vessel) for boiling the grains. Kettle can also be used if baby boiler is available otherwise kettles working on electricity, kerosene or gas can be installed. Pans for preparation of medium are also required.
2. Stove or steam line for boiling of wheat grains and preparation of medium.
3. pH meter to check pH of the medium.
4. Autoclave for sterilization of spawn medium and oven for sterilization glassware. Two electrically operated autoclaves with 100-145 bottle capacity having a dia. of 2 ½' and 3 ¼' height are sufficient. If boiler is available steam operated autoclaves can be used for better efficiency. A small clinical autoclave can also be kept for sterilization of culture medium.
5. BOD incubator is needed to incubate cultures and master cultures.
6. Laminar flow cabinet (normally 4 ft. horizontal) is needed for isolation and multiplication of cultures and spawn inoculation.



Fig. 5.9. Equipments for spawn laboratory (a) boiling kettle, (b) autoclave, (c) laminar flow and (d) BOD incubator

7. Refrigerator is needed for short-term preservation of mycelial cultures.
8. Other items like glassware, chemicals for medium preparation, non-absorbent cotton, polypropylene bags (or bottles), disinfectant (formaldehyde), calcium carbonate, calcium sulphate are also required.

9. Steel racks in incubation room and cold storage for keeping bags/bottles, exhaust fans, filters, office table, working tables, troughs, sieves, inoculating needles, scalpels, test tubes, petri plates etc. are also required.
10. AHUs can be installed for creating positive pressure by filtered air. Similarly air curtains are desirable to keep aseptic conditions in the lab.

I. Economics

Economics of establishing a spawn laboratory for production and sale of at least 1,00,000 kg spawn per annum is given below:

		Cost (Rupees)
1.	Fixed cost	
a	Land procurement and development (300 m ²)	Available
b	Cost of construction:	
	i) Cost of construction of 152 m ² area @ Rs. 8000/- per m ²	12,16,000.00
	ii) Cost of insulation of incubation room and cold store (250 m ²) @ Rs. 500/- m ²)	1,25,000.00
	Total:	Rs. 13,41,000.00
c	Cost of machinery	
	i) Cost of 4 ACs of 1.5 ton capacity	2,00,000
	ii) Cost of other equipments	
	Autoclave (2 no.)	8,00,000.00
	Laminar flow	1,50,000.00
	BOD Incubator	75,000.00
	Refrigerator	10,000.00
	pH meter	5,000.00
	Gas stove	3,000.00
	Weighing balance	2,000.00
	Iron racks	1,00,000.00
	Total	Rs. 11,45,000.00
2.	Recurring expenditure	
a	Salary	
	Labour (2 No.) @ Rs. 3000/- month/person	72,000.00
	Technical Assistant (1 No.) @ Rs. 6000/- month/person	72,000.00
	Total	Rs. 1,44,000.00
b	Raw materials	
	i) Cost of wheat/sorghum/pearl millet grains (600 q) @ Rs. 1500/q (Considering 1.8 kg spawn/kg wheat and 5-10% contamination)	7,50,000.00

ii) Cost of calcium carbonate (3 q) and calcium sulphate (10 q) @ 5000/q	65,000.00
iii) Cost of non-absorbent cotton 10 q @ Rs. 6500/q	65,000.00
iv) Cost of rings	25,000.00
v) Cost of 7 quintal of polypropylene bags @ Rs. 6500/q	4,500.00
vi) Energy consumption/year	2,00,000.00
vii) Miscellaneous (cost of disinfectants, gloves etc.)	1,00,000.00
Total	Rs. 12,50,500.00
Total recurring expenditure =	Rs. 13,94,500.00

3. *Interest and depreciation*

1. On Building (Rs.13,41,000) (5% depreciation and Interest @ 12%)	2,27,970.00
2. On machinery (Rs.11,45,000.00) (10% depreciation and 12% Interest)	2,51,900.00
Total	Rs. 4,79,870.00

4. *Cost of production and return*

a Raw materials	12,50,500.00
b Wages and salary	1,44,000.00
c Interest and depreciation	4,79,870.00
Total	Rs.18,74,370.00

5. *Return*

a Income from sale of 1 lakh spawn bags @ Rs. 50/kg	50,00,000.00
Net profit per year Rs. (50,00,000 -18,74,370) =	Rs. 31,25,630.00

J. Mushroom Spawn Standards

No spawn standards as such have been set out in our country. However based on the research the following standards appears reasonable.

Pure culture can be equated to nucleus seed, master spawn to breeder seed and commercial spawn to foundation seed.

1. *Pure culture (Nucleus seed)*

- The culture should be genetically pure and true to type.
- Culture should be obtained from Research organization or authentic source.
- Free from any kind of fungal and viral contamination.
- Culture should be maintained on compost extract agar medium.
- Culture should indicate specific growth rate on defined medium and at defined temperature.

- f Visually the culture should be strandy and off white in colour in *Agaricus*, pure white and thick fluffy growth in *Pleurotus*, cottony fluffy with brown sclerotia (after 12-15 days) in *Volvariella*, pure white, dense, thick and fluffy growth in *Calocybe indica* and pure white later on turning to light brown pigmentation in *Lentinula edodes*.
- g Culture should be stored at 4-6°C for *Agaricus*, *Pleurotus* and *Lentinula* and between 18-22°C in *Volvariella* and *Calocybe indica*.
- h The incubation temperature should be between 32±2°C for *Volvariella* and *Calocybe indica* and 25°C for *Agaricus*, *Pleurotus* and *Lentinula*.

2. Master spawn (Breeder seed)

- a Breeder seed should always be prepared from pure culture.
- b Free from any kind of contamination.
- c It should be multiplied on wheat, jowar, bajra or barley grains.
- d Breeder seed should be incubated at 25±2°C for *Agaricus*, *Pleurotus*, *Lentinula* and 32±2°C for *Calocybe indica* and *Volvariella*.
- e The master spawn should be stored at 4-6°C for 40-45 days in *Agaricus*, *Pleurotus*, *Lentinula* and 18-20°C days in *Calocybe indica* and *Volvariella* for maximum 30-40 days.
- f It should be produced in autoclavable transparent glass bottles

3. Commercial spawn (Foundation seed/Certified spawn)

- a The incubation temperature should be 25±2°C for *Agaricus*, *Pluerotus*, *Lentinula* and 32±2°C for *Volvariella* and *Calocybe indica*.
- b Spawn should always be prepared from master spawn (Breeder seed).
- c Free from any kind of contamination.
- d It should be multiplied on wheat, jowar, bajra or barley grains.
- e Spawn should not be older than 60 days in *Agaricus*, 30-45 days in *Pleurotus*, *Lentinula* and 30-40 days in *Calocybe indica* and *Volvariella*.
- f Certified spawn should be stored at 4-6°C in *Agaricus*, *Pleurotus* and *Lentinula* and 18-20°C in *Calocybe indica* and *Volvariella*.
- g The bag should indicate lot no., date of inoculation, variety/strain and quantity.
- h For every new lot of commercial seed (foundation seed), fresh master spawn (breeder seed) should be used. Commercial spawn may not be used for further multiplication of seeds as it may lead to higher contamination and decline in yield.

Further Readings

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Raw Materials and Formulations of Compost for White Button Mushroom

B. Vijay

White button mushroom requires a well composted substrate for its growth. It is a saprophytic fungus and requires carbon compounds, which generally come from the agricultural waste materials. Besides carbon, it requires nitrogen and other essential elements, such as phosphorous, sulphur, potassium and iron, vitamins such as thiamine, biotin, etc. All the raw materials that contain these compounds are mixed in a fixed proportion and fermented in a set pattern to form a substrate, which is known as compost.

A. Raw Material and Ingredients Required for Composting

1. Agricultural base materials

These base materials form the bulk of compost and for this purpose wheat straw is favoured all over the world. However, quality compost can be prepared using variety of other materials including paddy straw, hay, barley, oat, maize stalks and leaves, sugarcane bagasse, sugarcane trashes and leaves, soybean stalks, mustard stalks, etc. These materials should preferably be freshly harvested/procured and should be around 5-8 cm long. These base materials act as a reservoir of cellulose, hemi-cellulose and lignin, which is utilized by *A.bisporus* during its growth as a carbon source. They also provide a little quantity of nitrogen. Besides acting as a nutrient source, they also add bulk to the compost, impart proper physical structure to the substrate and ensure adequate aeration during composting for the build up of microflora essential for the composting process and also for the nutrition of mushroom. Rice and barley straw are very soft and degrade quickly during composting. These materials also absorb more water as compared to wheat straw. While using these materials care must be taken regarding quantity of water used for wetting, schedule of turnings and adjustment to the rate and type of supplements.

2. Supplements

Above base materials do not have adequate amount of nitrogen and other nutrients required to start the fermentation process having required C/N ratio. Also the requirement of nitrogen cannot be met with the little nitrogen available in straw. The compounding mixture is supplemented with other materials having nitrogen and carbohydrate sources. These materials can be classified as follows.

a. Animal manure

Horse manure undoubtedly is the best material for compost preparation. However, due to difficulties encountered in procuring good quality horse manure, use of this material

has been restricted to few farms only. More and more farms are switching over to easily accessible materials. Chicken manure has proved to be the best alternative of horse manure. Other manures viz., pig, cattle and sheep have also been tried for compost preparation but with limited success. All these manures provide nitrogen to the compounding mixture, little of carbohydrate is also provided. These materials are highly variable in composition and their N-content may vary from 1 - 5 percent and it is released slowly during composting process. In addition to providing nutrients, they greatly increase bulk of compost, which is very important factor under Indian conditions considering the cost of wheat straw and these materials (specially chicken and horse manure). If horse manure is used in composting then it should be used alongwith bedding and urine, as it will not require any further supplementation. If it is not having enough bedding and urine when collected from a clean stable, supplementation with inorganic nitrogen along with some wheat straw may prove useful. Chicken manure if used, should preferably be a deep litter chicken manure having nitrogen content above 3%. If such manure is not available then the manure from cages can also be tried. Chicken manure is generally used under short method of composting. However, some of the growers are using this under long method and are getting fairly good yields, while some have met with failures. Chicken manure harbours heavy population of pathogenic nematodes and harmful fungi including *Sepedonium maheshwarianum*, *Stachybotrys atra*, *Papulaspora* sp. and *Verticillium* sp. Growers should, therefore, avoid the use of this material under long method of composting.

b. Carbohydrate sources

These materials are essentially required to hasten the composting process, to balance the C/N ratio and also for the establishment of the bacterial flora in the compost. Molasses, wet brewer's grains, malt sprouts, potato wastes, apple and grape pomace can be employed as carbohydrate sources, since these materials provide readily available nutrients to microorganisms.

3. Nitrogen fertilizers

This category includes fertilizers like, urea, calcium ammonium nitrate, ammonium sulphate. Nitrogen content of these fertilizers is very high (24-46%), which is released quickly, resulting in quick establishment of microflora.

4. Concentrate meals

Animal feeds are generally kept in this category, which include, wheat or rice bran, dried brewer's grain, soybean meal, cotton seed meal, castor meal, sunflower meal, etc. These materials supply both nitrogen and carbohydrates, which as in case of animal manures are released slowly. Nitrogen content may vary from 3-12% depending upon the source.

5. Supplements to rectify mineral deficiencies

In addition to carbon and nitrogen, *A. bisporus* also requires little quantities of potash, phosphorous, calcium and magnesium for its growth. Fertilizers viz., muriate of potash and superphosphate can be kept in this category. Besides this, gypsum and calcium carbonate can also be kept here. Gypsum also has stabilizing effect on ammonium content. An increased ammonium concentration is obtained with gypsum, which is an

indicator of a productive compost. Furthermore, gypsum serves as a calcium source for the mushroom and also for the oxalic acid produced by the mushroom mycelium, which gets converted into calcium oxalate. Requirement of phosphorous, potassium, and magnesium is generally met by chicken manure or horse manure when compost is produced by short or by indoor method. However, long method compost where chicken manure is not added addition of other materials may be required to meet the demand of these nutrients.

For making compost for *A.bisporus* above materials should judiciously be selected keeping in view the nutritional requirement of *A.bisporus*, cost and availability of raw materials (Table 1).

Table 6.1. Moisture and nitrogen content (dry wt. basis) of compost raw materials

	% Moisture	% N
Wheat straw	15	0.6
Horse manure - light	30	0.8
Horse manure - Heavy	50	1.0
Deep litter chicken manure	30	3.0
Wheat bran	10	2.0
Brewer's grain	40	2.0
Soybean meal	10	6.5
Cotton seed meal	10	7.0

B. Formulations

A large number of formulations are available with the growers and these are based on cost and availability of raw materials in the particular region. To initiate a composting process and to minimize the loss of dry matter during composting, 1.5-1.75 percent nitrogen is generally kept in the compounding mixture. The main objective of computing a formulation is to achieve a balance between carbon and nitrogen compounds. At stacking C:N ratio is adjusted to 25-30:1, which comes down to 16:1 after composting. N level in the compounding mixture at start should not be less than 1.5% as this will give improper compost with high C:N ratio and such compost will be easily attacked by cellulose loving fungi. It should also not be higher than 1.75% as such compost will be easily attacked by yellow moulds fungi and also more time will be required to finish the composting procedure. Known and estimated values of nitrogen and water contents of different materials viz., straw, chicken manure, wheat bran and other chemical fertilizers can be used as guidelines in computing formulations having desired balance of nitrogen and C: N ratio. Different batches of these materials can be tested for nitrogen for their correct estimates so that required quantity of these materials goes in a compounding mixture leading to productive compost. Formulations for white button mushroom compost should be so designed that composting mixture should have under mentioned percentage of different minerals on dry weight basis.

N	1.5-1.8%	CaO	1.5-3%
P ₂ O ₅	1.2-1.5%	MgO	0.4-0.5%
K ₂ O	2.0-2.3%		

Formulations having horse manure as one of the ingredients is termed as natural compost, while others are termed as synthetic composts. In addition to C and N, various other materials play an important role. Only in recent times importance of these minerals in mushroom cultivation has been realized. Chicken droppings have maximum amount of all the above elements and it should become an integral part of mushroom compost. An example as to how to arrive at standard formulation having desired N value is given in Table 6.2.

Table 6.2. Nitrogen computation guidelines

Ingredients	Fresh wt (kg)	Moisture (%)	Dry wt (kg)	%N	N (kg)
Wheat straw	300.00	10	270.00	0.40	1.08
Wheat bran	15.00	10	13.50	2.00	0.27
Chicken manure	125.00	10	112.50	2.60	2.93
Urea	5.50	-	5.50	46.00	2.53
Gypsum	20.00	-	20.00	-	-
Total wt.	465.50		421.50		6.81
N% = (6.81 x 100)/421.50 = 1.61					

C. Different Formulations

Some of the formulations suggested are given as under:

1. Formulae given by DMR, Solan

- | | | | | | |
|----|------------------|--------|----|---------------------|--------|
| a. | Wheat straw | 300 kg | b. | Wheat & paddy (1:1) | 300 kg |
| | Wheat bran | 15 kg | | CAN | 9 kg |
| | Chicken manure | 125 kg | | Urea | 5 kg |
| | BHC (10%) | 125 g | | Wheat bran | 25 kg |
| | Gypsum | 20 kg | | Gypsum | 20 kg |
| c. | Wheat straw | 300 kg | d. | Wheat straw | 300 kg |
| | Chicken manure | 210 kg | | Wheat bran | 21 kg |
| | Cotton Seed cake | 21 kg | | Cotton seed cake | 12 kg |
| | Gypsum | 15 kg | | Urea | 7 kg |
| | | | | Gypsum | 15 kg |

2. Natural compost (IARI)

- | | | | | | |
|----|--------------|----------|----|----------------|---------|
| a. | Horse manure | 1000 kg | b. | Horse manure | 1000 kg |
| | Wheat straw | 350 kg | | Wheat straw | 350 kg |
| | Urea | 3 kg | | Chicken manure | 300 kg |
| | Gypsum | 30-40 kg | | Brewer's grain | 60 kg |
| | | | | Gypsum | 30 kg |

3. Synthetic compost (PAU)

- | | | | | | |
|----|-------------------------|--------|----|----------------|--------|
| a. | Wheat+Paddy straw (1:1) | 300 kg | b. | Wheat straw | 300 kg |
| | CAN | 9 kg | | Chicken manure | 60 kg |
| | Urea | 3 kg | | CAN | 6 kg |

Superphosphate	3 kg
Muriate of Potash	3 kg
Wheat bran	15 kg
Gypsum	30 kg
BHC (5%)	250 g

Superphosphate	3 kg
Wheat bran	15 kg
Gypsum	30 kg
Lindane dust or BHC (5%)	250 g

4. Formulae given by IIHR, Bangalore

a.	Paddy straw	150 kg	b.	Wheat straw or	300 kg
	Maize stalks	150 kg		Paddy straw	400 kg
	Ammonium sulphate	9 kg		CAN	9 kg
	Superphosphate	9 kg		Superphosphate	9 kg
	Urea	4 kg		Urea	4 kg
	Rice bran	50 kg		Wheat bran	30 kg
	Cotton seed meal	15 kg		Gypsum	12 kg
	Gypsum	12 kg		Calcium carbonate	10 kg
	Calcium carbonate	10 kg			
c.	Wheat straw	300 kg	d.	Paddy straw	300 kg
	Chicken manure	120 kg		Chicken manure	150 kg
	Rice bran	20 kg		Wheat bran	12.5 kg
	Brewer's grain	22 kg		Gypsum	10 kg
	Urea	6 kg			
	Cotton seed meal	15 kg			
	Gypsum	10 kg			

5. Formulae given by Mushroom Research Laboratory, Solan

(Long method)

a.	Wheat straw	1000 kg
	CAN	30 kg
	Super phosphate	25 kg
	Urea	12 kg
	Sulphate of Potash	10 kg
	Wheat bran	100 kg
	Molasses	16.6 litres
	Gypsum	100 kg

(Short method)

b.	Wheat straw	1000 kg
	Chicken manure	400 kg
	Brewer's manure	72 kg
	Urea	14.5 kg
	Gypsum	30 kg

6. Formulae given by ICAR Research Complex, Shillong

a.	Paddy straw	400 kg
	Ammonium Sulphate	9 kg
	Urea	3.6 kg
	Molasses	5.0 kg
	Sulphate of Potash	3 kg
	Single Super phosphate	3 kg
	Wheat bran	30 kg
	Gypsum	30 kg
	Temik	40 kg
	BHC (5%)	250 g
	Kelthane/Ecalux	40 ml



Fig. 6.1. Commonly used ingredients and preparation of compost

7. Formulae given by RRL, Srinagar

a. Wheat straw or paddy straw	300 kg
Molasses	12 kg
Urea	4.5 kg
Wheat bran	50 kg
Muriate of Potash	2 kg
Cotton seed meal	15 kg
Gypsum	15 kg

In Haryana many people are making compost using wheat straw, paddy straw or their combination by long method of composting. Some of the formulations in use are:

Ingredients (kg)	1	2	3	4	5
Wheat straw	-	-	1000	1000	1000
Paddy straw	1000	1000	-	-	-
Chicken Manure	-	-	-	400	300
Calcium amm. nitrate (CAN)	-	12.5	12.5	-	15
Urea	16.5	12.5	12.5	15	20
Single super phosphate	12.5	12.5	12.5	-	10
Muriate of Potash	12.5	12.5	12.5	-	10
Wheat bran	50	50	100	-	40
Sunflower cake	35	-	-	-	-
Neem cake	-	-	-	10	-
Molasses	-	-	-	30	-
Calcium Carbonate	-	-	-	10	-
Gypsum	100	65	65	80	150

Many commercial units are making compost using only straw of wheat or paddy and chicken manure. For every ton of straw about 0.7-0.8 ton chicken manure and 0.05-0.15 ton gypsum is used. Gypsum is normally added at third turning but many units add it in the beginning or at second turning.

Formulations recommended for long method can also be used under short or indoor methods. However, it is recommended that for short/indoor composting one should use chicken manure based formulations for economic gains. Further, one can go up to 70% addition of chicken manure/ton of straw depending upon its N-content. Other materials can be added to balance the N-level in the desired range.

Further Readings

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Methods of Compost Preparation for White Button Mushroom (*Agaricus bisporus*)

B.Vijay

Agaricus bisporus, the white button mushroom is the most popular mushroom in the world and contributes around thirty per cent of world production of mushrooms. It is cultivated on a specially prepared substrate known as compost, which is a product of fermentation by a number of thermophilic organisms that decompose plant residues and other organic and inorganic matters. The main purpose of composting is to release the nutrients in the straw and supplements and to transform them in such a way that they are suitable for the nutrition of mushroom. During composting various chemical and biological processes help in achieving this. The nitrogen available in the ingredients is converted into proteins of the microorganisms and further a lignin humus complex is also formed during composting both of which later on are utilized by the mushroom mycelium as food. Compost if properly prepared is very selective in nature and only *A.bisporus* mycelium can grow successfully on it at the practical exclusion of other competing organisms.

Cultivation of this mushroom first originated in France around 1650, where melon growers observed spontaneous appearance of *A.bisporus* on used melon crop compost. Since then tremendous advancement has taken place in the cultivation technology of this mushroom particularly in the composting field. Today in our country white button mushroom is cultivated on the compost prepared by a traditional method known as long method of composting, on short method of compost or on compost prepared by an accelerated method also known as rapid composting method (Indoor compost). Comparison of these methods is depicted in Table 7.1. Present chapter would deal with all the three processes in detail.

A. Long Method of Composting (LMC)

Preparation of compost by such method is very old concept and has been abandoned in most parts of the world excepting in few countries in Asia. Compost prepared by such method besides taking more time (around one month) gives low yield, as it is prone to attack by many pests and diseases. Yields obtained using such compost range between 10-15 kg of mushrooms per 100 kg of compost. However, higher yields to the tune of 18-22 kg have also been reported by some seasonal growers who take single crop in the entire season.

Table 7.1. Processes of composting and their attributes

Attributes	Long method	Short method	Indoor method
Days required for compost preparation	28-30	16-20	10-12
Selectivity	Partial	Complete	Complete
Average yield (kg/100kg compost)	10-15	18-25	20-30
Effect on environment	Polluting	Less polluting	Non polluting
Average compost production / ton of straw	1.75-2.0 tons	2.0-2.5 tons	3.0-3.5 tons
Average final N % in compost	1.75-2.0	2.0-2.2	2.2-2.5
Prewetting area for 20 tons out put compost	-	60 x 40 ft	60 x 40 ft
Infrastructure required for 20 tons out put compost	Out door composting yard (60 x 40 ft.)	Covered composting yard (60 x 40 ft) + 1 tunnel (36 x 9 x 12 ft)	2 Phase-I bunkers (45 x 10 x 10 ft + one Phase -II tunnel (36 x 9 x 12 ft)
Man days required for 20 tons compost out put	30-35	20-25	15-20
Power requirement for 20 tons out put compost	Nil	700-900 KW	800-1000 KW
Compost handling equipments required (Large farm) (> 500TPA)	Nil	Turner, filling line, hopper regulator, Bobcats	Filling line, hopper regulator, Bobcat.

Compost by this method is prepared on clean cemented platform (Fig. 7.1). If such facility is not available then a simple brick platform can be used. Most of the growers who are cultivating this mushroom seasonally do not have any of the above two facilities and are producing the compost in open fields. Composting yard should preferably be covered by G.I. or asbestos roofing. If such facilities do not exist then provision should be there to cover the heap during rains. For a medium size farm producing around 20 tons of compost in one operation, a platform of size 60'x40' (18 m x 12 m) is sufficient enough. As a thumb rule 1.5 tons

**Fig. 7.1. Composting yard**

of compost at start of composting occupies around one square meter of space. Besides composting yard, provision should also be there to store the base materials. In general around 4000 litres of water is required per ton of raw material for its proper wetting. The ingredients of compost are straw, wheat bran, urea, etc. Any of the region specific synthetic formulation without chicken manure can be tried for compost production. Details of the formulation are given in the chapter 6 of this book. It is further mentioned that compost production should not be attempted with less than 300 kg of base materials, as required temperature may not be attained in piles made with lesser quantities.

Requirement of base materials should also be judiciously worked out. In general one ton of raw material would yield around 1.75 to 2 tons of finally prepared compost having the required moisture level. When the compost is prepared with manual labours, use of a set of 3 wooden or iron boards (2 sides boards-180 x 150 cm; 1 end board-140 cm x 180 cm) is still in use.

1. Method

First important step in the production of compost is to thoroughly clean the area, spray 2% formaldehyde solution so that unwanted organisms are killed. On the following day, wheat straw or any other recommended base material is spread on the platform. Wheat straw is very hard material and does not absorb water quickly, since it is coated with wax. This wax layer however, gets removed by the heat produced during composting or due to the physical actions like shredding, trampling, etc. and then, water is able to reach the inner portion of the straw easily. Water is sprinkled over the straw with a pipeline and straw is frequently turned till it absorbs sufficient moisture. Excess water escaping during wetting is collected in a goody pit and is recycled and used again for wetting the straw. Wetting of the straw may continue upto 24-48 hours till it attains 75% moisture. There should not be excessive wetting of the straw, as excess water fills the pores during composting resulting in anaerobic conditions in the pile, which is not a desirable trait of composting. On the contrary, if the moisture is too less in the compost pile plenty of oxygen is available to the microorganisms but desired high temperature is not attained in the pile, which is again not a desirable trait for their growth. When the straw is fully wetted it is collected as a low heap on one side of the yard. Other composting ingredients viz., chicken manure, wheat bran and other fertilizers excepting gypsum and insecticides are mixed, sprinkled with water and covered with a polythene sheet or wet gunny bags. Both wetted straw and these ingredients are kept as such for 24 hours. The day when wetting of these materials is completed is counted as -1 day and the day when the two are mixed is treated as 0 day.

a. Day-0

On this day two lots of the ingredients (straw + other additives) are properly mixed. The main aim of mixing the ingredients is to obtain a homogeneous product. The mixed ingredients are then made into a high aerobic pile with the help of boards (mould) described earlier. While making the pile, materials are slightly pressed from the sides and kept loose in the centre. When the mould is completely filled, the sideboards are moved, lengthwise and again the space is filled with the ingredients. This process is repeated till a compost pile is formed with all the materials. Else the compost piles can also be made without these boards as shown in Fig. 7.2. Dimensions of the pile are important and depend upon the prevailing outside



Fig. 7.2. Turning the pile

temperature. In the hills, where temperature may range between 7-20°C width of the stack should be kept between 130-150 cm and height of about 150cm, otherwise due to greater difference in temperature of compost and atmosphere proper temperature may

not be attained inside the heap which may result in unproductive compost. In plains where the temperature is higher, slightly smaller heaps (100-120 cm width and around same height) are recommended since there is not much difference in temperature outside and inside the compost and hence less natural aeration.

b. Day 1-5

Pile is kept as such for 5 days. Temperature of heap starts rising and may go upto 70°C in 24-48 hours. Maintaining a proper temperature inside the stack is an important parameter of compost preparation. High temperature besides favouring the growth of thermophilic microorganisms, also removes wax from the straw, which makes it more prone to the attack of microorganisms. Higher temperature attainment is directly related with the activity of microorganisms and is the result of their biological activities. However, role of higher temperature obtained during composting for the productive compost is still a matter of debate. Temperature above 80°C is also not desirable in the central core of the pile as it may result in anaerobic conditions and loss of friendly thermophilic flora.

c. Day-6 (1st turning)

Temperature is not homogeneous throughout the pile nor is the oxygen availability (Fig. 7.3). To give compounding mixture an equal opportunity towards fermentation, compost pile is turned at different intervals. In LMC, 7-8, turnings are given to the compost pile. The correct method of turning is as follows. Remove about one feet of the compost from top and sides of the pile, shake it vigorously so that excess of free ammonia is released in the atmosphere and the mass is properly exposed to air, keep this portion on one side (lot A). Now central and bottom portion of the pile are removed, shaken properly and kept separately (lot B). A new pile is then made out of these portions keeping lot A in centre and lot B on the top and sides. During reconstruction of the pile water is added whenever required. In practice however, compost pile is turned inside out.

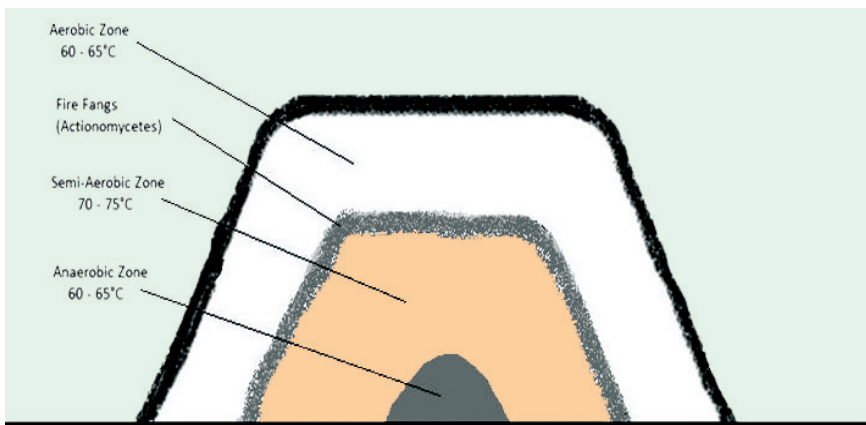


Fig. 7.3. Cross section of compost pile showing different zones

During the 1st turning itself the compounding mixture turns from golden yellow to dark yellow/light brown in colour and there is a slight shrinkage in its volume. This is accompanied by production of ammonia and sometimes foul smell due to anaerobic fermentation within the central core of the pile. Ammonia is produced under aerobic

conditions by the breakdown of carbohydrates and proteins while other obnoxious gases due to anaerobiosis. Besides ammonia, large quantities of CO_2 is also produced. After the 1st turning, temperature again starts rising and anaerobic conditions may still prevail, due to limited availability of oxygen in the central core of the pile. Oxygen penetration inside the compost mass depends upon several factors. It is less with more width of the pile, higher bulk density with higher outside temperature, low porosity and high moisture content than the recommended parameters. However, at any stage under LMC, 30-35% volume of the heap after eight hours of turning may be under semi-anaerobic or anaerobic conditions. Since this zone of the pile gets less than 5% oxygen, it becomes imperative to turn the compost again for maintaining proper aerobic conditions.

d. Day 10 (2nd turning)

Break open the pile and turn as described earlier. Pile will show further shrinkage and will exhibit higher temperature while colour of the ingredients will further darken. Ammonia production will be higher. Further, white flacks/powdery mass, which are known as fire fangs (*Actinomycetes*), will also be visible in the compost (indicator of a good compost).

e. Day 13 (3rd turning)

Again the pile is turned and the required quantity of gypsum is added. Role of gypsum in mushroom nutrition has already been narrated in chapter 6.

f. Day 16 (4th turning), Day 19 (5th turning), Day 22 (6th turning), Day 25 (7th turning)

The required quantity of recommended insecticide is added during last turning. One may spray Melathion or Decis @ 0.01% for killing insects and pests.

g. Day 28 (filling day)

Break open the pile, check for the smell of ammonia. If no ammonia smell is there in the compost and instead a sweet smell is felt, the compost is ready for spawning. If ammonia smell persists then additional turnings are required to be given after 2-3 days. Normally ammonia concentration at spawning should not be more than 8-10 ppm. Correct amount of ammonia present in the compost can be measured with the help of dragger tubes available in the market. Simply smelling compost is fairly good enough, as generally we cannot smell ammonia concentration below 10 ppm. Steps of long method composting have been shown in the flow chart (Fig. 7.4).

2. Improvements in long method of composting

a. Chemical pasteurization

Compost prepared by LMC harbours a large number of organisms at spawning, many of which are strong competitors of *A.bisporus*. Such compost is invariably attacked by yellow moulds (*Myceliophthora lutea* and *Sepedonium chrysospermum*), green mould (*Trichoderma viride*) and brown plaster mould (*Papulospora bysinna*). Out of these, yellow moulds are the most dreaded competitors of white button mushroom mycelium and in severe cases complete crop failure has been reported. Best way to eliminate these organisms is to use compost prepared by short method (pasteurized compost). However, procurement/production of such compost is beyond the reach of many growers in India especially for those who are seasonal growers. To control yellow moulds and

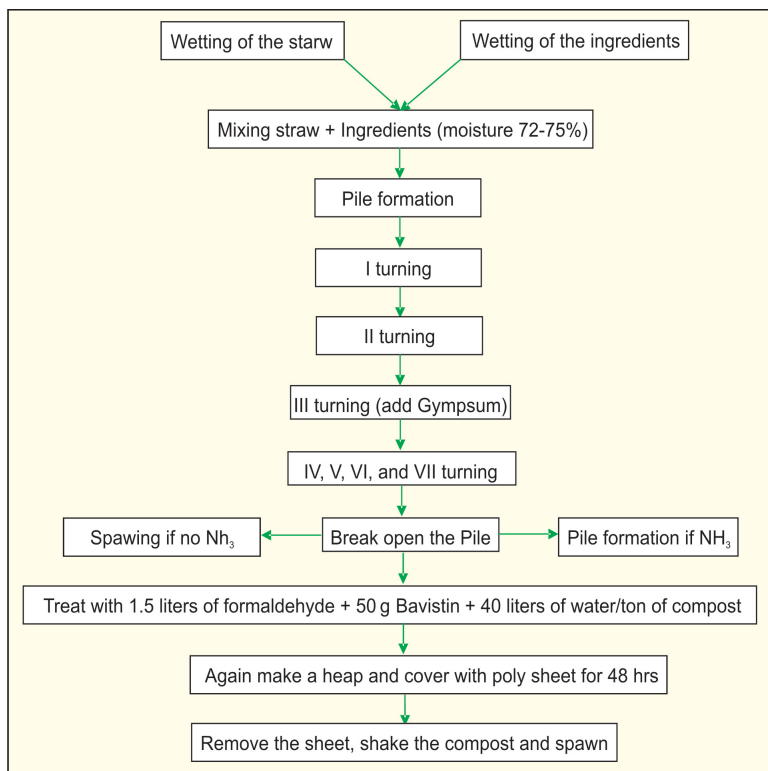


Fig. 7.4. Flow chart LMC

other diseases mentioned above, this Directorate came out with a novel chemical pasteurization technique of long method compost. The developed technique is as follows:

Prepare the long method compost as per schedule and on last day (turning) (27th day), break open the pile on a clean area. Now take 1.5 litres of formalin (formaldehyde 40%) and 50 g of Bavistin (50% Carbendazim), dissolve these chemicals in 40 litres of water for one ton compost. Spray this solution thoroughly in the entire compost mass so that each and every portion of the compost gets the dose of this solution. Now make a heap out of this compost and cover it by a polythene sheet for two days. Remove the cover after 2 days and vigorously shake the compost before spawning. It may be noted that above chemical solution is for one ton of finally prepared compost only and growers should prepare the chemical solution as per the quantity of compost available with them. Quantity of water can be adjusted as per the moisture of the compost but it should be sufficient enough to treat the entire compost. Growers are advised to procure standard make of chemicals only otherwise they may not get desired results. This technique works very well against the yellow moulds and also controls other competitors as well thereby increasing the yield (Table 7.2). Such chemical treatment of the compost is safe as there is no translocation of carbendazim or formalin in the fruit bodies when used for the treatment of compost at spawning.

Table 7.2. Effect of various chemical treatments on growth and yield of *A. bisporus* cultivated on long method compost prepared using 1:1 mixture of wheat + paddy straw

Treatments (per 100 kg compost)	Condition of spawn run	Days required for fruiting	Avg. fruit body wt. (g)	Yield kg/ 100kg compost	% increase in yield over control
Formalin (150 ml)	+++	33	9.5	15.0	42.0
Formalin + Bavistin (150 ml + 5 g)	+++	33	9.0	18.1	72.0
DDVP (30 ml)	+++	34	9.7	14.7	40.1
DDVP+ Bavistin (30 ml + 5 g)	++	34	8.5	14.4	37.1
Bavistin (5 g)	++	33	8.7	14.0	33.0
Formalin+DDVP (125 ml + 30 ml)	++	34	8.5	15.4	46.4
Control (water spray) 4 litre water /100 kg compost	++	33	8.8	10.5	-
CD 0.05			n.s.	2.25	

3. Attributes of a good compost

A good compost should be dark brown in colour, should not be greasy or sticky, should have distinct sweet inoffensive smell, free from ammonia smell, should have 68-72% moisture and pH 7.2- 7.8. There should not be visible growth of other undesirable organisms except for the fire fangs (Actinomycetes) and it should be free from insects and nematodes.

As indicated earlier composting is essentially a fermentation process brought about by the activity of various organisms. Their activity and growth determines the quality of the compost produced since these organisms convert ammonical nitrogen to microbial proteins, which are ultimately utilized by *A.bisporus* mycelium for its nutrition. Beside above, quality and composition of base materials, aeration and moisture also determine the quality of compost. Various factors, which govern the quality of compost, are as follows:

a. Nitrogen content

Nitrogen content of the compounding mixture is very important. It should be 1.5 - 1.75% in the beginning (on dry matter basis). If the N content is kept below 1.5%, compost is not properly fermented and the temperature of the heap may not go beyond 55-60°C due to lesser microbial activity. The compost so produced will be yellowish in colour and light in texture and will not be selective to mushroom mycelium. Moulds like *Stachybotrys atra*, *S.alternans*, *Stilbum nanum* and *Doratomyces stemonites* may inhabit such compost resulting in poor yields.

On the other hand if N content is kept above 1.75% level, C: N ratio will not be optimum and more of nitrogen will disappear from the pile in the form of ammonia resulting in the wastage of the nutrients. Such compost is invariably infested by *Sepedonium* spp. (yellow moulds), which may drastically reduce the yield. *Coprinus* spp. (Ink caps) and *Chaetomium olivaceum* (olive green mould) are also indicators of high nitrogen in the compost pile. N content of compost at the end of 28 days in long method compost is in the range of 1.75 to 2.0 %.

b. Carbohydrate content

During initial stage of composting free carbohydrates and nitrogen are utilized by the mesophilic flora and heat is generated in the process. Later on thermophilic flora takes over the mesophilic population. When the compost is cooled down, thermophilic flora can no longer grow due to low temperature while mesophilic flora also cannot grow since these organisms have already utilized most of the free carbohydrates. Normally there should not be any free or soluble carbohydrates present in the compost. Their presence is the indication of under composting and such composts are easily attacked by green mould (*T. viride*) or blackwisher mould (*D.stemonitis*).

c. pH

This is an important parameter of *A.bisporus* compost. *A.bisporus* mycelium grows best at 7.2 - 7.8 otherwise growth of *A.bisporus* will be slow and white plaster mould (*Scopulariopsis fimicola*, *S.brevicaulis*) may invade such compost.

d. Moisture content

Optimum moisture content for the natural compost (i.e. compost made using horse manure) is about 65-67% while for synthetic compost it is 68-72%. If it is more than 72% at spawning there may not be proper aeration, as free space will be occupied by water. Under such circumstances anaerobic condition may prevail resulting in killing of *A.bisporus* mycelium. Further, moulds like brown plaster (*P. byssina*), white plaster (*S. fimicola*) may appear in the compost.

e. Quality of raw materials

If raw materials especially wheat or paddy straw used in compost making are of poor quality (old and exposed to rains) it may result in improper compost. On such compost *Sepedonium* spp., *Alternaria alternata* and *Coprinus* spp. may appear resulting in low yield of mushroom.

4. Shortcomings of LMC

Compost production by LMC is a very old concept and has been done away by advanced countries many decades back. It is presently in vogue only in few countries like India, China and Indonesia. LMC has the under mentioned shortcomings.

- Since compost is prepared over a period of 28-30 days dry matter loss of ingredients is more. We normally get 1.75 to 2.0 tons of final compost from one ton of dry straw.
- Compost is produced under out door conditions and hence invaded by many pests/competitors/diseases and hence not perfectly selective.
- Frequent sprays of insecticides and fungicides are required.
- Most of the ammonia is lost in the atmosphere resulting in low final N content of compost.
- Low yields
- Not environment friendly

B. Short Method of Composting (SMC)

Long method of composting has many shortcomings as already mentioned. Growers in the United States around 1915 found that if compost prepared for *A.bisporus* is kept in shelves in growing rooms and subjected to high temperature (around 60°C) for sometimes gives higher and consistent yield. This process was later termed as “sweating out” and it laid down the foundation of pasteurization of compost. Based on the above principles/ findings, American Scientist, Sinden and Hauser in the year 1950, 1953 proposed a new method of composting, where pasteurization became its integral part, which was termed as the short method of composting (SMC).

This method of composting is being followed by most of the growers who are cultivating mushrooms round the year and has since revolutionized the mushroom industry. Short method of composting primarily consists of two phases:

Phase-I: Outdoor composting for 10-12 days

Phase-II: Pasteurization and conditioning of the compost inside an insulated room by free circulation of air under definite set of conditions. This phase lasts for around seven days

1. Purpose of pasteurization and conditioning

- a. It reduces the time of composting
- b. It converts ammonia into microbial protein, most of which otherwise goes waste in the atmosphere in LMC
- c. It conditions or sweetens the compost under definite set of temperature and aeration uniformly making compost more selective for the growth of *A.bisporus*
- d. It kills or inactivates insects/pests/diseases and competitors of *A.bisporus*, which if present hamper the growth of *A.bisporus* thereby reducing the yield
- e. Conditioning increases the biomass of thermophilic organisms especially that of *Scytalidium thermophilum*, which later on is utilized by the mushroom mycelium as food
- f. Through conditioning more compost per unit weight of ingredients is produced
- g. Conditioning and pasteurization increases the yield of mushrooms

During Phase-II steam pasteurization is done in a well insulated room constructed for the purpose. Boiler is required for the production of steam for proper maintenance of temperature inside the compost mass. Blower is required for the supply of fresh air and recirculation of ammonia and other gases for their conversion into microbial proteins. Details of pasteurization chamber are given in chapter 8.

2. Machinery required

Small farms would not require much mechanization owing to availability of cheap labour in the country. Also they have to handle little quantity of compost at a time, which otherwise can easily be handled manually. However, for a large export oriented unit (around 2000-3000 TPA), which handles the compost in bulk (around 30-40 tons of straw/day), mechanization of the operations viz., prewetting, turning, filling, emptying, spawning and bagging becomes necessary to hasten the process and to get a quality compost. Such farms also employ computers, which monitor and control the process of

pasteurization and conditioning inside the tunnels. Following machines will be required for an export oriented unit.



Fig. 7.5. Prewetting machine

b. Compost turner

The compost turner comes in varying capacities from 30-70 tons of compost handling per hour. It is fitted with a round stainless steel pick up drum, one spinner and one forming bore. The turner is generally mounted on 4 wheels, two of which are castoring wheels and rest two are powered, large diameter pneumatic wheels. Turner is usually fitted with a full width water spray pipe mounted at the front of the machine with water outlets over the full input width (Fig. 7.6).



Fig. 7.6. Compost turner

c. Pile forming case

This machine is used when the pile is formed for the first time. This is usually supported on four castoring wheels and is attached to the front of the compost turner which is pushed by the turner during pile formation.

d. Front end loaders

Bucket type loaders are employed for various composting operations viz, prewetting, and transportation of the compost during pile formation in combination of compost turner and forming case. They are generally attached with a tractor. Else, Bob Cat can be employed for the purpose (Fig. 7.7).



Fig. 7.7. Bob cat

e. Oscillating head filling machine

This is made up of two conveyer units mounted upon a self propelled chasis. The two conveyers are so designed that one feeds directly into the other from above. Conveyer

which is positioned above accepts the compost from the feed conveyers and transfer this compost to the conveyer positioned below. This is an oscillating type which fills the compost loosely in the tunnel over the entire width. The head filling machine comes in varying sizes suiting to the size of the tunnel.

f. Compost feed conveyers (2-3 units)

These are ordinary conveyer systems slightly elevated and can be coupled together to form a single conveyer system feeding one to the other during tunnel filling. The length and width of each conveyer is generally 7.5- 9 m and 0.6 m (Fig. 7.8).



Fig. 7.9. Hopper regulator



Fig. 7.8. Conveyor

g. Hopper regulator

This machine is required to feed the compost to the feed conveyers. It accepts the compost from the bucket of the front end loader and provides regulated output of the compost to the feed conveyor (Fig. 7.9).

h. Tunnel emptying winch with combination of spawn dosing machine

This unit is employed for emptying the tunnel filled with pasteurized compost by means of a polyethylene glide and pulling nets. The winch is equipped with one net reel for pulling, the nets, two spinners and a chain conveyer for the discharge of the compost.

Spawn discharging unit consists of twin spawn dispensers mounted over the full width of the compost flow on the discharge elevator.

i. Bag filling machine

This machine is used for filling the bags with spawned compost. The machine is equipped with a conveyer with two filling stations (Fig. 7.10).

One or more of the above machines may be needed depending upon scale of operation, labour availability, type of raw materials used, etc Front-end loaders, hopper, conveyers and oscillating head filling machines are useful for any commercial unit.



Fig. 7.10. Bag filling machine

Besides the above machines, small instruments like multiprobes digital thermometers, oxygen meters, ammonia measuring equipments and computers are also required for a mushroom farm to maintain quality and high productivity of mushrooms.

3. Methodology

Compost by short method can be prepared by any formulation given in the text earlier. However, a formulation based on wheat straw and chicken manure is widely used in the country. (Wheat straw 1000 kg, chicken manure 500 kg, urea 15 kg, wheat bran 75 kg, gypsum 30 kg).

a. Phase-I or outdoor composting

Like LMC, this phase of SMC also starts with the wetting of the ingredients. Wheat straw and chicken manure are wetted thoroughly till they absorb sufficient water (around 75%). Leached water collected in a goody pit constructed for the purpose is regularly sprayed over the raw materials. After thorough wetting of the substrates an aerobic stack



Fig. 7.11. Under stack aeration ducts

or a simple heap is made out of such materials. After 2 days the stack is broken, water is added to the dry portions and again a stack is made. Growers may provide artificial aeration to this heap and to the stack to be made later on for better results. They may pass up to 10 to 15 m³ of air/ton of wet compost/hour through the stack. This will result in achieving high temperature and more homogenous compost. To have artificial ventilation in the stack, working floor of the composting yard is provided with under stack aeration ducts connected with the required capacity small blowers installed at one end of the yard. These blowers blow small quantities of air regularly or at fixed intervals through G.I. or plastic pipes (Fig. 7.11), which have small holes running length wise of the yard. Stack is made on these pipes. Prewetting and mixing of ingredients is a must before starting actual composting procedure on zero day and the stack made during this process are wide with low height of 3-4 feet.

0 Day

On this day the stack is again broken and the entire quantities of other raw materials like urea and wheat bran are added, water is also added if required and a high aerobic stack is made. Dimensions of the stack will be the same as mentioned for LMC. Turnings can be done manually or by compost turners built for the purpose. Similarly the compost is again turned after every 2 days and gypsum is added at third turning. In all three to four turnings are given. On 8th – 10th day the compost is ready for pasteurization to be affected in bulk chamber. This marks the end of Phase -I.

Characteristics of the compost after phase-I and before Phase-II

- Brownish throughout. Pieces of straw gleaming and wet
- Straw rather long but can be broken with some force
- Properly hydrated, around 72-75% moisture; when squeezed drops of water appears between the fingers

- Very heavy smell of ammonia. pH approximately around 8.2 - 8.5
- Still sticky and slimy, hands get dirty and wet
- Actinomycetes (fire fangs) not so apparent
- Nitrogen content between 1.5 - 2.0%; ammonia concentration around 800-1000 ppm

b. Phase-II

This phase of composting is generally performed in pasteurization tunnel in bulk. Phase-II process can be divided into two stages namely conditioning and pasteurization.

i. Conditioning

It can be divided into pre-pasteurization conditioning (PPC) and post pasteurization conditioning (POPC) (Fig. 7.12 & 7.13). During this phase of composting, whole of the compost mass is brought to a temperature range optimum for the growth of thermophilic flora (45-52°C). During this phase major part of NH_3 gets fixed in lignin-humus complex or as microbial biomass and excess of ammonia is released into the atmosphere. POPC again regenerates the lost thermophilic organisms during pasteurization. It has also been found that maximum ammonia generation takes place at 45-50°C, which

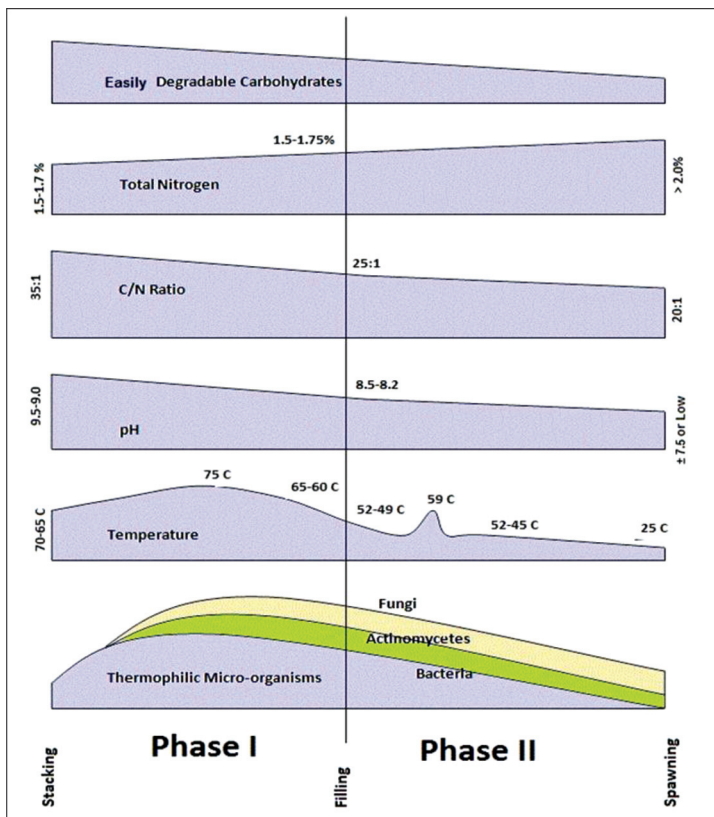


Fig. 7.12. Showing changes during composting in Phase-I & II
(Source: Vedder, 1978)

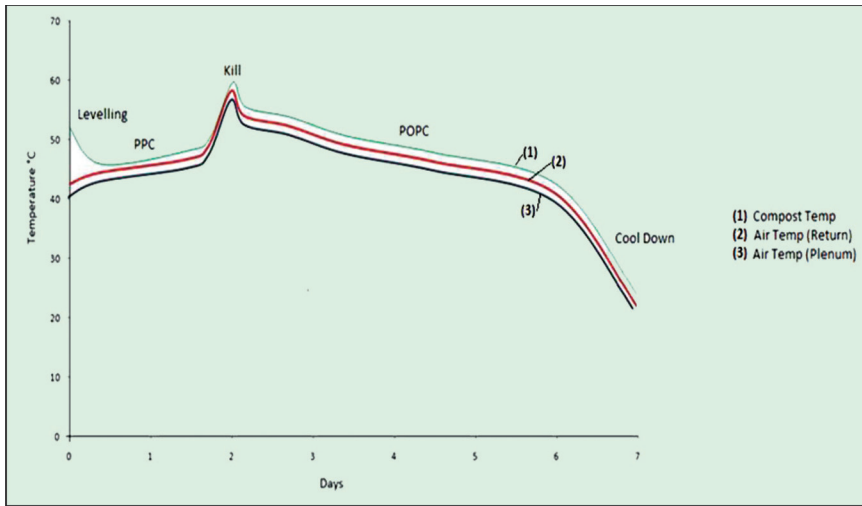


Fig. 7.13. Temperature variation with respect to time in Phase-II (Source: Vedder, 1978)

corresponds well with optimum temperature range of majority of thermophilic flora. Compost should not be conditioned below 40°C, as some mesophilic fungi may set in at this temperature rendering compost unsuitable for mushroom growth specially *A.bitorquis*. Besides keeping compost at a particular range of temperatures (45-52°C), during this phase enough of oxygen is supplied (O_2 concentration above 10%) to the compost mass to maintain fully aerobic conditions. Both pasteurization and conditioning make the compost most selective for the growth of white button mushroom at the expense of other harmful competing organisms.

ii. Pasteurization

Main purpose of pasteurization is to kill or inactivate harmful organisms. They are eliminated when the compost is subjected to a temperature above 55°C for certain period when humidity in the compost and surroundings is high. Therefore, use of live steam to heatup the room and compost sometimes becomes essential. It has been found that compost is pasteurized properly if it is kept at 59°C for 4-6 hours. Temperature above 60°C is harmful as this temperature may kill all kinds of organisms including thermophilic fungi very essential for governing the phase-II of composting. Activity status of the compost is also very important to achieve pasteurization temperature. If it is an active compost, its temperature starts rising immediately after filling and may rise by 1°C per hour and the required temperature of pasteurization can be achieved in few hours only by self-generation of heat. Pasteurization of the compost can either be done soon after room/tunnel filling or after few days.

iii. Phase-II in tunnel (Bulk pasteurization)

In this process the compost is treated in bulk inside a specially built chamber known as the tunnel (Fig. 7.14 & 7.15). The compost is filled in the bulk chamber upto the height of 2- 2.2 meters in such a way that one square meter of space occupies approximately 900-1000 kg of compost. Several temperature sensors are placed at different points of the tunnel to measure the temperature. One sensor is placed below the plenum in the

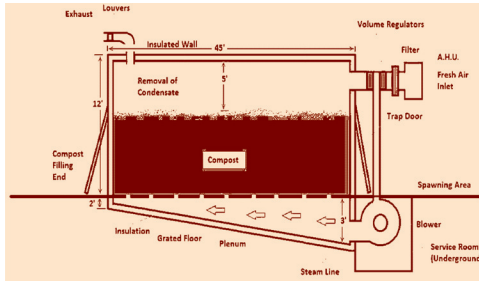


Fig. 7.14. Schematic diagram of phase-II bulk Chamber (45' x 9' x 13')



Fig. 7.15. Bulk chamber

ventilation duct below the grated floor, one to three are placed inside the compost mass and one or two above the compost for air temperature. Immediately after filling, all the doors are closed and the blower is switched on to bring the air in plenum, compost and air above the compost at a uniform temperature (around 45-48°C). There will be a little difference in temperature at all the three places and this difference may be 1-3°C. Levelling off may take 4-5 hours and at this stage no fresh air is generally introduced in the tunnel and air introduced through the leakage of the dampers and ducting would suffice the purpose. After levelling that is to say after 4-5 hours (more in case of bigger tunnels >15 tons) of filling the tunnel, we will start Pre Pasteurization Conditioning (PPC). This is to increase the population of thermophilic fungi at this stage, which will demand more oxygen for their growth and multiplication and this may reach above 15% of the total gaseous volume inside the tunnel. Fresh air is therefore introduced in the tunnel through the dampers (10% opening). Now the compost is kept between 45-52°C for two days. Two days after conditioning, the compost is now ready for pasteurization. Now opening of the damper is narrowed down, which will gradually increase the temperature of the compost by approximately 1°C/h. Required temperature (58-59°C) of compost needed for pasteurization may reach in 10-12 h by self-generation of heat (Fig. 7.13). The difference in the temperature above the compost (air temperature), inside the compost and plenum (below the compost) should be as less as possible and may not exceed 3°C. Some quantity of steam can also be used if temperature is not rising. This process is called pasteurization or killing. Duration of the pasteurization is normally 4-6 hours. It will eliminate harmful insects, nematodes and competitor moulds from the compost and at the same time will preserve the nutrients in the compost, which can effectively be utilized by *A.bisporus* mycelium. Temperature variation over time in Phase-II operation is given in the Fig. 7.12. Temperature can be monitored or regulated through automatic computerised systems available in the international market. A low cost alternative has been developed at the Directorate wherein one can set the minimum and maximum temperature and as soon as the temperature goes above or below the set temperature range, there is siren and corrections in tunnel parameters thereafter can be made manually.

After killing, fresh air is again introduced/increased in the tunnel and temperature of the compost is brought down @ 1.5°C/hour and finally maintained between 45-48°C till there is no detectable smell of ammonia (less than 10 ppm) in the compost. This phase is known as post pasteurization conditioning (POPC) of the compost, which is normally accomplished in 3-4 days. Temperature of the compost is gradually brought down to 25-30°C after conditioning by introduction of fresh air in the tunnel and when this temperature reaches, the compost is ready for spawning.

Above method of pasteurization is recommended for the commercial tunnels having more than 15 tons output of the compost. Smaller tunnels while adopting above procedure may require frequent injection of steam during PPC and especially when pasteurization is affected, this increases the cost of production of compost. Such tunnels may resort to traditional pasteurization wherein levelling is done at higher temperature (around 50°C) and after that opening of the damper is so adjusted that compost temperature starts rising and it attains pasteurization temperature mentioned as above. Usual conditioning is done afterwards for 4-5 days or till the period when compost is free from ammonia and spawning done as usual. At the end of conditioning (at spawning) compost should be dark brown in colour with a full coating of white powdery mass due to abundant growth of actinomycetes. This is a sign that Phase-II was performed in a perfect manner with abundant supply of fresh air.

Line flow chart and composting (SMC) at glance is given in the Fig. 7.16 and Fig. 7.17 respectively.

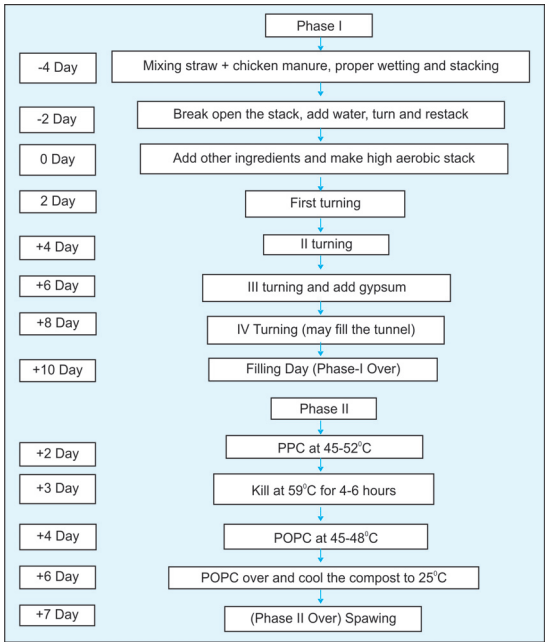


Fig. 7.16. Flow chart SMC

Phase-II process is almost a biological oxidation (90%) and hence here O₂ and temperature play very important role. It is advisable to connect temperature probes with a computer or data logger for round the clock changes/monitoring of the temperature. Further, gadgets are available in the market to monitor ammonia concentration and oxygen level inside the tunnels. These can also be installed in the tunnel to monitor above gases round the clock. The fresh air inlets are fitted with 2 micron washable HDPE filters.

As the composting proceeds there is loss in biomass. In phase-I there is about 30% loss in weight and in phase -II, 20-25 % loss in weight takes place. As a result from the standard formula of one ton wheat straw and 0.5 ton chicken manure, we can get about 2.5 tons of final compost.



Fig. 7.17. Pictorial flow chart SMC

Characteristics of the compost after Phase-II

- Dark brown in colour, full of thermophilic fungi and actinomycetes.
- It is soft, straw breaks rather easily.
- Moisture around 64-66%. No liquid oozes when squeezed firmly
- Pleasant sweet smell
- No stickiness. Hands stay clean and dry
- N content > 2%
- Ammonia below 10 ppm

Advantages of bulk pasteurization

- More compost per unit size of the room can be treated at a time.
- The cost of pasteurization in tunnel is less.
- Same tunnel can be utilized for spawn run in bulk, which gives effective use of the space.
- Yield per unit weight of compost is generally higher.

C. Indoor Composting

Compost prepared either by LMC or SMC involves traditional outdoor composting, which causes environmental pollution. Large amount of malodorous gases viz., ammonia, methane, hydrogen sulfide and other methylated sulphur compounds are emitted in the atmosphere creating nuisance. This foul smell is more when the compost is fermented at high temperature under anaerobic conditions. Laws governing pollution are becoming stringent day by day in India and many mushroom units producing compost by LMC or by SMC are threatened to close down their operation or to shift their operations away from the municipal limits. Need is, therefore, felt to control the composting process in such a manner that there is least possibility of environmental pollution and at the same time to produce high yielding compost in shortest possible time. Work on such composting procedure started in France way back in the year 1967 but only recently put to use by commercial units abroad. In this case whole composting process is carried out indoors in specially built tunnels and hence the name indoor composting. Since such compost is produced under total environmental controlled conditions. Sometimes it is also called environmentally controlled composting (ECC) or rapid indoor composting (REC), or aerated rapid composting (ARC). In India work on this line was started at our Directorate few year back and technology to produce such compost in 12 days time perfected. Facilities required and methodology for the production of such compost is presented below:

Most important aspect of indoor composting is that besides being environment friendly, it takes less time and gives more compost biomass (around 25-30% more) per unit weight of the ingredients taken and hence over all yield of mushrooms in such compost is higher.

1. Facilities required

a. Composting yard

In indoor composting Phase-I is performed indoors and hence requirement of composting yard is greatly reduced. A small composting platform is required for prewetting and mixing of the ingredients, which is mainly performed either by front-end loaders or by preheap turners by big commercial units. A platform of the size 60x60x14 ft (h) would suffice the purpose for a medium size farm (250 TPA).

b. Phase-I tunnels or bunkers

These are specially built non-insulated tunnels having full width opening at the front. Dimension of the bunkers would depend upon the output of the compost required. Generally the bunkers are 1.5 times more the size of the phase-II tunnels. It has a plenum (ventilation duct). A perforated concrete floor is constructed above the plenum, which is serviced by a centrifugal fan having $\frac{1}{4}$ the capacity of phase -II blower, which means that a ventilator having air displacement of 50 m³/hour/ton of compost at 50mm WG water pressure would suffice the purpose. Alternatively, the bunkers have no plenum and several pipes are buried in the floor along the full length of the bunkers having small holes (5-8 mm dia). These pipes are converged into a manifold, which in turn is connected to a high-speed blower fan (around 1000 pascals). A timer is usually attached to the blower, which pulsates the air in the bunker periodically as per the setting of the timer. A minimum of 2 such phase-I tunnels (bunkers) are required (Fig. 7.18).



Fig. 7.18. Bunkers and ventilation systems

c. Phase-II tunnels

Structure and design of these tunnels are the same as required in case of short method of composting.

2. Selection and mixing of ingredients

Selection of the raw materials for indoor composting is very critical and should have the following qualities:

- High bulk density,
- Good structure and texture,
- Perfectly mixed raw materials,
- Well balanced chemical composition and
- High level of nutrients

3. Procedural requirements

Two methods, INRA method (double phase high temperature process) and Anglo Dutch method (single phase, low temperature process) are prevalent in most parts of the world giving almost equal yields. This Directorate has developed a method combining the two methods as mentioned above. Methodology developed is presented below:

For preparing compost by this improved method of composting, ingredients say – wheat straw 1000 kg, poultry manure 500 kg, wheat bran 70 kg, cotton seed cake 20 kg, and gypsum 40 kg are first thoroughly mixed in dry form. They are then thoroughly wetted so as to achieve around 75% moisture percentage. Run off water should regularly be collected and sprinkled over the wetted straw. On the following day these wetted ingredients are then spread over the composting yard (around 8-10" height) and trampled hard by running Bobcat several times over the wetted ingredients or by other means so as to increase the bulk density of the ingredients and also to shred the straw. Wetted straw together with other ingredients is then made up into heap and left as such for 48 hours. Temperature in the heap may rise up to 55-60°C. On the following day, material is again flipped to bring the uniformity and proper mixing and transferred to phase-I bunker, for phase-I operation. This material will weigh around 4 tons and height of the compost in the bunker is kept up to 1.8-2 meters. Temperature sensors are installed on the top and in the Centre of the pile in the bunker and blower fan switched on @ 5 min/h with the help of a timer installed for the purpose. Temperature will rise to 60-65°C after 24 hours in the centre and 48-52°C at the bottom, sides and on top of the compost. After 24 hours air flow inside the tunnel is increased to 10 min/hour. This will further increase the

temperature in the centre of the compost between 72-75°C while it will remain same in other parts of the compost mentioned as above. No foul smell will be noticed while performing phase-I operation in the bunker, however little bit ammonia smell will be there. After 3 days of partial fermentation in phase-I tunnel, entire compost mass is taken out and a complementary turning is given, more water can be added if required and is transferred to another bunker or to the same bunker at the same sets of conditions mentioned as above for 3-4 days. Total period of phase-I operation in the bunker should normally last for 6-8 days. Afterwards compost is transferred to phase-II tunnel for usual phase-II operations to be completed in 6-7 days.

a. Composting schedule

- 4 day: Mixing and wetting and of the ingredients out doors
- 3 day: Turning, trampling by Bobcat and thorough mixing of the ingredients, addition of water.
- 2 day: High aerobic heap
- 0 day: Filling in the phase-I bunker
- + 3 day: Emptying the bunker, turning and mixing of the compounding mixture and re-filling the compost in another phase-I bunker
- +6 day: Phase-I operation over and compost transferred to phase-II tunnel
- + 12 day: Phase-II operation over

The phase-II operation is same as described for SMC. As temperature inside bunkers sometimes rises above 75°C, it may be desirable to add some inoculum in the form of readymade compost to the ingredients at the time of filling the tunnels or phase-II.

b. Advantages of indoor composting

- Requirement of composting yard is reduced to 1/3
- No emission of foul smell
- Number of labourers and cost of production reduced
- Duration of composting greatly reduced
- Reduced effects of weather and seasonal variations
- More compost per unit weight of the ingredients
- Higher yields
- Compost turner is not required

c. Disadvantages of indoor composting

- Low bulk density of compost
- Aesthetic look of the compost is not good (brown in colour)
- Since turnings are less, initial superior blend of raw materials and homogeneity at the time of filling phase-II tunnel is critical

Further Reading

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3. Vedder, P.J.C. 1978. *Modern Mushroom Growing*. Educaboek, Netherlands, 420 p.
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Farm Design for Commercial Button Mushroom Cultivation

B. Vijay

White button mushroom is a temperate mushroom requiring cooler climate for its growth. It is an indoor crop and is an ideal tool in converting agricultural wastes in to proteinaceous food. In early days its cultivation was mainly confined to the hills. In the eighties growers realized the potential of this crop and started its cultivation in the northern plains in the winter when the climate was suitable for its growth. Many entrepreneurs in the plains further ventured and started its cultivation round the year by employing artificial cooling facilities (chilling stations). Today its cultivation is done through out the country. Some are doing it seasonally while many of them have preferred to go for round the year cultivation. Today India boasts of having world's biggest farm, the Agro Dutch Foods Ltd, Lalru Punjab and many more environment controlled units exist in different parts of the country cultivating this mushroom round the year.

Mushroom being an indoor crop does not require arable land, except for some non-agricultural land to build the infrastructure for preparation of substrate, raising of crop, preparation of spawn and postharvest handling. As mentioned above this mushroom is grown seasonally and in environment controlled cropping houses and both require building of basic infrastructure. Seasonal growing is done for 3-4 months when outside temperatures are favourable for the crop, i.e., during winter months in N.W. plains and from September to April in the hills.

Seasonal cultivators of this mushroom are using traditional methods of its cultivation and are mainly cultivating this mushroom in the thatched structures employing long method of composting. They usually take single crop in the entire season and are harvesting 12-15 kg mushrooms/ 100 kg compost. Environment controlled units are cultivating this mushroom round the year by having suitable infrastructure at their disposal which includes a modern composting yard having bulk pasteurization facilities. Of late few of them have shifted to indoor composting while new upcoming units have chosen to produce their compost entirely by indoor method. Besides these facilities they are having insulated cropping rooms and other ancillary structures required for mushroom cultivation. Few of the bigger units are having their own spawn lab and processing unit as well. An entrepreneur can start mushroom cultivation modestly using seasonal growing houses and after gaining sufficient experience can shift to round the year cultivation employing suitable climate control facilities. Suitable infrastructure including different machineries are required at the farm to carry out different operations to govern the whole process of cultivation in such a fashion so that one gets optimum returns from his farm in this

competitive environment. The one who designs the farm in most scientific manner looking to the need of the crop and easy accessibility to the different infrastructure for their operation convenience in less space, utilizing less money will gain handsome returns in the years to come. Present chapter would deal in detail the infrastructure and machineries required for the seasonal and environment controlled units.

A. Selection of Site and Pre-Requisites

Before selection of site, the following points have to be taken into consideration for greater operational efficiency and cost effective production of mushrooms at the farm:

1. Chosen site should preferably be away from the municipal limits and entrepreneur should purchase sufficient land in one go looking to the future expansion.
2. The site should be serviced by a motorable road, or nearer to a road head to reduce costs on transportation of raw materials to the farm/finished product to the market.
3. Plentiful availability of water at the site either through a perennial source or should have sufficient underground water.
4. Easy availability of raw materials especially straw and poultry manure around the chosen site at cheaper rates in the area.
5. Availability of cheap labour in abundance.
6. Uninterrupted proper power supply at the chosen site.
7. Nearness to the market for the proper disposal of the produce.

B. Components of a Mushroom Farm

For round the year cultivation of this mushroom employing environment-controlled conditions a medium size plant would require under mentioned components.

1. Spawn unit

For producing in-house spawn for self requirement and for sale to other units. This will have under mentioned major components.

- a Cooking/autoclaving room:** For boiling the grains and sterilization of the bottles/ pp bags.
- b Inoculation room:** For inoculation of the sterilized bottles/ pp bags
- c Incubation room:** For incubating the inoculated bottles. Insulated and provided with AC.
- d Cold store:** For storage of prepared spawn for its further disposal

Besides above some ancillary structures like office, small lab space, delivery area, etc. may also be required.

Machineries required: Air conditioners, Laminar flow system, Autoclaves, BOD incubators, Boiler, Boling cattles, Refrigerators, racks, pH meter, gas stoves, etc.

2. Composting unit

This will have under mentioned main components for production of compost

- a Pre wetting area:** For dumping of raw materials and their pre wetting (uncovered).
- b Composting yard:** For making piles out of the wetted materials (covered)
- c Phase-I bunker:** For phase -I composting (incase indoor composting is employed).
- d Phase-II tunnels:** For performing pasteurization and conditioning of the compost.
- e Casing soil chambers:** For pasteurization of the casing soil.
- f Spawning area:** For spawning of the prepared compost

Besides above certain ancillary rooms like boiler room, underground service room, store room, workers room, etc. would also be required.

Machineries viz., boiler, blowers, air handling units, gratings, digital thermometers, compost retaining boards, ventilation system for phase -I bunkers would be required by a medium size farm (up to 200 TPA). Large farm besides above may require a front end loader (Bobcat) and other compost handling equipments including turner, filling line, etc.

3. Cropping unit

A cropping unit will have series of insulated rooms of designated size depending upon the production targets. Besides rooms there will be AC/ compressor room, packing room, central corridor housing air handling units and pipelines.

Machineries required: Insulated doors, central chilling station (ammonia or freon based), air handling units, computer based controllers (optional), racks, and trolleys, harvesting trays, etc. would also be required. For continuous electric supply to phase-I, phase- II tunnels and cropping rooms, generators of desired capacity would also be needed.

4. Post harvest handling unit

It will have under mentioned components:

- a Pre-cooling chamber (cold room):** For storing the mushrooms before canning
- b Canning hall:** For housing the canning line for processing
- c Laboratory:** For quality control of processing
- d Store:** For housing the processed can
- e Office:** For sitting of the staff
- f Machinery required:** Canning line of desired capacity (details in chapter 22)

5. General layout/location of various units

The layout is so planned that all the infrastructures required to be built are accommodated in least possible land without over looking mushroom cultivation requirements. The general layout of a mushroom farm has to be carefully planned after selection of the site, keeping in view the several factors including accessibility of road to the composting yard as raw materials are to be dumped here for their processing to the compost. Wind direction is also kept in mind for choosing the location of the composting facilities. During most of the time of the year wind should flow from cropping area to the compost yard and not vice versa. Phase-I bunkers are constructed in line nearer to the phase -II tunnels for their operational convenience and also to avoid heat losses. The

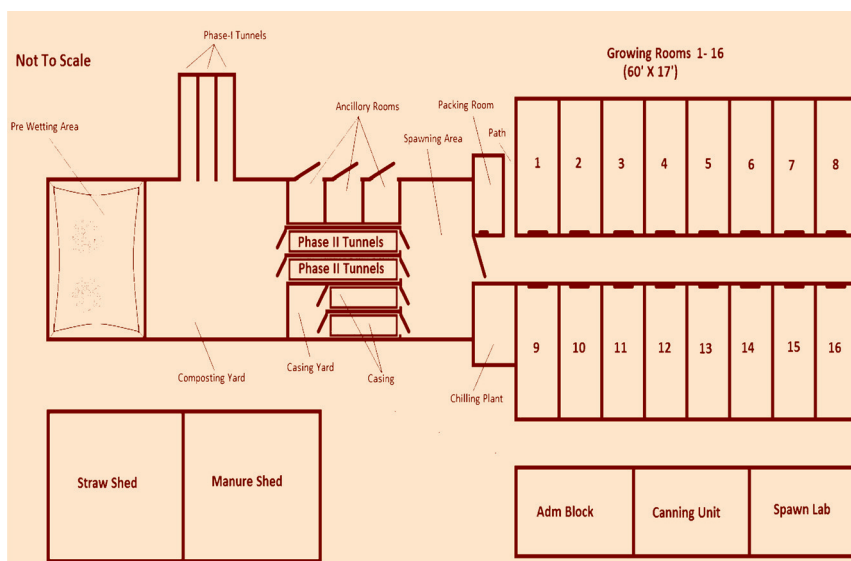


Fig. 8.1. General layout of the farm

bulk chambers are built nearer to the phase-I bunkers. Both these structures are preferably built away from the road at the distant end of the yard so that the distant end of the phase-II tunnels opens nearer to cropping rooms and away from composting yard (Fig. 8.1). The cropping rooms are built away from composting area for reasons of cleanliness and avoiding contamination by pests and pathogens. The casing pasteurization chamber is built nearer to the composting yard or within the composting yard with small platform for preparing the casing soil (Fig. 8.1). Enough space for future expansion of composting yard, construction of more phase-I & II chambers and growing rooms should be left vacant for planned development of a mushroom farm in a phased manner. Spawn unit is built far away from the composting yard and nearer to the cropping area. Processing unit can be a separate entity or can also be built within the building housing cropping rooms.

The foundation of the buildings is dug on the firm ground. The underground water pipes, electrical cables and sewers are laid well before the actual construction starts. The entire site area should preferably be fenced or brick walled for security reasons.

In areas where land is scarce, double story cropping houses can be built to economize on space. The cropping rooms are generally built in double rows with a path/gully in between for various operations and services.

a. Composting unit

The components of composting unit will depend upon the method of compost production chosen. If one is going for indoor compost production, in such a case requirement of composting yard will be greatly reduced and it will be 1/3 of the normal yard required when one has chosen SMC. Now a days trend is for indoor compost production due to environment legislation. In such a case a small pre wetting area, and small covered composting yard would be required with minimum of two-phase-I bunkers and one phase-II tunnel. Size of all these structures would depend upon the production targets of the unit and size and numbers of the tunnels.

b. Prewetting area (PWA) (lagoon)

This area is constructed nearer to the road. It is a simple cemented structure having a saucer like depression in the center so that it looks like a lagoon and water remain collected during the prewetting of the compost ingredients (Fig. 8.1). Center of the lagoon should be around 1 ft deep. Excess water of the lagoon is collected in a goody pit built specially for the purpose at a convenient place around PWA for its reuse. Floor of the PWA should be such that it can withstand the load of the front-end loader while performing the wetting operations. It is usually not covered and is open to the sky. PWA terminates in the composting yard. Water connection with 2"-3" dia. pipe should be available in PWA permanently with additional portable hosepipe for use during pre-wetting. One dewatering pump with a hose should be installed in the goody pit to pump out the run-off water for its reuse during pre-wetting. Water in the goody pit may be aerated continuously to avoid foul smell.

c. Composting yard

The composting yard (Fig. 8.2) is required for phase-I of composting. It is a prerequisite when one is going in for short method. The composting yard should necessarily be a covered shed with 2-3 ft sidewalls on the two sides (length wise) where rain will not interfere in the normal process of composting. The foundation of the composting yard should be laid on a firm ground and it should necessarily be reinforced if mechanization of the composting yard has to be done as it has to withstand the load of heavy machines. The floor is given a run-off of 1 cm per running meter away from the bulk chamber and towards the goody pit end.



Fig. 8.2. Composting yard including Phase-I bunker

The roof of the outdoor composting platform is built on tresses or RCC pillars 16 ft high with a GI or any other suitable roofing. The covered composting yard should be big enough to hold maximum compost stacks for phase-I of composting. When adopting indoor compost production wetted ingredients are just made up into a heap for 3-4 days and do not require rick formation in such a case a small platform can suffice the purpose. However, a large composting yard would be required if SMC is adopted. On an average

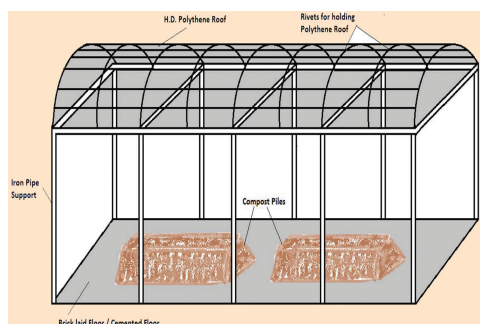


Fig. 8.3. Low cost composting yard

one ton compost occupies about one meter length of the composting yard, with an extra space of 2-3 m left on each side for turning with machines. Two bulk chambers will have a platform with 10-15 m width. For two bulk chambers of 25 tons capacity each, a composting yard of 25 m x 13 m should be good enough to concurrently run phase-I operation at a time for both the chambers. A drain should run on the two sides of the platform to facilitate periodic cleaning. A few three phase 15 amp. power connection

should also be provided at the composting yard for operating machines like hopper regulator, compost turner, filling lines, etc. The yard should be well lighted with tube lights and strong searchlights to facilitate round the clock operations at the composting yard. An overhead water tank is necessary, particularly where water is scarce, to store water for timely operations. The floor of the composting yard for long method of composting should be simply cemented/brick layered with a low cost roofing of high-density polythene fixed on iron tubular structure or it can also have thatched roof (Fig. 8.3). In practice (90%) of the farms cultivating this mushroom seasonally are preparing their compost in the open fields and do not have any specially built composting yard built for the purpose.

However, such growers are facing lot of disease and pest problems. We recommend that the compost by long method by seasonal growers should at least be prepared on a cemented platform- let it be open to the sky.

d. Phase-I tunnels (bunkers)

This facility is required when indoor composting is employed at the farm. These are specially built non-insulated tunnels having full width opening at the front (Fig. 8.4). Dimension of the bunkers would depend upon the output of the compost required. Generally the bunkers are 1.5 times more the size of the phase -II tunnels. It has a plenum (ventilation duct) constructed below the actual floor. A perforated concrete floor having around 1 cm openings at a distance of 1ft each to the entire floor area is constructed above the plenum or it has simple RCC /steel gratings having 20% opening to the entire surface area of the tunnel (Fig. 8.5) which is serviced by a centrifugal fan having 1/4th the capacity of phase two blower which means that a ventilator having air displacement of 50 m³/hour ton of compost at 50 mm WG water pressure would suffice the purpose. A plenum floor involves pressurizing the entire airspace beneath the concrete floor, allowing the air to move up into the substrate through the holes or through series of slates. Alternatively the bunkers have no plenum and several pipes (5-15 cm dia) are buried in the floor along the full length of the bunkers having small holes (5-10 mm dia) at a distance of 15 to 30 cm each (Fig. 8.6). These pipes converge into a manifold, which in turn is connected to a high-speed blower fan (around 1000 Pascal). A timer is usually attached to the blower, which pulsates the air in the bunker periodically as per the setting of the timer. A minimum of 2 such phase-I tunnels (bunkers) are required.



Fig. 8.4. Bunker



Fig. 8.5. Gratings over the plenum

A bunker for 20-25 ton compost output at the time of spawning may have the dimensions 45 x 10 x 8 with 9 pipes of 2.5 m dia. at distance of 1 ft. (6" from the wall). To equalise the pressure either the pore size may be increased or distance between the holes may be gradually decreased from 1.5 ft. to 9". These 9 pipes are linked to a bigger pipe of about 6" dia. which inturn is linked to a centrifugal blower.



Fig. 8.6. Bunker with aerated pipes

i. Pasteurization facility

A modern farm employing either indoor method or SMC essentially requires this facility. The bulk pasteurization chamber is principally used for phase-II of composting for pasteurization and conditioning of the compost. For this purpose, an insulated chamber is built with facility for steam injection and controlled recirculation and fresh air entry in the tunnel through a blower. The insulated chamber is built with purpose of cutting off the external environment and simulating a desired environment inside for controlled fermentation of the compost ingredients.

In Bulk pasteurization chamber compost is handled in bulk inside the tunnel or chamber and hence the name bulk chamber. The compost after phase-I is filled into specially built chamber, which is properly insulated and provided with steam connection and air blowing system for re-circulation. The compost is filled in the chamber on top of its grated floor built over the plenum. The plenum has an air circulation duct used during pasteurization/conditioning (Fig. 8.7).

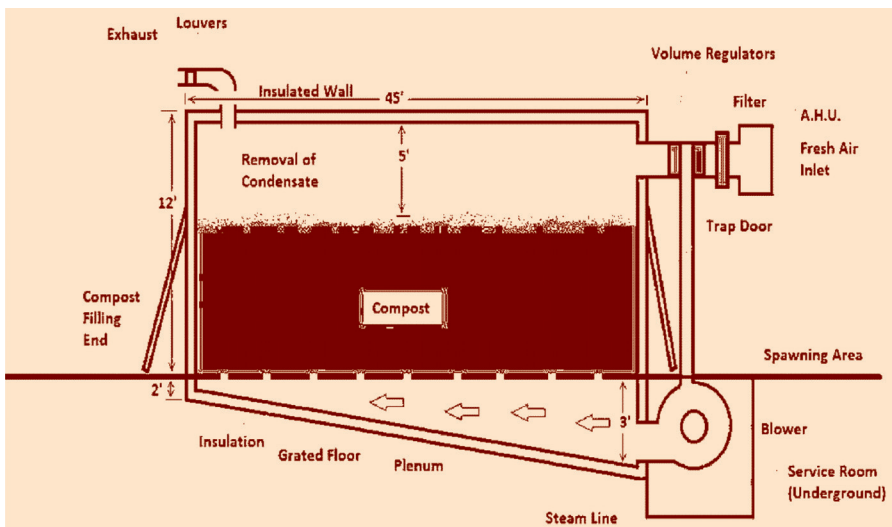


Fig. 8.7. Cross-section of the bulk chamber (45' x 9' x 13')

The bulk chamber should be constructed on one end, (away from road) of the composting platform. One end of the bulk chamber should open into the platform and the distant end in the clean spawning area. The foundation of the bulk chamber should be dug on a firm base ground. The floor must be laid with a good run-off provided with a drain to facilitate cleaning. It is pertinent here to note that this floor is given a slope towards the service area end (blower end). A large tunnel will be around 90 cm deep towards the blower end while it will be around 15 cm deep towards other end (filling end). Floor should be properly insulated with thermocol/glass-wool 5 cm thick (15 kg/m² density).

The insulation is covered with isolating membrane of PVC sheeting followed by 5 cm cement floor and finally the finish. Such floor is constructed for both cropping room and the chamber. The walls should be 9" thick (one brick lengthwise) built over the concrete foundation. The length and breadth of the bulk chamber will vary, depending upon the amount of compost to be treated in the chamber, with the height of 13 ft, the roof is made of 4" thick RCC. The walls, ceiling and the floor below the plenum are insulated with 5 cm thick insulating material (15 kg/m² density) necessary for effective insulating effect during pasteurization and conditioning of the compost. Required K value of the insulating material should be around 0.5-0.6 kcal/ m²/h. Air leakage in bulk chamber must be prevented at any cost. The bulk chamber has two floors one is real insulated floor while another false or grated floor, which is laid above the actual floor or plenum over the ventilation duct. The grated floor must allow the air to pass through, for which approximately 25-30% of the floor area is left in the form of gaps for ventilation/circulation of air and steam. The plenum is divided with a perforated brick wall (one or two) in the centre for supporting the grated floor. The gratings can be made of wood (painted with bituminous paint), coated iron strips mounted on angle iron frame or with concrete beams. Alternatively a concrete floor can be poured over the plenum as in case of phase -I tunnels having openings. If nylon nets are to be used for mechanical filling and emptying, then cemented grated floor with appropriate RCC strength is built specially for the purpose. The doors of the bulk chamber are made of angle iron or wooden frame with 2-3" insulation in the middle and covered on both side with aluminum sheets, else they can also be made up of puff panels. The chamber will have two exhaust vents, one for recirculation exit and the other for exhaust of gases on introduction of fresh air via dampers.

The steam line is also connected at the entry point of the blower. The walls and ceiling can be damp proofed by coating bituminous paint on inside over the cemented surface, which will also serve as an effective vapour barrier. The grated floor inside and the work floor outside should be of the same height for operational convenience especially when tunnel has to be filled mechanically.

Two types of tunnels (bulk chambers) are in use, two door bulk chambers and single door bulk chambers. In the single door bulk chamber, the same door is used for filling and emptying and the other end is utilized for fixing installations (blower, etc.). In double door bulk chamber, one door is used for filling (which opens into the composting yard) and the other for emptying (opening into the sterile spawning area).

The bulk chamber can be filled/emptied manually or by conveyer belts. The uses of machines for filling/emptying are labour saving, time saving and ensure homogenous filling as well as maintenance of absolute cleanliness during operations. For mechanical emptying two nylon nets are used, one fixed over the RCC grated floor (gliding net) and

the other moving over the lower net (pulling net). The compost when brought out is fed into the spawn-dosing machine where requisite amount of spawn is mixed with the compost and the seeded compost is then poured into clean polythene bags for transport to the growing rooms.

The dimension of the tunnel for producing 20-25 ton of compost are 36' x 9' x 13'. One may replace the plenum with plastic pipes fitted with spigots (Fig. 8.8). The centrifugal fan can be placed at the bottom as well as on the roof (Fig. 8.9) depending upon the space and design.



Fig. 8.8. Plastic pipes ready for spigot fitting
(Source: <http://www.21food.com/>)

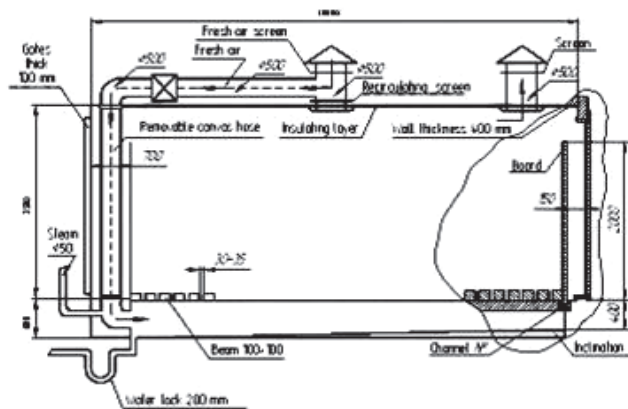


Fig. 8.9. Line drawing of Phase-II tunnel for 20-22 ton compost output
(Source: <http://www.agaricus.ru>)

e. Air handling units of the tunnel (AHU)

For effective pasteurization and conditioning of the compost in the tunnel specific requirements of air and ventilation are to be met, which are generally met by providing/ installing AHU in the tunnels (Fig. 8.10). Effective pasteurization and conditioning is attained when 150-200 m³ air per ton of compost per hour is blown through the compost mass. For this purpose high speed centrifugal fan is chosen and is placed on the slope end of the ventilation duct in the underground service area. Compost is spread over the plenum on the grated floor in about 2-2.2 meter thick layers. Nylon nets are generally placed under the compost if mechanization is necessary. These together give a resistance of around 60-65 mm WG during pasteurization taking together the resistance of the air ducts, the in and out openings, the perforated floor, etc. the static pressure of the blower fan should be around 100 mm WG at 150-200 m³ air per ton of compost per hour. Blower fan must be well protected internally and should be made up of sheet steel. Aluminum is ideal for air ducts and should at least be 2 mm thick and there should not be any leakage in the duct system. Ducts are generally insulated with glass wool or any other suitable material. Fresh air is regularly required in the tunnels and since this air is drawn from the open atmosphere, chances of fungal spore's contamination are likely and hence the incoming air in the ventilation duct should be filtered and should pass through 2 mm fungal spore filters. The pre filters and filters should be washed at regular intervals.

The inlet and exhaust openings must be fitted with a flap valve, which opens only when positive pressure is created inside the tunnel. The dimensions of inlet and exhaust openings should be the same.

Since, India is a tropical country where temperature during summer months goes above 45°C. Cooling of compost for spawning during this period becomes difficult by simple introduction of fresh air. Special cooling arrangements are therefore required to be made in the AHU of the tunnel for this purpose. A ten ton capacity cooling equipment or cooling coils from the central chilling plant is installed at the top of the AHU or such coils can be fitted in the blower section of the AHU. This arrangement is very effective in cooling of the compost in tropical areas during summer months. Installation of such facilities however requires heavy investment. Compost during these months can satisfactorily be cooled during nights when the temperature is low.

f. Casing pasteurization chamber

Casing pasteurization chamber is just a mini bulk chamber. It has all the necessary components as required for the tunnel. Only difference is that the plenum is not having any slope and capacity of the blower for proper steam injection and its uniform distribution inside the casing mass is around 1/4 the capacity of the tunnel (Fig. 8.11). The size of the chamber will depend upon the size of the compost chamber and the size of the growing rooms. One chamber load should provide casing for one compost lot from each tunnel. The casing inside the chamber can be treated in the bulk and in such case it is filled up to the height of 90 cm only as against the tunnel where compost is filled upto the height of 2-2.2 meters. Else casing after wetting is filled into the perforated wooden/aluminum trays which are stacked one over the other inside the chamber and steam treated at 65°C for 6-8 hours. This chamber can be built near to the composting yard or within the composting yard with a separate casing mixing platform (Fig. 8.1).



Fig. 8.10. Tunnel with air handling unit

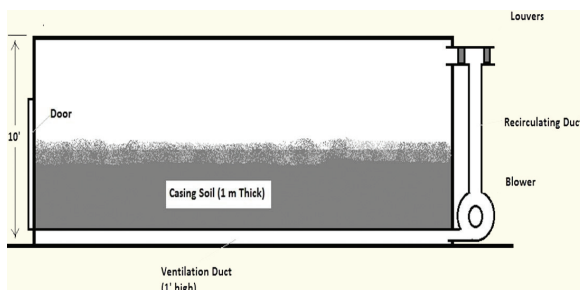


Fig. 8.11. Casing pasteurization chamber

g. Spawn unit

The layout plan of a spawn laboratory is given in Fig. 8.12. A total built in area of 60' x 30' x 12' should be good enough to house the entire spawn unit. This area will be divided into different work areas like boiling/autoclaving room, inoculation room, incubation room (insulated and with AC), cold room (heavily insulated with chilling facilities), store, office and delivery area.

h. Cropping unit

Since mushrooms are grown indoors under simulated environment specially created for mushroom growth, the cropping rooms are required to be built specially for the purpose. Two types of cropping rooms are built suiting to particular requirement - those required for seasonal growing and those for environment controlled growing round the year (Fig. 8.13).

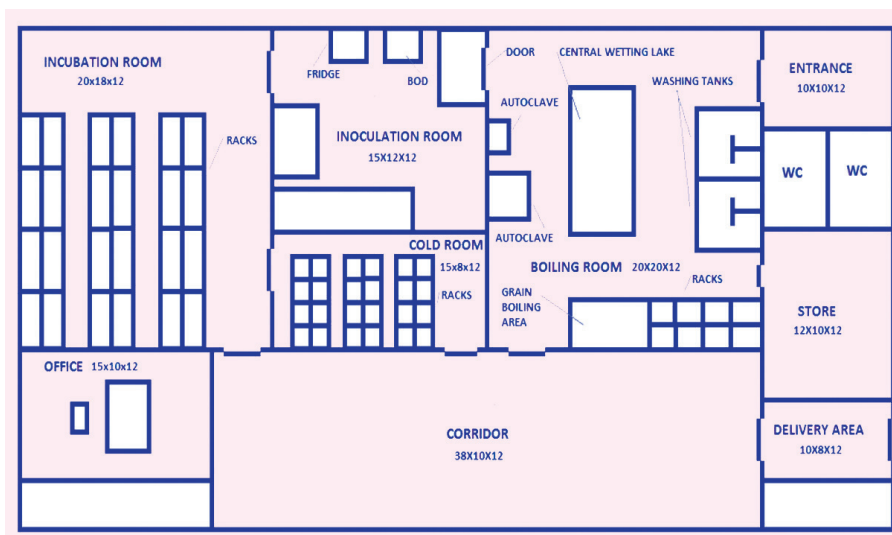


Fig. 8.12. Layout of plant of a spawn lab

Seasonal cropping rooms: Seasonal cropping rooms are simple rooms with modifications for maintaining various growth parameters. These cropping rooms will have a cemented floor, cemented walls, cemented ceiling or a false ceiling with arrangement for forced air circulation inside. The seasonal cropping rooms are built of simple brick walls with roof made of asbestos sheets and a false ceiling. The room is more or less made air tight to make the air handling system work effectively for obtaining necessary air changes during growing. No insulation is required for seasonal growing rooms, as it will not allow heat dissipation from the room efficiently. These simple rooms are used for seasonal mushroom growing, coinciding various phases of growth with prevailing outside temperatures. No energy is generally used for heating/cooling of the rooms under seasonal growing conditions. However few units in plains have installed heavy-duty coolers to bring down the temperature in summer conditions. The cropping rooms for seasonal growing can also be made with a thatched roof and a false polythene ceiling. The door is installed on one end and the exhaust vents on the opposite end of the door (Fig. 8.14). The mushrooms are grown on beds made out of bamboo sticks and sarkanda stems (a plant abundantly growing as a weed in North western plains of India). These growing rooms can also be built as low cost structure, steel pipe frame with high-density polythene covering from outside. The real low cost growing houses built in rural areas are made of walls, roof and door of sarkanda.

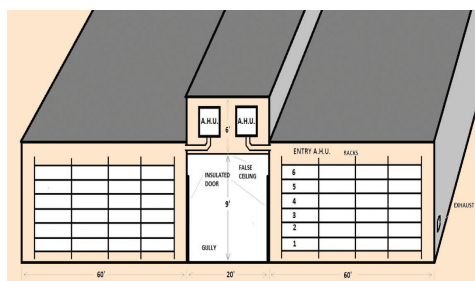


Fig. 8.13. Cropping section of the mushroom unit

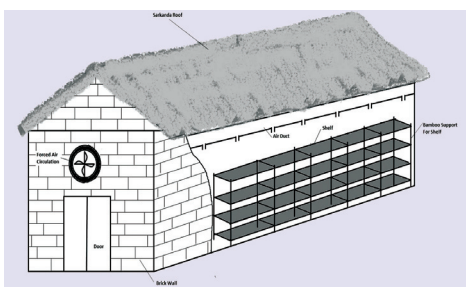


Fig. 8.14. Cropping section of the mushroom unit

The mushroom houses made with bamboo frame and synthetic fiber cloth material, both inside and outside, with paddy straw insulation in between has also given good results under hill conditions for seasonal growing.

i. Environment controlled cropping rooms

The environment controlled cropping rooms are built like hermetically sealed chambers where the air movement is controlled either manually or semi automatically with mechanical control systems. These cropping rooms are appropriately insulated and the dimensions of a cropping room are determined by the amount of compost to be filled into the room. Rooms with greater length and narrower width gives better results as far as air handling inside the room is concerned. A cropping room, with a capacity to take compost from one bulk chamber, is considered advantageous as one bulk chamber load can straightaway be filled into one cropping room. Further, cropping cycles to be taken will determine the numbers of growing rooms in the unit. Now a days 60 days cropping cycle is generally taken and in this manner a minimum of six crops are taken / room in a year. In such conditions a minimum of 12 rooms are required to have constant supply of mushrooms from the unit round the year. In this case every room is filled with the spawned compost every after 5 days. Both bulk chamber and cropping rooms of 20-25 tons compost capacity are considered to be operationally efficient, as the filling/ emptying operation and spawning can conveniently be done in one day when machines are not to be used. However, bigger units may have the growing rooms handling compost to the tune of 60 tons or more. Growing rooms are such designed that maximum compost can be accommodated in least possible area without over looking to the mushroom growing requirements. To give an example a room size of 60 x 17x 13 ft can easily accommodate 20-25 tons of compost when cultivation is done in shelves or bags.

The foundation of growing rooms should be laid on dry and firm ground. The floor is laid as explained for bulk chamber. The walls will be made of one brick thickness (9" thickness) and ceiling made of 4" thick RCC. The growing rooms will have a single insulated door and 2 vents for exhaust on the back wall 2-3 ft above ground level. One opening is provided on top of the door for entry of the Air Handling Unit (AHU) delivery duct or for fresh air intake inside the room through AHU. The walls, ceiling and floor should be insulated with 5 cm thick insulating material. The room should be made airtight and all leaks closed to prevent ingress of heat from outside. The cooling, heating and forced air circulation in the growing room is done via AHU installed for each cropping room individually. The floor and walls of the cropping rooms should have a smooth finish.

j. Structural details special to cropping rooms

i. Floor

The floor must be well laid out and should be strong enough to take the heavy load of metal racks to be kept inside for growing mushrooms. The floor should be insulated with insulating material 5 cm thick (sheets of thermocol or glass wool or polyurethane). The insulation should be protected by a PVC sheeting, below and above, against moisture. It is then covered with wire mesh and finally 5 cm thick concrete floor is laid on top, which is given a smooth finish. The floor should have slight slope towards the entry point for discharge of cleaning water and placement of formalin trough for foot wash. The trough is connected near the wall to an exhaust drain to carry washings from the room. The water discharge hole is protected at this point to prevent leakage of air from the growing room. PUF pads can also be used specially in place of wall between rooms.

ii. Walls

The walls are made of brick 22.5 cm thick, which are given a smooth finish with cemented plaster. The insulation sheets are fixed on the walls (5 cm thick thermocol, glass wool/polyurethane), with the use of hot coal tar. Holes are drilled on four corners of the sheet/inside the cement wall for expansion fasteners which are fixed by screwing in the nail with 4"-5" long steel wire tied on its head. The wire hangs out of the sheet to be used for tightening of wire net fixed on top of the insulation. The layer of cement plaster is then applied (2 cm) on top of this and given a smooth finish. Bituminous paint is applied on cement plaster as a vapour barrier. The painting can be avoided in cropping rooms if the cook out is not done by steam. This wall will be good enough to give a K-value of 0.5-0.6 kcal/m²h, even lesser and will facilitate proper control of climate inside the cropping room.

iii. Roof

The roof is made of RCC (1 : 2 : 4) 12-15 cm thick. The inside is given a cement plaster finish for application of insulation (as explained for the wall). The roof on the outside is protected by tarring it on top, followed by 10 cm thick loose soil, 5 cm thick mud capping and finally the tiles. This will protect the roof from weathering effects of rain and will ensure longer life of insulation and prevent seepage of moisture into the room in rainy season. In hilly areas with a high rainfall index, slanting GI sheet roof over the insulated RCC roof will be excellent and in that case mud capping/tiling of the roof is not required.

iv. Doors/vents

The doors of the bulk chamber and the cropping room are made of wood or angle iron frame covered on inside and outside with aluminum sheets/GI sheets with insulation of 5-7 cm in the middle. The doors will have a rubber gasket lined on inner periphery so that the door becomes air tight when closed. The door will operate on hinges, with a strong locking latch for opening and closing of the door. The exhaust vents are fitted with wire net, louvers and insulated lids. The louvers allow the CO₂ laden air to exhaust under positive pressure created by the blower inside the air handling unit.

v. Lighting arrangement

There should be a provision for tube lights and a mobile strong light for inspection in each cropping room. The tube lights should be protected with water proof housing. The tube lights should be fitted on all the walls vertically at various heights to facilitate lighting of all beds. There should be provision for a few electric points (5 and 15 Amp.) for operation of water spraying equipment and CO₂ measuring instruments.

vi. Water connection and sewers

One clean water pipe line (1" or 1.25") with tulle pump installed to it for delivering clean water for spraying should be provided in each room. Underground drainage line for carrying the washings from the room and wash basin discharge should be laid before construction of the building. This waste water line should be connected to the common sewer. In H.D. polythene cropping rooms, sunkun traps on the floor for fresh water and drainage water are provided inside the growing house with each trap of 1' x 1' x 1' dimension fitted with an iron lid on top. It is desirable to lay underground drainage in the

central gallery in advance of erecting the structure for carrying away the waste water/ washings from the cropping rooms.

vii. Gallery

The gallery between the rows of cropping rooms should be wide, (12-15 ft) to allow efficient performance of various operations. The height of the gallery should be same as for the growing rooms alternatively it may be about 8' with a false ceiling, leaving another 5 ft above for pipeline and space for AHUs.

viii. Racks

Racks are made up of the angle iron for horizontal and vertical support with iron mesh strips used for the shelves for housing compost. Length (vertical axis) of the racks is generally made up of 5 cm thick angle while horizontal support is made up of 3.5-4 cm thick. Width of the each shelf on the racks should not be more than 135 cm in any case as width more than that creates hindrance in performing various operations during cropping and most important of that is harvesting. Cultivation can be done in bags or in shelved beds. Five to seven rows of shelves (depending on height of the room) can be provided one above the other in the racks keeping a minimum distance of 60 cm in between. This distance can slightly be narrowed down if cultivation is employed in shelved beds. In such a case all the four sides of the shelf should be provided with 15- 20 cm high iron sheets for housing the compost in the beds. If more than 5 shelves on each rack are kept in the room than there should be provision of trolley running in between two rows of racks just above the fourth shelf for carrying out the various operations. Depth of the compost in shelves is generally kept at 15-20 cm while bags can be filled up to the maximum height of 30 cm. A room of standard size (60 x 17 x 12 ft) can accommodate 2 rows of racks each 4.5 ft. (135 cm wide). This will absorb 9 ft (270 cm) of the room and the rest 8ft can be used to have one central path of 3 ft. and 2 side paths of 2.5 ft. Length of each rack would be 52-55 ft.

ix. Air handling unit

This unit is employed for creating proper weather inside the growing room specific to white button mushroom. Air handling unit is generally installed in each room at the top of the door, which is made up of aluminium or G.I. Sheets. In certain cases it can also be placed on the top of the floor of the growing room or in the corridor. Indirect cooling of air through chilled water (5-6°C) is generally employed in mushroom cultivation. Mushroom generally require 225 m³ of air per hour per ton of compost. To meet this requirement a high speed centrifugal fan of required capacity having working pressure around 50 mm WG is generally mounted in the body of AHU (Fig. 8.15). Alternatively if the capacity of the growing room is to accommodate around 20-25 tons of compost, then a fresh air fan of 600 mm dia of low pressure can also be chosen for this purpose, but in such case a booster fan of 375 mm dia will also required to be mounted in AHU for extracting fresh air from outside (Fig. 8.16). In AHU cooling coils, humidifiers, heaters, eliminators and other components of AHU are mounted on the back of the supply air fan. Cooling coils are generally connected to the chilling unit via insulated ducts, which supply chilled water at 5-6°C to these coils. This water is generally chilled in an insulated tank or by cooling unit comprising of a compressor, condenser, evaporator and a cooling tower. Heating unit of AHU can employ strip heaters or steam through a low-pressure boiler. Humidifiers can use free steam from the boiler to generate required humidity in combination with air



Fig. 8.15. Modified AHU with fresh air fans

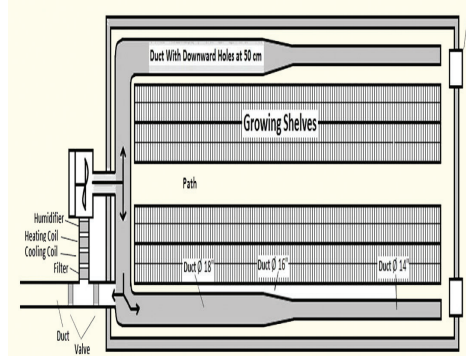


Fig. 8.16. A standard AHU with centrifugal blower and ducts inside the growing room

pressure or can employ fine jets, which produce fine mist of water in the humidifier section of the AHU. PVC eliminators, eliminate the free water going inside the growing room. Booster fan in combination with supply air fan supplies fresh air inside the AHU through fresh air dampers. Since fresh air coming from outside atmosphere may contain fungal spores, which may contaminate the crop, this air is generally passed through pre filters and a HDPE micro filter section (2-5 μm). The AHU has a mixing chamber with recycling dampers, which can regulate supply of fresh air or room air inside the growing room. Out let of the AHU is connected to the distribution duct in the growing room, which is generally made up of PVC sheeting having its end month closed. It hangs below the ceiling in the central corridor of the room. This duct has ports (5 cm dia) facing downward at a distance of around 50 cm each. When the air is blown inside the room via AHU a positive pressure is created and CO_2 laden air of the growing room is expelled in the atmosphere through an outlet. In such cases back vents are not provided in the growing rooms. Alternatively AHU can be so fabricated having provision to exhaust CO_2 laden air of the growing room in the atmosphere through an out let. In such cases back vents are not provided in the growing rooms.

Central cooling unit can employ ammonia, freon or vapour absorption machine (VAM) for cooling purpose. If size and capacity of growing unit is small, say 250 MT per annum employing around 12 rooms then cooling employing evaporator, inside the AHU can also be chosen. In such a case each AHU will be a self contained cooling unit, employing, compressor, condenser and an evaporator. This unit will also have heating and humidifying arrangements.

k. Processing unit

Design of the processing unit with its various components is given in the Fig. 8.17 & 18. Utmost strict hygienic conditions are required to be maintained in the canning hall and hence special care has to be given at this front while designing/ constructing canning unit. The floor must be well laid off preferably having kota stone having slope



Fig. 8.17. An automatic canning line

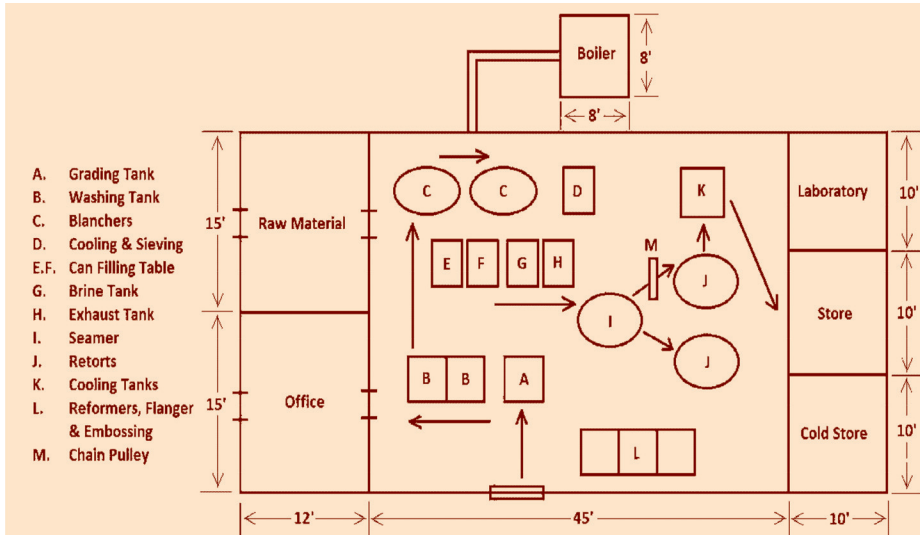


Fig. 8.18. Design of a canning unit

at one end. Walls should have ceramic tiles up to the height of 5-6 ft. Height of the canning hall should be not less than 14 ft in any case. Surrounding where this facility is built should be clean and away from the composting yard.

Floor of the canning hall should have enough strength to support the weight of different utilities to be installed required for the canning operation. Canning hall should be big enough looking to the future requirements or processing of other items. All the doors and windows should have wire mesh shutters to prevent the entry of insects and flies. Three-four exhaust fans should be installed in the hall at the appropriate places. Cold room should be properly insulated with minimum of 10 cms insulating material and separate product cooler of required tonnage should be installed to it. FPO license is required for processing purpose.

Further Readings

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2. Vijay, B. and Gupta, Y. 1997. Cultivation of white button mushroom. Technical Bulletin number. 83p.
3. www.agaricus.ru

Crop Management of White Button Mushroom (*Agaricus bisporus*)

O.P. Ahlawat

Button mushroom cultivation has two major components, composting (preparation of substrate/compost), and the crop management, (raising of mushroom crop). The substrate preparation has undergone scores of innovations/improvements suiting environment protection laws in many developed countries. At the same time, casing medium has also been standardized with use of peat and its alternative materials (FYM, Spent Mushroom Compost and Coir Pith) with prime objective to improve productivity and quality of mushrooms. Similarly, the crop management techniques have also been improved upon to harvest highest possible mushroom yield over a shortest period of time. All the operations/applications done after completion of composting are handled under the head crop management. These include:

- A. Agronomic crop management
- B. Environmental crop management

A. Agronomic Crop Management

Agronomic crop management deals with the compost quantity to be filled per m² bed area, moisture content of compost, spawning method employed, compost thickness in a bed or bag, casing application and thickness, watering regimes employed, harvesting of crop and after care, pest management, hygiene maintenance and so on. However, more important among these are

- 1. Spawning and spawn run
- 2. Casing materials, casing treatments, casing application, case run and pinhead formation

1. Spawning and spawn run

The steps involved are (Fig. 9.1)

- Good quality compost with temperature of 25°C
- Mixing of grain based spawn (@ 0.5-0.7% of wet compost weight) of *A.bisporus* under clean conditions (i.e. with clean hands and pre-sterilized area)
- Filling of spawned compost into polythene bags (12-15" depth) or beds (6-8" depth)
- Little compressing and levelling of spawned compost



Fig. 9.1. Process of spawning and filling in bags for white button mushroom

- Loosely closing the mouth of polythene bags filled with spawned compost (Covering with a clean newspaper / plastic sheet if filled in trays/shelves)
- Shifting the compost filled bags in cropping rooms with a temperature of $23 \pm 1^\circ\text{C}$ (air temp.), RH of 95% and high CO_2 conc. (1.0-1.5% strain dependent), and keeping the bags under above conditions for 12-14 days
- Completion of spawn run (change of dark brown compost mass in to light brown colour)

Precautions

- Use of fresh pure culture spawn
- Spawning under clean conditions (preferably under positive pressure created using bacterial filters before inlet fans and air curtains at doors)
- Proper treatment of spawning area and tools with formalin, and cleaning of hands with dettol
- Maintaining good hygienic conditions during spawning by keeping all the doors/ windows closed

2. Casing and case run

Casing is a 3-4 cm thick layer of soil applied on top of spawn run compost and is a pre-requisite for fructification in *A. bisporus*.

a. Casing materials

Earlier sub-soil material or organic matter rich soils were used as casing in button mushroom cultivation. Presently peat is the most desirable casing material used world wide with excellent mushroom yields and superior fruit body quality. However, peat is not available in India. The other alternative recommended materials are,

- Well decomposed Farm Yard Manure (FYM) preferably two years old
- Well decomposed Spent Mushroom Compost (SMC) (two years old anaerobically decomposed)
- Composted coir pith (coir industry waste) (well decomposed & water leached)
- 1:1, 2:1 and 1:2, v/v of well decomposed FYM and SMC
- 1:1, v/v of decomposed FYM or SMC with composted coir pith
- Decomposed powdered bark of some forest trees

- Paper industry waste
- Burnt rice husk is also in use along with decomposed FYM (2:1, v/v) in seasonal cultivation of button mushroom in Hayrana and Punjab with reasonable success

b. Quality of casing materials

- Soft texture
- Light weight
- High water holding capacity
- High porosity
- Deficient in available form of C and N
- Neutral pH (7.0 – 7.5)
- Low conductivity (400-600 μ moh)

c. Casing treatment

Casing material should be treated properly before its application on the spawn run compost and the steps involved are:

- Make a heap of casing material
- Wet it up to 50-60% water holding capacity
- Fill in trays and shift them to pasteurization chamber
- Steam pasteurization at 60-65°C for 6-8 hours
- Auto-Cooling

Alternatively,

- Make a heap of casing material on a cemented platform
- Wet it up to 50-60% water holding capacity
- Drench the wet casing with formalin @ 1 litre/m³ (40% formaldehyde) by mixing with shovel
- Cover it with polythene sheet and seal the outer periphery thereafter by pouring sand/soil on outside margin
- Keep the material for 24-48 hours in sun for fumigation effect
- Remove the cover after 48 h and expose the material to open air and sunlight by spreading over with clean tools and permitting the formalin fumes to escape in to air for 2-3 days before it is used as casing (formalin treatment effect decreases at low temperature due to inadequate fumigation)

d. Casing application (Fig. 9.2)

- Unfold the fully spawn run bag and make the top surface even by gentle pressing with hands
- Light spray of water on spawn run compost
- Application of 4-5 cm thick layer of casing uniformly using iron rings of 4 cm height or wooden blocks
- Water sparay in installments immediately after casing application



Fig. 9.2. Process of casing soil application for button mushroom cultivation

Precautions

- Casing material should not be sieved but used as such with clumps, which permits more air spaces in casing
- Top casing surface should have small mounts and valleys
- Care should be taken to prevent re-infection of the casing materials
- Store casing material in a sterilized /clean room before use in polythene bags or synthetic cloth bags
- Apply water to casing in a few installments so that water does not run into spawn run compost

e. Case run and pinhead formation

Case run is done at a temperature of $24 \pm 1^\circ\text{C}$, RH-95% and $\text{CO}_2 > 7500$ ppm (strain dependent) for about one week. There is no requirement for fresh air introduction during case run. It is considered complete when mycelia come in the valleys of casing layer. After case run, the environmental conditions are changed by bringing down the temperature to $15-17^\circ\text{C}$ (air), RH to 85% and CO_2 to 800-1000 ppm (strain dependent) by opening of the fresh air ventilation and exhausting CO_2 . This change in environmental parameters induces pinhead formation in 3-4 days (strain dependent) time. The pinheads develop into solid button sized mushrooms in another 3-4 days (Fig. 9.3). At this stage, the air inside the cropping room is changed 4-6 times in an hour to maintain appropriate CO_2 conc. as CO_2 production is at its peak during first flush (actually peaks at case run).



Fig. 9.3. Arrangement of bags in cropping room and mushroom at button stage of development

3. Supplementation

Supplementation with protein rich supplements such as cotton seed meal, soybean meal, alfa-alfa meal, feather meal, etc. has been found to increase the mushroom yield.

Supplementation can either be done at spawning or after spawn run before casing. The later is more useful. Supplement is first grounded coarsely and denatured by treating with 5000 ppm formalin and before its mixing in compost. The practice normally increases the temperature of compost by 4-5°C and if done at the time of spawning or in poor quality compost, it results in killing of mushroom mycelium or increased incidence of moulds. If these problems are overcome supplementation can give 20-25% enhanced yield. Supplementation at casing in spawn run compost also helps in early and higher mushroom yield.

4. Ruffling

Ruffling of compost on completion of spawn run is done just before casing. This practice is particularly useful for round the year cropping when 5-6 crops are taken per year and cropping period is reduced to about 4 weeks, as this practice helps in exhaustion of compost earlier than normal. Ruffling of casing after a 3-4 days or so after casing is done by some growers to get uniform pinning.

5. Watering

Mushroom contains nearly 90% water and that gives us an idea how water is important for the crop. Mycelium gets water from compost during spawn run and compost + casing during case run and from casing during fruit body formation. Water level in casing is maintained in 2 ways. One way is by its regular spray when pinheads are pea sized and then by maintaining RH at 80-85% during cropping. If one of the factors, (water spraying and RH) during cropping is disturbed, it will affect crop productivity. Low RH during cropping will result in drying of beds, lightweight mushrooms, discoloration of mushrooms and crop losses. Drying of casing will seal the casing medium resulting in mat formation, which becomes impervious to water, and results in tremendous crop losses. Water has to be replenished in casing to accommodate the water losses from casing due to mushroom growth and evaporation. Lesser the water loss to room air, better it is. Bed moisture and RH are although two different factors, but are interdependent. Water spraying on mushroom beds at pin breaks should be avoided. The casing should be wet enough when fresh air is brought in and room temperature lowered. The wetness should be sustained till pin heads become pea sized, and that is the stage when bed will require additional watering to allow pea-sized pins to develop into button sized mushrooms. Watering to beds requires monitoring at each stage. RH in the cropping room is monitored by using dry & wet bulb thermometers. Two ordinary stem thermometers are put in the cropping room, placing one in the casing/compost bed and one hanging in the air nearby (few cm apart). Bed temperature is 1-2°C higher than air temperature. Computer control of AHU ensures application of cropping parameters with precision during spawn run, case run and cropping. The water used for irrigation (spraying) on mushroom beds should be clean, neutral in pH and free from salts, heavy metals and other impurities. Water good enough for drinking/watering for vegetables/field crops is also good for mushroom cultivation. It is desirable to test the quality of water before the mushroom growing is started at a particular site.

6. Harvesting and after care

Mushrooms with 4-5 cm dia., with hard pileus and closed veil are ready for the harvest. Mushrooms are harvested by holding them between forefinger and thumb, and rotating in clockwise/anticlockwise direction. The soiled stem portion is cut with sharp

edged knife and mushrooms are collected grade-wise in baskets. Dropping of the stem cuttings on the floor or the bed should be avoided, as these will promote the growth of undesirable microorganisms. Cleaning of mushroom beds and floor is recommended after each crop harvest. Fresh casing is applied at places from where mushrooms have been removed. Water is sprayed at the rate the mushrooms have been harvested, i.e. for every kg of mushroom harvested 1 litre of water is added after harvesting. Damaged pins/ mushrooms, if any, are also to be removed from the bed manually. If bunching of mushrooms is observed, then there is a need to address the climate controls for creation of optimal environmental conditions during pinhead formation.

Mushrooms after harvest are graded, packed in PP bags/card board boxes and preferably chilled at 4°C for 6-8 hours before sending to the market. The pre-market chilling enhances the shelf life of mushrooms. While harvesting care should be taken to keep the pileus free from casing soil, as it stains the mushrooms. Washing of mushrooms to make them extra white for increased acceptability in the market is undesirable, especially with Potassium metabisulphite solution. Unwashed mushrooms stay fresh for a longer period. Mushrooms should be handled carefully, and not bruised during the harvesting operation. Bruising will damage the mushroom tissue, which will turn the pileus dark/ pink on exposure to air. While packaging mushrooms in PP bag one should not forget to make a small hole (0.2 mm), as it will prevent the development of aflatoxins in transit or storage.

Button mushroom can be stored at 4°C for a few days without any deterioration in its quality but it is desirable to consume/market fresh mushrooms. Since button mushroom has a very short shelf life and it cannot be stored for longer periods, hence it requires processing for long storage. Mushrooms are best preserved in brine solution after blanching, either in cans or jars. The properly processed mushrooms stay in good condition for over a period of 1 year. It is possible to transport canned mushrooms over longer distances without any deterioration in their quality. But fresh mushrooms can only be transported short distances in refrigerated vans/by air to reach up to a remunerative market.

B. Environmental Crop Management

Mushroom is an indoor crop, raised in cropping rooms with simulated environmental conditions suiting to a particular mushroom. Hence management of crop environment becomes utmost important. It includes the temperature, RH, CO₂ concentration, air speed/ evaporation rate over crop beds, air changes in the room/oxygen availability and other such factors, which directly influence crop productivity.

The environment management in the cropping room includes addressing of the following factors:

1. Temperature
2. Relative humidity (RH)
3. CO₂ concentration

1. Temperature

Temperature in the room has two areas for monitoring i.e., air temperature and bed temperature. Temperature has direct bearing on crop productivity in synergy with other

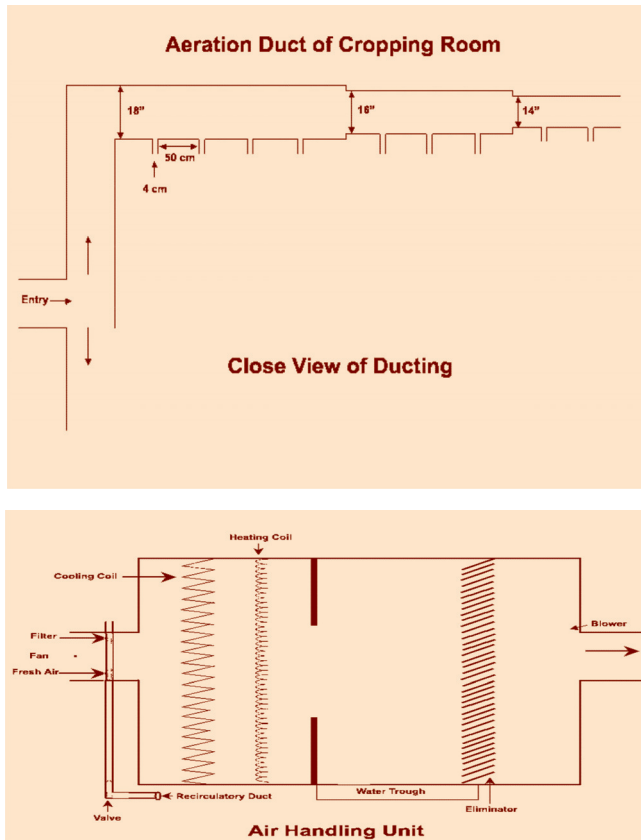


Fig. 9.4. Schematic view of Air Handling Unit and aeration duct

factors like RH and CO_2/O_2 conc. in the cropping room. The bed temperature in the cropping room is directly influenced by the air temperature, so it is the air temperature that has to be addressed. The air temperature inside the room can be manipulated with use of cooling/heating coils in an Air Handling Unit (AHU) installed inside or outside the cropping room for climate control. An independent AHU is desirable for each cropping room. The AHU inside contains a set of cooling coils, heating coils, RH fogging jets and a centrifugal blower fan for blowing the conditioned air into the cropping room (Fig. 9.4). The AHU is generally installed on top of the entry door and is joined with a recirculating duct from inside the cropping room. The cooling coils are fed with chilled water from the chiller, while the heating coils are fed with steam from boiler and fogging jets get water from trough placed at the bottom of the AHU by a small pump. The cooling requirement will depend upon compost quantity fed inside the room, outside prevailing temperature, insulation on the walls, etc. The blower fan blows the conditioned air into the room (Fig. 9.3). The fresh air into the room goes in via AHU through a control valve, and during most of the crop raising period fresh air valve is placed at 20-30% and recirculating at 70-80%. During spawn run the entire air is recirculated (100%) and no fresh air entry is required.

a. Spawn run

For spawn run air temperature of $23 \pm 1^\circ\text{C}$ is maintained inside the cropping room, which corresponds to bed temperature of $24\text{-}25^\circ\text{C}$ ($1\text{-}2^\circ\text{C}$ higher than air temperature). During this phase, the fresh air valve is closed and entire air is recirculated, allowing the carbon dioxide to accumulate to the level of 15000 ppm, desirable for quick spawn run. Higher concentration of CO_2 accelerates the spawn run/vegetative growth of the mushroom. Any increase or decrease in temperature effects the CO_2 production of the compost and the RH of the room. With increase in temperature, RH will tend to fall, and just vice versa with decrease in temperature. The properly insulated room will ensure uniform temperature inside the cropping room at every stage of crop growth. The heat from the cropping room is removed via cooling coils fitted inside the AHU.

b. Case run

The environmental conditions suitable for spawn run, are suitable for case run as well. The same conditions, as for spawn run will be continued for next 7 days for case run, i.e., temperature of $23 \pm 1^\circ\text{C}$ in the air and $24\text{-}25^\circ\text{C}$ in the bed. The RH/ CO_2 will also be same as for spawn run. Under aforesaid conditions the case run will be completed within one week, and at the same time the mycelium is observed in the casing valleys. Valleys are the areas between the peaks as can be seen on top of casing. The CO_2 conc. and RH should also be maintained within the optimum range for quick and effective case run.

c. Cropping

After completion of case run, cooling inside the room is enhanced to bring the air temp. down to $15\text{-}17^\circ\text{C}$ in the room within 2-3 days time. Simultaneously, the fresh air vent is opened to 30% and rest of the air is recirculated (70%). This brings down the CO_2 conc. inside the room to 800 to 1000 ppm, desired for pinhead formation. Likewise, the RH is also reduced to 85% from 95%. This facilitates pinhead formation on the casing within a week's time. The pinheads grow into full button sized mushrooms in another 3-4 days. At this stage fresh air can be slightly reduced to achieve 1000-1500 ppm CO_2 concentration. The environment parameters are maintained as above during entire period of cropping. Since the temperature has influence on RH and CO_2 production from compost hence should be manipulated, keeping in mind its effect on other two factors. All the three parameters work in synergy with each other to induce pinning. The pinning will be affected adversely if any of these factors is not in its optimal range.

High temperature for a long period of time during cropping will lead to sealing of casing, and will result in stopping of pinhead formation. The mycelium will continue growing in vegetative phase and will seal the casing, making it impervious to water, thus resulting in serious yield losses. The desired temperature in cropping room can be maintained with good precision by the use of sensors and controlling devices attached to cooling/heating coil inlets fitted inside the AHU. These devices are easily available and are effective in temperature control in the cropping room.

2. Relative humidity

Relative Humidity (RH) is the ratio/proportion between absolute humidity (AH) and saturation point of humidity (SPH) at a given temperature, expressed in percentage. Absolute humidity is number of grams of water vapours contained in a cubic meter of air

at a given temperature. Saturation point of humidity is the maximum number of grams of water vapours feasible in a cubic meter of air at a given temperature. Relative humidity (RH) of 85% is necessary for obtaining highest pin head formation in synergy with other factors like temperature and CO₂ concentration. RH of 85% permits slow evaporation of water from the crop bed to air in the cropping room and thereby facilitating the upward movement of nutrients in the compost. This exchange of air facilitates loss of CO₂ + heat into the air, necessary for healthy pin head development and crop productivity.

In the event of RH falling below 85% inside the cropping room, more moisture from the crop bed will be withdrawn resulting in drying of the casing layer. This will seal the casing and result in crop losses. Lower RH in the room will be indicated by bed temperature falling below the air temperature, an undesirable situation to be avoided at any cost. Under normal circumstances the bed temperature is always higher by 1-2°C than air temperature for development of a healthy crop of mushrooms. For round the clock monitoring of RH, monitoring of the bed and air temperature inside the room is desirable. The incoming air should be humidified enough to prevent loss of moisture from the crop beds. Evaporation of moisture from crop beds has to be taken into consideration for calculating the g of water vapours required per m³ air in a room for maintaining the required RH for cropping. Air in a cropping room contains 9.6 g water vapours per m³ of air at 14°C (A), the saturation point of humidity at 14°C is 12 g/m³ (S). The RH of the room air will be $A/S \times 100 = 9.6/12 \times 100 = 80\%$. The ultimate expression is the quantity of water vapours contained per m³ of the air space of the room at a given temperature. 31 g of water vapours gets evaporated from 1 m² bed area at 17°C/85% RH/hour. The change in room temperature will alter the RH in the room. Use of RH sensors with cut off/starting devices for recording and maintenance of RH in a cropping room is very useful. The sensors will control the fogging jets in the AHU as per the requirement in the room. For obtaining a temperature of 17°C and RH of 85% in the cropping room, air temperature is brought down to 14°C at exit point of AHU with 100% RH. The air on reaching the crop bed will receive some heat from crop bed and raise the air temperature to 17°C with RH automatically falling to 85%.

3. Carbon dioxide

Carbon dioxide concentration is the third important factor in management of environment inside the cropping room. CO₂ is produced by actively growing microorganisms in compost during spawn run, case run and by mushroom mycelia and mushrooms during entire cropping cycle (Fig. 9.5).

During spawn run, higher concentration of CO₂ is desirable, which helps in quick and quality spawn run. For spawn run, CO₂ concentration between 10000-15000 ppm is desirable (strain dependent) and it helps in quick spawn run in compost. Higher concentration of CO₂ is also desirable during case run (Fig. 9.6).

For pinning and cropping, the CO₂ concentration is lowered around ambient (800-1000 ppm). CO₂ concentration upto 1500 ppm is maintained during pinning & cropping, and this is done by venting/opening of fresh air duct to bring in oxygen and exhaust of CO₂ from exhaust vents under positive pressure.

The opening of vent will bring in fresh air, which is conditioned in AHU (heated or cooled/humidified) and then blown into the cropping room via ducts. The CO₂ gets

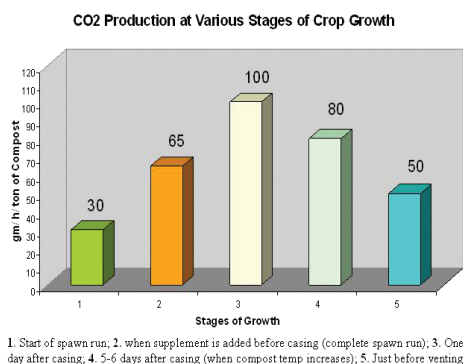


Fig. 9.5. CO₂ production during different stages

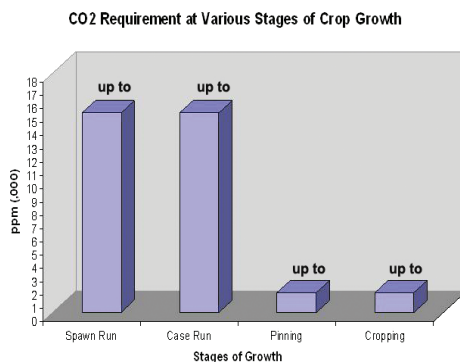


Fig. 9.6. CO₂ requirement at different stages

mixed up with the fresh air and is carried under positive pressure towards the exhaust vent and finally exhausted. This also facilitates the exhaust of heat alongwith the CO₂ from the room air. The heat is removed via cooling coils after the room air gets into the AHU via recirculating duct. During air circulation, recommended air speed over the crop beds is 15cm/sec. Ensure that the desired air movement is there in the central shelf in the middle row. This can be checked with the help of a burning incense stick, which will indicate the direction of air movement in the cropping room. Higher concentration of CO₂ during pinning can seal the casing or produce onion shaped mushrooms with a bulbous base & a small cap. During development from pinhead to button sized mushroom, higher concentration of CO₂ will lead to long stiped mushrooms with a small cap (opened), which reduces the crop yields. By gentle movement of air over the crop beds, the CO₂ is carried away from the crop canopy, thus saving the bad effect of CO₂ trapped between the mushrooms in the crop canopy. To ensure healthy crop production, about 6 air changes per hour are recommended from the venting time to completion of first 2 flushes. During this period, CO₂ production is highest (10 g/h/m²) and it requires to be removed at a faster rate. Along with CO₂, heat is also produced @ 10W per hour from one m² bed area at 17°C and 88% RH.

In subsequent flushes, 4 air changes per hour are sufficient to maintain right O₂ content in the cropping room (about 16%). During first two flushes fresh air vent is opened to 30% entry and 70% recirculation, and in subsequent flushes the fresh air

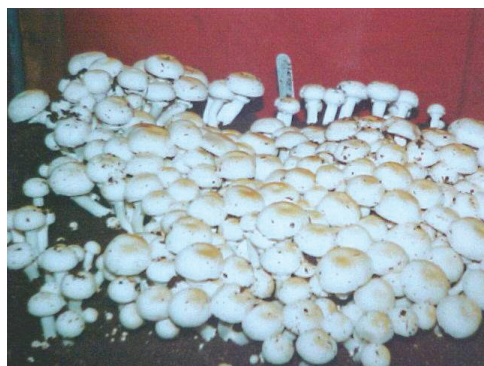


Fig. 9.7. High CO₂ symptoms in button mushroom

vent is put at 20% and recirculation at 80%. Use 2 µm mesh filters on fresh air entry points into the cropping room to restrict the entry of diseases/competitor mould spores. The CO₂ after mixing with the room air, gets exhausted under positive pressure from exhaust vents, thereby helping in heat + CO₂ removal from the room.

Maintenance of right combination of casing moisture (about 50 ± 2%), CO₂ concentration, RH and temperature at

pinning stage of crop growth helps in obtaining a heavy pin set, thus resulting in a luxurious crop growth and excellent yield of mushrooms.

If onion sized mushrooms/drum sticks (Fig. 9.7) are observed, correct air circulation for effective CO₂ removal from crop beds is required. Lack of air movement and accumulation of CO₂ creates this type of situation. Long stemmed mushrooms are again the outcome of CO₂ accumulation in the air around crop canopy due to faulty air movement/air circulation inside the cropping room.

C. Airing Procedure for Fruiting

Venting or opening of fresh air for induction of fruiting after case run is a critical phase in mushroom growing. Whether to cool first or bring in fresh air first is a question bothering commercial mushroom growers. The airing is done suiting a particular situation, whether one wants to have a heavy first flush followed by moderate flushes later or equally spaced flushes. The airing accordingly is handled under 3 heads:

1. Soft airing
2. Moderate airing
3. Severe airing

1. Soft airing

Soft airing means that we will have severe restriction on venting to get smaller flushes suiting to market demand and the air is opened slowly. The growing parameters to be manipulated for soft airing are listed below:

Air temperature	:	19°C in 48 hours 17°C in 72 hours
Compost temperature	:	21°C in 96 hours
CO ₂ concentration	:	4000 ppm in 48 hours 2000 ppm next 24 hours 1000 ppm after 72 hours
RH	:	98% to 92% in 48 hours.

2. Moderate airing

Moderate airing means that we will have some restriction on airing/venting to get well spaced flushes of moderate levels.

The growing parameters to be manipulated for moderate airing are listed as under:

Air temperature	:	17°C in 24 hours 20°C in 72 hours
Compost temperature	:	20°C in 72 hours
CO ₂ concentration	:	2000-2500 ppm in 24 hours Less than 1000 ppm in 48 hours
RH	:	98% to 92% in 24 hours

3. Severe airing

Severe airing is done to obtain a heavy first flush and no restriction is put on airing. This results in heavy pin set and large first flush, followed by smaller subsequent flushes. The growing parameters to be manipulated for severe airing are listed below:

Air temperature	:	15°C as soon as possible
Compost temperature	:	20°C in 48 hours
CO ₂ concentration	:	Less than 1000 ppm in 12 hours
RH	:	98% to 90% in 12 hours

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Post Composting Supplementation for High Yield of White Button Mushroom

B.Vijay

The nutrient sources are added to compost at the time of its preparation for balancing the C: N ratio and to start the fermentation process. The microorganisms developed during the course of composting phase utilize these nutrients resulting in formation of nitrogen rich lignin humus complex. This along with decomposed straw is later utilized by the mushroom mycelium for its growth. Here we are talking of a nutrient, which is first, attacked by microorganisms and later by mushroom mycelium. These nutrients can be designated as pre-composting supplements. However, there is another class of nutrients, which are added at any time after completion of composting for direct utilization by the mushroom mycelium. These are generally referred as post composting supplements.

It has become a routine practice to supplement the compost at spawning and at casing (post composting supplements) in advanced countries as this encourages stronger and healthier growth of mycelium, which results in higher yield. There proprietary products of protein or carbohydrate origin are readily available in the market, which guarantee the increased production to the tune of 20% or more. In India, since the mushroom cultivation is still not very well developed and organized, many farmers have not adopted this practice. Lots of work has been done in the country on this aspect and it has been proved beyond doubt that supplementation increases the yield of *A.bisporus* and this practice can become integral part of button mushroom cultivation. Supplementation can be tried both with compost prepared by long method or by short method compost. Number of considerations are to be kept in mind for raising a successful crop through supplementation of the compost, like choice of supplement, type of compost used, mode of application and rate of supplementation, etc.

A. Choice of Supplement

Supplements used in the mushroom cultivation can be of both animal and plant origin which may be carbohydrate-rich, protein-rich or oil-rich substances. However, protein-rich materials give better results. In India, cotton seed meal, soybean meal, cottonseed cake, deoiled soybean meal have been tried with fair amount of success. Besides these, yeast extract, ammonium sulphate and vitamin B complex have also been used as supplementing agents with fair amount of success. Other supplements tried/worth trying include alfalfa meal, lucerne meal, corn gluten meal, cracked soybean, groundnut cake and sunflower meal. Supplements from animal origin include feather meal, bone meal, etc., which have not been tried in India so far.

B. Compost Formulations and Type of Compost Used

Initial compost formulations and type of compost produced affect the response to subsequent supplementation. It has been observed that supplementation with the same substances may not increase the yield in different compost. It has further been observed that too wet or too dry compost which does not support better growth of mycelium may not prove fruitful for supplementation. Better response to supplementation is always achieved when one starts with the formula in which required ingredients are added. However, a meager compost having no nitrogen may respond positively to supplementation. This increase may be due to the make up of already lacking nitrogen status. As already stated, supplementation can be tried both with the compost prepared by long method and short method. It has, however, been found that sometimes long method compost may behave erratically with the supplements giving little increase/no increase or lesser yields.

The length of composting period also determines response to supplements in these composts. In general, it has been observed that long method compost prepared over a time of 28 days in which dry matter loss was more responded more favourably to supplements than the composts which were prepared in 20 and 16 days.

C. Mode of Application

First requirement in this case would be to coarsely grind the supplements. The supplements like soybean or cottonseed meal may carry different weed moulds and are to be eliminated before their application in the compost. Formalin (40% formaldehyde) is generally used for this purpose, which serves the dual role. It sterilizes the supplement and at the same time, partially denatures the proteins present in the supplements. 5000 ppm (0.5%) formaldehyde treatment of cottonseed and soybean meal is sufficient. Required quantity of supplement is taken in a clean container for its treatment and formalin dissolved in water is poured over the supplement. One kg of supplement would require around 1.0 ml of commercial formalin dissolved in 700 ml of water. This solution is properly mixed in the supplement and dough is made. Later the container is sealed with a polythene cover and left as such for 48 hours to facilitate the proper action of the chemical.

D. Rate of Supplementation

Rate of application of supplement in compost varies from 1-6%. Rate of a particular supplement is determined by its ability to mix properly in the compost and also the temperature control facilities available with the grower. Moisture content of the compost, compost depth and its density is also taken into consideration. Best results are however obtained when supplementation is practiced in perfect compost. If all these factors can be manipulated, supplements can be used at as high as 5-6% to get dramatic yield increase. If supplementation has to be done in the compost kept in shelves than its addition @ 1.5 kg/m² gives best results. When tried in bags then best results are obtained with one percent supplement on wet weight of compost. Higher doses of supplements than the recommended doses can be counterproductive.

E. Time of Supplementation

Breakdown and utilization of nutrients of supplements by mushroom mycelium and other organisms present in compost result in heating up of the compost. Sometimes

heat generated is so high that mycelium may be killed. Care, therefore, must be taken about the time and rate of application. Mostly supplements are added in the compost at spawning or at casing. Better results are however obtained when supplements are added in the fully colonized compost at casing.

F. Supplementation at Spawning (SAS)

In this case, pretreated supplement mentioned as above is mixed in the compost alongwith spawn and filled in the bags or trays or shelves. In India, supplementation at this stage has been tried both with unpasteurized (LMC) and pasteurized compost (SMC). Growers who are not having cooling facilities at their farm should not resort to this practice at this stage as temperature tends to increase in the compost due to supplementation (3-4°C rise) which may sometime exceed too high resulting in death of mycelium or high temperature may generate secondary metabolites including ammonia lethal to mushroom mycelium. Selectivity of the compost may also decrease when supplementation is tried at this stage, which increases the risk of weed moulds incidence. Sometimes the supplements stick to the spawn, which in turn, contaminate the compost (personal observation). It is, therefore, suggested that while trying supplementation at this stage, proper care should be taken to sterilize the supplements with higher doses of formaldehyde. Occurrence of weed moulds and rise in temperature should be monitored. However, studies conducted at this Directorate, author has found increased yield to the tune of 15-20% (Fig. 10.1). No response/low yields/or crop failure were also reported. Supplementation at spawning in SMC has been found successful. In colder areas where room temperature remains low during spawn running stage supplementation at this stage becomes boon as increased temperature favours early spawn run. Supplementation at this stage should be tried with LMC only when the compost is perfect.



Fig. 10.1. Button mushroom crop after supplementation

G. Supplementation at Casing (SAC)

In this case, required quantity of supplement is thoroughly mixed in the properly colonized compost just before casing and casing applied as usual. When cultivation is done in racks or shelves spawn run compost is scraping opened, ruffled and required

dose of supplement is properly mixed in the entire compost. Compost is re-levelled, pressed and casing layer applied as usual. Increase in yield due to supplementation at this stage with cottonseed meal or soybean meal is over-whelming (15-30% increase) whether tried on LMC or on short method compost. Some of the common supplements for casing are soybean meal and cottonseed meal and the recommended doses for these are 1% fresh weight of compost.

H. Supplementation and Crop Management

Introduction of supplement in the compost temporarily deviates its selectivity from normal, which often involves occurrence of weed mould and high temperature in the compost beds, which may sometimes kill the mushroom mycelium. If temperature rises too high in the compost beds, greater differences in the bed temperature and air temperature are required to be maintained. In certain cases, depth of compost may also be reduced to overcome this problem. Supplementation can be tried successfully in bags (10-12" depth) or in trays (6-8" depth). In case of occurrence of weed mould, the infected portion should be removed and spot treatment with formaldehyde, bavistin or any recommended fungicide can be done. Mould incidence is generally rare when supplements are added at casing.

Compost and casing moisture levels play an important role in determining the benefits of supplementation. Since supplementation increases the yield to the tune of 20-30% or even more, water requirement of the crop would be more. Higher compost moisture in combination with supplementation at spawning proved superior to the treatment with lower moisture level. We have found 68% moisture level as the optimum for supplementation studies.

In India at present, no readymade supplements are being marketed. Number of supplements are, however, commercially available in USA and European countries. Supplementation is more effective when done at casing, less effective at spawning and gives only average results when done at just before phase-II of composting. Some of the commonly used supplements in market in foreign countries are Millichamp, Spawn mate, Champ food, which are soya derived products and are often used by European and American mushroom growers mostly at casing getting fairly high increase in yield.

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Growth Regulators for Mushroom Yield Enhancement

O.P. Ahlawat

Mushrooms especially *Agaricus* spp. require a well-decomposed substrate for their growth and fructification. The substrate supports all metabolic activities by supplying the essential nutrients, vitamins and minerals. The microbes, developed during the process of decomposition of agro-wastes, not only help in preparation of a productive and selective substrate (compost) for white button mushroom but also regulate fructification phenomenon. The microbes stimulate fructification either by acting as the rich source of nutrients or by producing growth stimulating metabolites, which indirectly promote the fructification phenomenon.

Research carried out on this line has supported the involvement of bacteria in mushroom fructification and yield increase. Mushroom being grown under heterogenous and multiculture environment behaves in a similar fashion for their nutrition as the higher plants. The yield stimulatory role of exogenous microorganisms/metabolites can be divided into three different categories.

A. Biofertilizer

The history of modern biofertilizers started with the discovery of a nitrogen fixing bacterium "*Rhizobium*" in 1888 by Beijerinck. Starting from modest laboratory preparations in the mid thirties of this century in U.S.A., rhizobial inoculants (also known as legume inoculants) have become industrial propositions in U.S.A., Europe, Australia and India. Following the success of legume inoculants all over the world, carrier based *Azotobacter* inoculants and PGSB (plant growth stimulating bacteria) inoculants including PSB (phosphate solubilizing bacteria) are becoming popular around the world.

Mushroom substrate being rich in nitrogen and other nutrients and a multiculture substrate rarely shows deficiency of macronutrients like carbon, nitrogen and potassium. However, some other nutrients, like phosphorus being ignored because of its low requirement,

plays crucial role in several metabolic activities of mushrooms, where phosphorus acts as the co-factor in catalyzing the biochemical reaction operating inside the cells.



Fig. 11.1. Healthy crop (Button mushroom)

Inoculation/mixing of biofertilizer containing phosphate solubilizing bacteria at spawning @ 1.0%, w/w in compost gives early spawn run, early pinning and increases the yield to the tune of 20-30% with more mushrooms in first two flushes. The quality of mushrooms also remains unaffected (Fig. 11.1).

1. Source

The good quality biofertilizer can be obtained from National Biofertilizer Centre, Ghaziabad (UP); Dept. of Microbiology, CCSHAU, Hisar; Dept. of Microbiology, HPKV, Palampur; Dept. of Microbiology, PAU, Ludhiana and Division of Microbiology, IARI, New Delhi. There are several other manufacturers but they have their own manufacturing units so quality aspects should be checked before purchasing from such sources.



Fig. 11.2. Mixing of biofertiliser along with Spawn

2. Methodology

Commercially biofertilizers are available in a packaging of 200 g/pack on an inert carrier like charcoal. So, one quintal of ready made compost requires 5 packet (1 kg) of biofertilizer. The mixing of biofertilizer should be done at spawning because that will save the extra labour input required for the operation. The biofertilizer should be mixed thoroughly and only calculated amount should be used (Fig. 11.2).

3. Precautions

Following precautions should be taken while purchasing and mixing the biofertilizer:

- The biofertilizer should be fresh and active (check expiry date)
- It should be stored at a cool place preferable in dark after purchase
- Only required quantity of biofertilizer should be used
- Biofertilizer should be purchased from an authentic source

B. Bacterial Inoculants

From literary point of view there is no difference between biofertilizers and bacterial inoculants but here we are separating these two on the basis of their preparations and availability. The preparations, which are commercially available are categorized as biofertilizers, while the preparations, which are not available in market are termed as inoculants.

As it has already been mentioned that mushroom cultivation system is a multiculture system and one microorganism affects the activities of other and vice versa. Mushroom fructification is also stimulated by multiple factors and among these microbial factor/load is very crucial. The suitable manipulation in total microbial load in the compost can help the mushroom mycelium to propagate at a much faster rate with increased yield.

The mushroom mycelium grows at a much faster rate in the presence of growth stimulating bacteria like *Bacillus megaterium* and *Alcaligenes faecalis* under *in vitro* conditions. Similarly, the killed cells of these bacteria support better mycelial growth under liquid culture conditions. The inoculation of such bacteria not only stimulate early pinning in *A. bisporus* but also influence the overall mushroom yield. In *A. bitorquis* besides these two bacterial species other bacteria like *Bacillus circulans*-II and *B. thuringiensis* also increase the mushroom yield. In all the cases, the inoculation with these bacteria do not affect the mushroom quality. In case of *A. bitorquis*, where the problem of false truffle disease incidence is very common, the inoculation with these bacteria restrict the disease incidence.

1. Methodology

The inoculation treatment can be carried out in the following steps:

- a) Raising the culture of desired bacterium on the solid agar medium
- b) Raising the liquid (broth) culture of desired bacterium with optimum level of bacterial count/ml (10^7 - 10^8 /ml) of broth culture (liquid medium)
- c) Mixing/inoculation of broth culture at casing @ 0.1% (v/w)

2. Precautions

- a) Purity of the microbial culture
- b) Desired population of microbial cells/ml of broth culture (10^{7-8} /ml)
- c) Proper mixing of the microbial inoculant in casing soil

C. Hormone

Hormones are either a plant or microbial products. The microorganisms, which influence the growth characteristics/behaviour of other microorganisms, affect through some metabolites like anti-microbial compounds and growth promoting hormones, including indole acetic acid, indole butyric acid, cytokinin and gibberillic acid. There are plenty of reports available on use of these hormones in horticultural crops either to improve the yield of the fruits/vegetables or their quality. Mushrooms are different from higher plants because of the nature of growing medium and other aspects like their position in plant kingdom, but still there are a few reports on use of hormones in mushroom cultivation.

Work done in India and abroad has indicated that the commercial preparations of indole butyric acid (IBA) stimulate the mushroom mycelial growth under *in vitro* conditions. The spray of such a formulation on mushroom beds stimulates early pinning as well as higher yield of mushrooms. Most of the yield is harvested during first 15 days of the cropping. The results are equally well both in *A. bisporus* and *A. bitorquis*.

1. Methodology

The hormone IBA spray can be done in following steps:

- a. The commercial preparation of IBA i.e. Veradix-2 should be mixed thoroughly in water @ 0.1% (w/v)
- b. The spray should be done @ 50 ml/10 kg mushroom compost bag each at the pinning initiation stages of 1st, 2nd and 3rd flush of cropping

2. Precautions

- a. Only desired commercial product should be used because over or under spray of hormonal formulation will not give the desired results.
- b. The spraying should be done only at the pinning initiation stage (Fig. 11.3) else it will hinder the fructification phenomenon by promoting the vegetative growth of mushroom mycelium.
- c. The desired quantity of product at desired rate should be sprayed.
- d. Veradix – 2 spray should not be followed by ordinary water spray on that particular day.



Fig. 11.3. Stage for Veradix-2 spray

There are few reports by the farmers wherein urea has been sprayed to initiate and promote pinning. There are also some biologicals of plant origin (extracts) that are being claimed to increase yield or rapidly degrade spent substrate. These results, however, could not be verified at this directorate.

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Quality Traits in Cultivated Mushrooms and Consumer Acceptability

Shwet Kamal

Mushrooms are prized for their delicacy, nutritional and medicinal values. Amongst various edible mushroom species cultivated in India (button, oyster, milky and paddy straw mushrooms), white button mushroom is commercially the most important and accounts for 85% of the total mushroom production, which is approximately one lakh tons per annum. White button mushroom plays an important role in the economy of small and medium grower's as well as export-oriented units earning valuable foreign exchange. In India, this mushroom is cultivated under organized and unorganized sectors. Rapid strides in cultivation technology have helped in popularizing this mushroom. Production per unit compost has been increasing steadily due to refinements in composting and cultivation methods. During the early period S-11 was the commonly used strain under all cultivation conditions. In fact this was possibly the first strain to be introduced in India about 5 decades back. Now, farmers have started demanding higher productive and better quality mushroom cultivars. The productivity and important quality traits of varieties and hybrids of white button mushroom available for cultivation in the country are listed in Table 12.1. Recently a number of strains have been received from other countries but still they have to be tested under Indian conditions before these are made available to the farmers for commercial cultivation.

Table 12.1. The productivity and important quality traits of some varieties and hybrids of white button mushrooms available for cultivation in India

Varieties/ hybrids	Yield(kg)/100kg compost in 6-8 weeks of cropping		Originating Breeder/Institute	Important quality traits
	Unpasteurized compost	Pasteurized compost		
A) <i>Agaricus bisporus</i> Varieties				
S-11	10-14	15-18	Mental, Germany	Long stiped, mushrooms open quickly, dark brown gills, wide adaptation, good yield on LMC
S-791	8-9	14-16	Darlington, UK	Large and stout fruit bodies more dry weight, pink to light brown gills, high yielding.

Varieties/ hybrids	Yield(kg)/100kg compost in 6-8 weeks of cropping		Originating Breeder/Institute	Important quality traits
	Unpasteurized compost	Pasteurized compost		
MS-39	6-8	12-14	Single spore selection	Medium sized fruitbodies, light brown gills
P-1	6-8	14-16	Pune Selection	Long stiped, fruitbodies open quickly, dark brown gills
NCS-100	8-10	13-16	DMR, Solan	Fruitbodies tough, short stiped, peak yield in first flush
NCS-101	8-10	14-16	DMR, Solan	Fruitbodies tough with good post harvest qualities, peak yield in second flush
S-130	12-15	18-20	Sylvan, USA	Tough fruit body, small stipe, broad pileus, uniform flush
S-140	12-15	18-20	Sylvan, USA	Tough fruit body, broad pileus, extra-white, uniform sized
Delta	—	16-18	Amycel, Canada	Mushroom with large round cap, smooth to slightly scaly, small and thick stipe, suitable for canning
X-13	—	16-18	Le Lion, France	
Hybrids				
U-1	-	14-18	Fritsche, Holland	Suitable for canning, nice white medium sized fruit bodies
U-3	-	16-20	Fritsche, Holland	High yielding, suitable for fresh marketing, strip broad and small, suitable for canning
M-7207	—	—	Mycelia, Belgium	Highly productive average size (4-6 cm dia) Fruit bodies with good keeping qualities, bulbous stipe
M-7218	—	—	Mycelia, Belgium	Extra thick veil, opening of the cap delayed, slightly scaly with well rounded fruit body, firm texture and nice flavour
M7219	—	—	Mycelia, Belgium	Even flushed, medium size (4-6cm), solid cylindrical stipe, suitable for both canning and fresh market

Varieties/ hybrids	Yield(kg)/100kg compost in 6-8 weeks of cropping		Originating Breeder/Institute	Important quality traits
	Unpasteurized compost	Pasteurized compost		
NCH-102	-	16-19	DMR, Solan	High yielding, uniform medium sized fruit body
B) <i>Agaricus bitorquis</i>				
NCB-6 (RAB-50)	-	12-14	Vedder, USA	Medium sized white mushroom, more dry weight, good yielding
NCB-13 (PDAB-55)	-	13-15	Vedder, USA	Large extra white fruit bodies, more dry weight, high yielding
Hybrids				
K-26	-	13-15	Fritsche, Holland	Suitable for canning, good quality, high yielding
K-32	-	13-15	Fritsche, Holland	Long, stiped, easier to grow, more dry weight.

The yield and quality are complex quantitative trait and the expression of these traits depends upon genotype, environment and genotype x environment interaction. The environmental factors that include quality of compost and casing, temp (air and bed temp.), CO₂ concentration and relative humidity prevailing during cropping and management practices such as water spraying and mushroom harvesting techniques influence the quality and productivity of harvested mushrooms. Therefore, proper environmental control and agro-techniques are important to ensure good quality mushrooms. The morphological traits including fruit body shape, length, weight, stipe/pileus weight ratio, gill openings, colour, etc. are the highly variable quantitative traits and are influenced by the numbers of fruit bodies emerging in a flush and environmental factors. For example, if the number of fruit bodies are more then the fruit body weight is reduced or vice-versa. Besides button mushroom, there are number of oyster mushroom species available in the country that can be grown during winter/ summer months. The species/ strains suitable for cultivation in India are listed in the Table 12.2.

Table 12.2. Productivity and suitability of different species/strains of oyster mushroom available for cultivation in India

Sr. no.	Season	Species/strain	Yield g/kg dry substrate
A)	Winter season	<i>Pleurotus florida</i> strain-III	500-800
		<i>P. ostreatus</i> strain-III	500-600
		<i>P. ostreatus</i> strain-IV	600-800
		<i>P. eryngii</i>	400-700
B)	Summer season	<i>P. sajor-caju</i>	600-700
		<i>P. florida</i>	600-700
		<i>P. sapidus</i>	500-600
		<i>P. djamor</i>	500-600
		<i>P. membranaceus</i>	500-600
		<i>P. cornucopicae</i> -starin -II	400-500

A. Desired Quality Trait as per Market/Consumer Preference

1. White button mushrooms

- Extra white and uniform sized mushrooms
- Medium size and unopened button shaped fruit bodies
- Broad stipe and short, gills colour pink to light brown
- Tough mushroom with more dry weight
- Longer shelf life
- Good taste and aroma
- No insect infestation/damage

2. Oyster mushroom (*Pleurotus* spp.)

- Extra white variety/ natural colored mushroom
- Medium sized and uniform non-wrinkled fresh mushroom
- Good taste, aroma and more dry weight
- Light brown mushrooms on drying
- No insect infestation/ damage
- Short stipe with large and fleshy pileus

Various agriculture universities have released varieties of oyster mushrooms under different names. For example, TNAU released variety M-2 of *P. sajor-caju*, Con of *P. ostreatus*, MDU-1 of *P. djamor*, and APK-1 of pink oyster *P. eos* (RRS Aruppukottai) and Ooty-1 (RRS Aruppukottai).

3. Paddy straw mushroom (*Volvariella volvacea*)

- Egg shaped and uniform unopened mushroom
- Bluish/ grayish colored mushroom
- Good taste and aroma
- Tough and stout mushroom with more dry weight
- Longer shelf life
- No insect infestation/ damage

4. Milky mushroom (*Calocybe indica*)

- Uniform fruit body size
- Pure white colored smooth pileus
- Short, thick and small stipe.
- Fruit body with pleasant aroma
- Short duration flush break

RRS Aruppukottai (TNAU) has released APK-2 variety of Milky mushroom.

5. Shiitake mushroom (*Lentinula edodes*)

- Uniform fruit body size
- Smooth convex pileus without spots

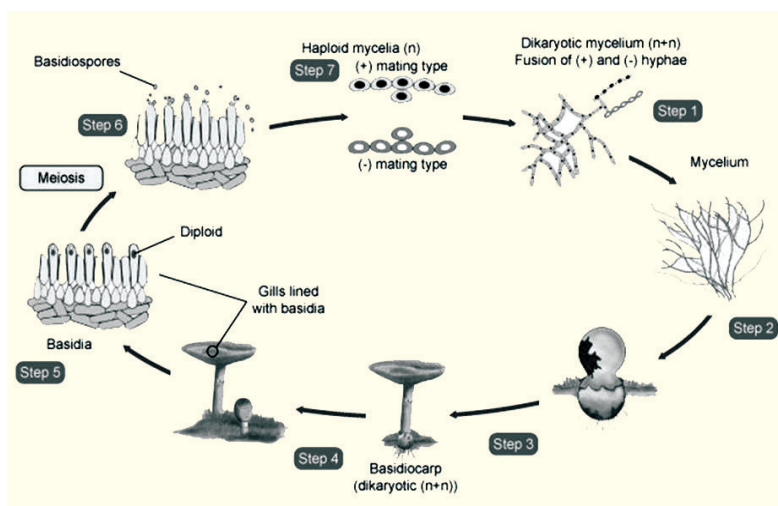


Fig. 12.1. Life cycle of a typical basidiomycete fungus

- Short stipe
- Off white gills

The yield and quality of mushrooms obtained by a grower depends on the genetic makeup of the variety/ hybrid of mushroom and the environmental conditions in which it is grown. The character, behavior and overall performance of a variety/ hybrid are a result of interaction between genotype and environment. The manipulations of genotype using traditional and advanced technique of breeding provide an opportunity for reshuffling of genes and selection of new gene combinations resulting in improvement of yield and quality. Fig. 12.1 gives an idea of the life cycle of the mushrooms.

B. Life Cycle

The cultivated mushrooms belong to highly evolved class of fungi-Basidiomycetes. The life cycle of a typical basidiomycetes mushroom has three nuclear phases:

1. Homokaryotic haploid phase: initiated by meiosis
2. Heterokaryotic (dikaryotic) phase: initiated by plasmogamy but deferred karyogamy
3. The transient diploid phase: initiated by karyogamy in the basidia.

The homokaryon, with genetically identical nuclei, usually has uninucleate cells and is known as a monokaryon. The dikaryon (heterokaryon) of Basidiomycete is the predominant phase in nature and functions as the genetic equivalent of the diploid phase in higher plants. It differs from the diploid stage where the plasmogamy is not immediately followed by karyogamy and hence the two genomes remain in separate haploid nuclei which form conjugate pairs and remain closely associated throughout the vegetative growth of the fungus. Under appropriate environmental conditions this heterokaryon produces fruiting bodies during which karyogamy is affected followed by meiosis to produce the haploid phase again. Thus the mushroom fungi have three cardinal events of plasmogamy, deferred karyogamy and meiosis.

Genetic manipulation in different mushrooms requires different approach depending upon their sexuality and mating systems. In mushrooms, generally two types of mating system exist.

1. Homothallism

Homothallism is the mode of sexuality wherein a single spore germinates to give rise a fertile mycelium that has the genetic capability to form fruit bodies under optimum growing conditions. Homothallism is of two types, primary and secondary.

a. Primary homothallism

Primary homothallism refers to the sexuality pattern wherein a uninucleate single spore (containing a single post-meiotic nucleus) is capable of forming fertile mycelium and fruit bodies. Classical example of this kind of sexuality behavior is *Volvariella volvacea*. Hence the genetic manipulation is easier and most of the time the selection of a single spore can yield a superior strain for cultivation.

b. Secondary homothallism

Secondary homothallism refers to the sexuality pattern wherein a binucleate single spore (containing two post-meiotic nuclei) is capable of forming fertile mycelium and in turn fruit bodies. The self-fertility of the single spore is due the presence of two nuclei containing different mating type factors. *Agaricus bisporus*, the leading global mushroom, is the best authentic example of this system of sexuality. In this mating type system the two post-meiotic nuclei migrate into each of the two spores on the basidia making it a unique example of homothallic condition. The basidia in *A.bisporus* are bisporic (81%), trisporic (18%) and tetrasporic (1%). Among the 2-spored basidia, not all the spores give rise to fertile mycelium and fruit bodies. These spores may carry same mating type allele due to random migration of post meiotic nuclei (Fig. 12.2).

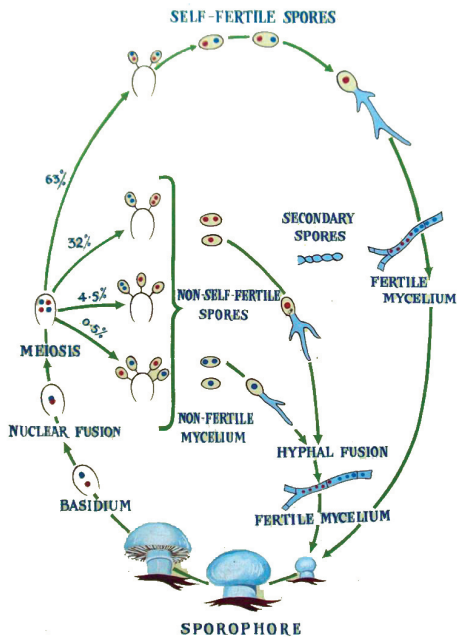


Fig. 12.2. Secondary homothallic pattern of life cycle in *Agaricus bisporus*

2. Heterothallism

Heterothallism is the sexuality pattern wherein a single spore (carrying a post-meiotic nucleus) germinates to give rise to self-sterile homokaryotic mycelia having nuclei of the same genotype. Hyphal fusion occurs between compatible monokaryons to produce dikaryotic mycelia with binucleate cells and clamp connection, producing fruit bodies. The edible mushrooms exhibiting heterothallism are *Agaricus bitorquis*, *Lentinula*,

Pleurotus, *Pholiota*, *Tremella*, *Auricularia*, *Coprinus*, etc. The heterothallism is regulated genetically by mating type factors and is of two types: a) unifactorial and b) bifactorial.

a. Unifactorial heterothallism

This type of heterothallism is also referred as bipolar incompatibility wherein a single mating type factor (gene A) with heteroallelic condition at the locus determines the sexuality behavior. Of the 90% heterothallic species, 25% have bipolar incompatibility system (Fig. 12.3).

b. Bifactorial heterothallism

This type of heterothallic behavior is also known as tetrapolar incompatibility system wherein two unlinked mating type factors (genes A and B) with heteroallelic condition at both the loci govern the sexuality behavior. All the mating combinations between homokaryons with heteroallelic conditions at both the loci give rise to compatible reactions and further to the formation of fruit bodies (Fig. 12.4).

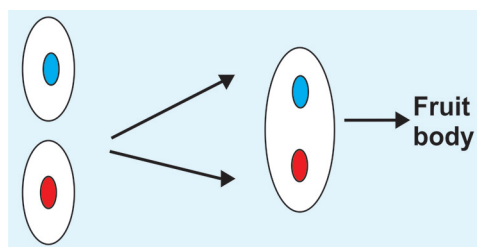


Fig. 12.3. Diagram showing unifactorial bipolar heterothallism

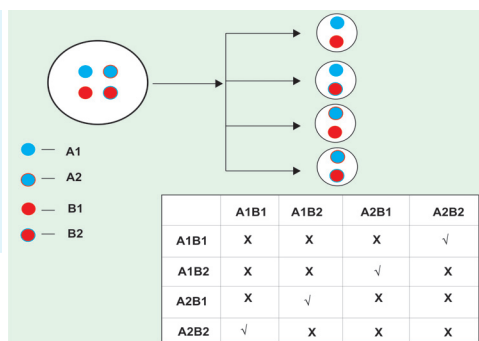


Fig. 12.4. Diagram showing bifactorial tetrapolar heterothallism

C. Methods of Improvement

The approaches used for breeding new varieties in different mushroom will be different depending upon the mating system. Some of these are

1. Introduction

Scoring available germplasm and introducing mushroom cultivars is the easiest and quickest method.

2. Selection

Selection can be made from multi spore or single spore cultures.

a. Multi spore culture: Selection amongst multi spore cultures was mainly used by the commercial spawn maker for the purification/rejuvenation of old and degenerated cultures.

b. Single spore isolates: Selection amongst single spore isolates has been the most widely followed method of developing superior strains owing to the secondary homothallic life cycle of *Agaricus bisporus*.

3. Hybrid breeding

It involves mating (anastomosis) of self-sterile and cross compatible homokaryotic isolates.

a. Mating of compatible homokaryons: The compatible homokaryons are grown side by side in petridishes on agar medium. The mycelia bits (plugs) from junction are transferred on a new malt extract agar plates for preparation of hybrid spawn.

b. Evaluation of hybrids: After confirmation of hybrid status using fructification test, the new hybrids are evaluated for yield, quality and resistance/ tolerance to insect pests and diseases in initial evaluation trials (IET). The superior hybrids are rigorously tested under various agro-climatic conditions before releasing them for commercial cultivation.

D. Future Thrust Areas

Currently grown strains/hybrids of white button mushrooms are poor yielder giving about 15 kg mushroom per 100 kg compost. Hence, there is an urgent need to develop high yielding and better quality mushroom hybrids. The indiscriminate use of pesticides for the control of insect-pests and diseases has resulted in emergence of resistant races of pests in several crops including mushroom. These coupled with reports of residual toxicity of pesticides necessitate the development of high yielding and better quality strains/hybrids resistant/tolerant to major insect-pest and diseases. These resistant varieties/hybrids will also be an important component of integrated pest management (IPM) and sustainable mushroom farming.

Besides developing high yielding, better quality and resistant hybrids, the future breeding programmes will mainly focus on:

1. Development of strain/ hybrids more suitable for processing.
2. Production of strains of white button mushroom with increased shelf-life.
3. Development of bruise less strains by silencing the gene responsible for enzymatic browning in fruit bodies using antisense RNA technology.
4. Identification and transfer of viral resistance genes from *Agaricus bitorquis* to *Agaricus bisporus*.
5. Identification and transfer of gene(s) encoding for anticancer and ant-HIV principles from medicinally important mushrooms such as *Lentinula edodes*, *Ganoderma lucidum* and *Grifola frondosa* to the most commonly grown mushroom
6. *Pleurotus* spore causes allergies and some spore deficient strains with wide temperature tolerance will be more useful.
7. Paddy straw mushroom with better shelf life and suitable for wide temperatures from 25°C to 40°C will be more suitable for tropical and subtropical conditions.

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Economics of Button Mushroom Cultivation under Environment Controlled Conditions

B. Vijay

White button mushroom (*Agaricus bisporus*) cultivation is a highly scientific activity. If done in a proper manner it gives very high returns to the entrepreneurs whether he is cultivating this seasonally or round the year. In India, its cultivation was first started in the hills as it requires low temperature for its growth but slowly growers realized the potential of this commodity and started cultivating this mushroom in the plains in winter season. Mushroom cultivation is a labour-intensive job and in the recent past many large farms had to abandon their operations in Europe and America due to very high labour cost. Complete mechanization of a farm where labour requirement will be less is a very high capital investment proposition making this activity uneconomical and uncompetitive. In India labour availability coupled with plentiful supply of agrowastes and requisite temperature make this activity attractive and economical. Many big units have come up in India cultivating white button mushroom. Most of their produce is exported to America and European countries.

Mushroom cultivation involves investment depending upon the size of the unit/production targets. Before starting this venture one should have thorough knowledge in this field and should survey the market for sale of the produce. Expenditure on a mushroom farm can be divided into fixed assets and recurring expenditure.

A. Fixed Assets

The items permanent in nature and last longer than duration of one crop are covered in this category. These include land, building, boiler, blowers, compost handling equipments, computers, air-conditioning equipments, shelves, etc.

B. Variable Cost/Recurring Expenditure

This component includes the expenditure involved in the production of crop. These include raw materials like compost ingredients, spawn, casing soil, energy cost, pesticides, labour charges, salary of the employees, etc.

Mushroom cultivation is a labour-intensive job if done on a large scale. Experienced labour is employed for composting, spawning, casing and spraying of the beds. Their wages, therefore, would be higher. Ordinary labour can be employed for picking.

Cultivation of *A.bisporus* can be done seasonally under natural conditions when the temperature is suitable for its cultivation. It can also be cultivated throughout the year using cooling facilities, which control the environment suitable for the growth of *A.bisporus*.

In the present chapter, economics of mushroom cultivation throughout the year would be discussed taking a 100% EOU (around 3000 TPA), medium units (500 and 200 TPA) and a small unit (25 TPA) into consideration. All the projects are based on the assumption that compost is prepared by indoor method taking 6 crops / year/ room of 60 days duration, considering air bed ratio of 1:5 and mushroom yield of 18 kg/100 kg compost.

C. Economics of Plant Having 3000 TPA Production

1. Infrastructure required

	Facility	Unit	Size (ft.)	Total area (sq.ft.)
1.	Growing rooms	60	75 x 27 x 13	1,21,500
2.	Pasteurization tunnels	9	65 x12 x13	7,020
3.	Prewetting area with lagoon	1	120 x 100	12,000
4.	Phase-I bunkers	7	90x12x12	7,560
5.	Casing soil chambers	4	35x12x10	1,680
6.	A/C Compressor room/Generator room/Electric Cabin	1	75 x 27x 13	2,025
7.	Boiler room	1	18 x 15 x 12	270
8.	Canning facility	1	75 x 54 x 13	4050
9.	Can store room	1	75 x 27x 13	2,025
10.	Stores/tool room/Workers room/canteen	4	18 x 15 x 13	1,080
11.	Office	10	15 x 12 x 12	1800
12.	Spawning area	1	120 x30 x13	3,600
13.	Service room (underground)	1	120 x 9 x 9	1,080
14.	Corridor	1	864 x 25 x13	21,600
15.	Spawn lab	5	3000 sq.ft.	3,000
16.	Cold room	1	37x27x13	1,000
17.	Staff quarters	Items	-	5000
Total			1,96290 sq.ft. Or 18000 sq.mtrs.	

In addition to above, land would be required for casing soil dump, road, paths etc. Total approximate land required for the project around 5 hectares

2. Investment involved in the construction of infrastructure

	Item	Rs. (laks)
A.	Land procurement and its development (Leveling, tree plantation fencing, etc.)	50.00
B.	Compost Unit (cost of construction/sq.ft.)	
1.	Pre-wetting area @ Rs.50/-	6.00
2.	Phase-I tunnels @ Rs.300/-	22.70
3.	Pasteurization tunnels @ Rs.400/-	28.00
4.	Casing soil pasteurization rooms @ Rs.400/-	6.70
5.	Under ground service room @ Rs.300/-	3.25
6.	Spawning area @ Rs.300/-	10.80
7.	Boiler room @ Rs.300/-	0.80
Total		78.25

Item	Rs. (lakhs)
C. Production and canning facility:	
1. Cropping rooms @ Rs.400/-	486.00
2. Canning hall @ Rs.400/-	16.20
3. A/C room/Shed @ Rs.300/-	6.00
4. Cold room @ Rs.400/-	4.00
5. Can store room @ Rs.300/-	6.00
6. Corridor in the cropping room @ Rs.100/-	21.60
Total	539.80
D. Spawn Laboratory	
1. 5 rooms (3000 sq. ft.) @ Rs.400/-	12.00
E. Miscellaneous	
1. Store/tool room/worker room canteen/office @ Rs.300/-	8.65
2. Staff quarters	20.00
Total	40.65
Grand total A + B + C + D + E =	Rs. 708.70

3. Investment on machinery

A. Plant and machinery for composting unit	Unit Rate (Rs. lakhs)
i. Imported machinery	150.00
Includes - casing soil mixer, computer control units, control switch panels, oxygen measurement equipment, central computer, special low voltage cable, tunnel pulling nets, tunnel gliding nets, net cleaning machines, floor grill moulds, ammonia measuring equipments, high pressure sprayers, filling conveyer plus feed hopper, oscillating head filling machine, tunnel emptying winch with combination of spawn dispenser and bagging machine, air handling units for the tunnels, etc.	
ii. Indigenous machinery	100.00
Includes - boiler, tractor, trailer, doors of the tunnels and casing soil chamber, truck, RCC gratings in the tunnels, front end loaders, electrical system in the composting yard, water pumps piping and valves, tube well, electrical system for the tunnels, lighting in the yard and tunnel area, over head water tanks, casing soil blowers, ducts and gratings.	
Total	Rs. 250.00

B Machinery for Growing rooms	Rs. lakhs
1. Imported	250.00
Includes – air handling units, control switch panels, computer controllers, CO ₂ controllers, central computer, low voltage control cables, etc.	
Indigenous	300.00
Water chilling plant, low pressure boiler, hot water pumps and pipings, ducting for AHU including chilled water pumps and piping, racks for growing rooms, Doors for growing rooms, electrical panels and cables ,etc.	
Total	550.00

C.	Canning and spawn laboratory	250.00
	Includes - automatic canning line, boiler, spawn production and quality control equipments.	
D.	Miscellaneous equipments & expenses	100.00
	Includes - transformer, diesel generator sets, streetlight and cables, structural steel for support, erection of machinery and piping, painting, freight and insurance and other miscellaneous equipments.	
E.	Total cost of the equipments/machinery required for	
1.	Composting Unit	250.00
2.	Growing rooms	550.00
3.	Canning and spawn laboratory	250.00
4.	Miscellaneous	100.00
	Total	1150.00

Total cost of the project		Rs. lakhs
A.	Land + Development	50.00
B.	Civil works	
i.	Compost unit	78.25
ii.	Production and processing	539.80
iii.	Spawn laboratory & miscellaneous	40.65
	Total	708.70
C.	Machinery	1150.00
	Total= A+B+C	1858.00

4. Manpower requirement and wages involved / annum

		Rs. in lakhs
1.	Expenses on Managers and permanent staff	24.00
2.	Expenses on labourers approximately 200 @ Rs.100/- day	60.00
	Total	Rs. 84.00

5. Expenses on raw materials

		Rs. lakhs
1.	Wheat + paddy straw	220.00
2.	Water	6.00
3.	Casing soil	35.00
4.	Fuel	36.00
5.	Energy	140.00
6.	Spawn	30.00
7.	Poultry manure	36.00
8.	Urea	6.00
9.	Gypsum	3.00
10.	Wheat grains	10.00
11.	Disinfectants and Pesticides	5.00
12.	Selling expenses freight and insurance	36.00
13.	Repair and maintenance	10.00
14.	Poly bags	36.00
15.	Chemicals for spawn production	5.00
	Total	Rs. 614.00

6. Interest and depreciation

	Cost	Interest & Depreciation (lakhs)
On land		
15% Interest	50.00	7.50
On Building		
5% depreciation	658.70	131.74
15% Interest		
On Machinery		
10% depreciation	1150.00	287.50
15% interest		
Total		426.74

7. Cost of production

1.	Raw materials	614.00
2.	Wages and salary	84.00
3.	Interest & depreciation	426.74
Total		1124.74

8. Total production at 100% capacity utilization

At 18% conversion	3240 tons – accepted	3000 tons
At 20% conversion	3600 tons – accepted	3300 tons
Cost of production/kg	Rs.37.50/- (At 18% conversion)	
-do-	Rs.34.00 (At 20% conversion)	

9. Canning operation (presuming 3300 tons available for canning)

Cost of A-10 Can	25.00
Cost of canning and brine solution	15.00
Cost of mushrooms 2kg drained wt. approx. 3kg fresh wt.	102.00
Total	Rs.142.00
Sale price of one case containing 6 A-10 size cans (2kg drained weight) @ \$ 23	1 \$ = Rs.48
Total A-10 cans produced from 3300 tons mushrooms	11,00,000 cans or 1,83,333 cases
Sale price of 1,83,333 cases @ Rs.1100 per case	20.16 crores
Total production cost of 1,83,333 cases	15.62 crores
Net profit at 20% conversion	Rs.4.54 crores

D. Economics of a Plant Having 500 TPA of White Button Mushroom Production

1. Infrastructure required

S.No.	Facility	Unit	Size (ft.)	Total area (sq.ft.)
1.	Growing rooms	12	80 x 17 x 15	16320
2.	Pasteurization tunnels	2	60 x 10 x 13	1200
3.	Phase-I Bunkers	3	80 x 11 x 10	2640
4.	Prewetting area with lagoon	1	80 x 60x14	2400
5.	Casing soil chamber	1	22 x10 x 10	220
6.	A/C Compressor room/Generator room/Electric Cabin	1	40 x17 x15	680
7.	Boiler room	1	15 x 15 x 13	225
8.	Canning room	1	80 x 17 x 15	1360
9.	Can store room cum office	1	40 x 17 x 13	680
10.	Stores/tool room	1	20 x 15 x 13	300
11.	Office	3	15 x 12 x12	540
12.	Spawning area	1	35 x 20 x 13	700
13.	Service room (underground)	1	30 x 9 x 9	270
14.	Spawn lab.		1500 sq.ft	1500
Total				29035 sq.ft or roughly 2700 m²

In addition to above land would be required for casing soil dump, straw storage, poultry manure storage, etc. Total approx. land required for the project 4 acres.

2. Economics of the project

		Rs. lakhs
A.	Land procurement and its development (Leveling, tree plantation fencing, etc.)	20.00
B.	Compost Unit	
i.	Pre wetting area with lagoon @ Rs.100/-sq.ft	2.40
ii.	Phase-I tunnels @ Rs.300/sq. ft.	8.00
iii.	Pasteurization tunnels @ Rs.400/- sq.ft.	4.80
iv.	Casing soil chamber @ Rs.400/- sq.ft.	1.00
v.	Boiler room, store/tool room, spawning area and service room @ Rs.300/- sq.ft.	4.50
Total		Rs. 20.70
C.	Production facility	
i.	Growing rooms @ Rs.400/- sq.ft	65.30
ii.	AC compressor room/Generator room/Electric cabin	2.00
Total		Rs. 67.30
D.	Canning facility	
i.	Canning hall @ Rs.400/- sq.ft.	5.45
ii.	Can store room @ Rs.300/- sq.ft.	2.00
Total		Rs. 7.45
E.	Spawn laboratory and office @ Rs.400/- sq.ft.	8.00
Total= Land + Civil works= A+E =		123.45

A.	Plant and machinery	Unit Rate (Rs.lakhs)
i.	Compost and casing unit Includes – Bob cat, filling line, air handling units, phase-I blowers, boiler, doors, gratings of the tunnel, Electrical system and water system ,etc.	30.00
ii.	Production unit Includes- water chilling plant, air handling units, low pressure boiler, racks, vapor proof lightings, Electrical Panels, cables and doors of the growing rooms, spray system,etc.	130.00
iii.	Canning spawn lab. and other equipments including DG sets	45.00
Total cost of the equipments		205.00
Total cost of the project		328.45

3. Recurring expenditure

1.	Wages and salary	20.00
2.	Raw materials	70.00
3.	Energy and fuel	35.00
Total		125.00

4. Interest and depreciation

	Cost	Int.& Depre.(Rs.)
On land		
15% Interest	20.00	3.00
On Building		
5% depreciation	103.45	20.69
15% Interest		
On Machinery		
10% depreciation	205.00	51.25
15% interest		
Total		74.94

5. Cost of production

1.	Raw materials	70.00
2.	Energy and Fuel	35.00
3.	Wages and salary	20.00
4.	Interest & depreciation	74.94
Total		199.94

6. Total production at 100% capacity utilization

At 18% conversion	518.4 tons (Accepted 500 tons)	
At 20% conversion	576 tons (Accepted 530 tons)	
	18%	20%
Cost of production/kg	Rs.40.00	Rs.38.00

Since the project is big, half of the production is proposed to be sold as fresh while half can be processed and canned.

7. Sale and profit projections

Installed capacity	=	500 TPA
Sales	=	250 tons fresh
	=	250 tons canned
a. Sale of fresh mushrooms		
250 tons @ 60,000/ton	=	150.00 lakhs
Profit = 150-100 lakhs*	=	50.00 lakhs
(*Cost of production for 250 tons of fresh mushrooms)		
b. Sale of canned mushrooms		
1 ton fresh mushroom gives 2727 cans of No.1 tall cans		
250 tons fresh mushrooms	= 250 x 2727	= 681750 nos. cans
Crates of 24 cans = 681750/24	=	28400 crates
Sale price of 28400 crates @ Rs.1000		
Per crate in Indian market	=	284 lakhs
Expenditure on cans, crates, labels	=	90 lakhs
Chemicals and on processing		
Production cost of 250 tons of fresh Mushrooms	=	100.00 lakhs
Total cost of canning	=	190.00 lakhs
Net profit in canning	=	284 - 190 = 94 lakhs
Net profit (fresh + canned)	=	94+50 = 144.00 lakhs

E. Economics of a Plant Having 200 TPA Mushroom Production

1. Total Infrastructure required

The approximate land required for the project around 2 acres.

Sr.No.	Facility	Unit	Size (ft.)	Total area (sq.ft.)
1.	Growing rooms	8	60 x17 x 13	8,160
2.	Pasteurization tunnels	1	40 x 9 x 12	360
3.	Phase-I bunkers	2	50x10x10	1000
4.	Prewetting area with lagoon	1	60x40x14	2400
5.	Casing soil chamber	1	20 x10 x 10	200
6.	A/C Compressor room/Generator room/Electric Cabin		30 x17x13	510
7.	Boiler room	1	15 x12 x 13	180
8.	Stores/ tool room/Workers room/canteen	4	15 x 12 x 13	720
9.	Office block	1	30 x 18 x 13	540
10.	Spawning area	1	20 x 20 x 13	400
11.	Packing Room	1	18 x 12 x 13	216
12.	Service room (underground)	1	12 x 9 x 8	108
13.	Spawn lab	3	18 x 15 x 12	810
Total				15604 sq.ft. or 1450 sq. mt

2. Economics of the project

		Rs. lakhs
A.	Land procurement and its development (Leveling, tree plantation fencing, etc.)	10.00
B.	Compost Unit	
i.	Pre wetting area with lagoon @ Rs.100/-sq.ft	2.40
ii.	Phase-I tunnels @ Rs.300/sq. ft.	3.00
iii.	Pasteurization tunnel @ Rs.400/- sq.ft.	1.44
iv.	Casing soil chamber @ Rs.400/- sq.ft.	0.80
v.	Boiler room, store/tool room, spawning area and service room @ Rs.300/- sq.ft.	4.20
Total		Rs. 11.80
C.	Production facility	
i.	Growing rooms @ Rs.400/- sq.ft	32.60
ii.	AC compressor room/Generator room/Electric cabin/packing room	2.20
Total		Rs. 34.80
D.	Spawn laboratory and office @ Rs.400/- sq.ft.	5.40
E.	Total= Land + Civil works= A+D =	62.00

A.	Plant and machinery	Unit Rate (Rs. lakhs)
i.	Compost and casing unit	8.00
	Includes – filling line, air handling units, phase-I&II blowers, boiler, doors, gratings of the tunnel, Electrical system and water system, etc.	
ii.	Production unit	50.00
	Includes- water chilling plant, air handling units, low pressure boiler, racks, vapour proof lightings, Electrical Panels, cables and doors of the growing rooms, spray system ,etc.	
iii.	Spawn lab. and other equipments including DG sets	8.00
Total cost of the equipments		66.00
Total cost of the project (land+ bldg. + Machinery)		128.00

3. Recurring expenditure

1.	Wages and salary	8.00
2.	Raw materials	25.00
3.	Energy and fuel	20.00
Total		53.00

4. Interest and depreciation

	Cost	Interest & Depression(Rs)
On land		
15% Interest	10.00	1.50
On Building		
5% depreciation	52.00	10.40
15% Interest		
On Machinery		
10% depreciation	66.00	16.50
15% interest		
Total		28.40

5. Cost of production

1.	Raw materials, energy and fuel	45.00
2.	Wages and salary	8.00
3.	Interest and depreciation	28.40
Total		81.40

6. Total production at 100% capacity utilization

At 18% conversion	216 tons (accepted 200 tons)
At 20% conversion	240 tons (accepted 220 tons)
Cost of production/kg	Rs.40.70 (18% conversion)
Cost of production/kg	Rs.37.00 (20% conversion)

7. Profit analysis (220 tons production)

Total production	-	220 tons
Cost of production @ Rs.37, 000/ ton	-	82.00 lakhs
Net sale realization @ Rs.60, 000/ ton	-	Rs.132 lakhs
Net profit (20% conversion)	-	Rs.50.00 lakhs
Net profit (18% conversion)	-	Rs.40.00 lakhs

F. Economics of a Plant Having 25 TPA of Mushroom Production**1. Total Infrastructure required**

	Facility	Unit	Size (ft.)	Total area (sq.ft.)
1.	Cropping rooms	4	20 x13x13	1040
2.	Corridor in the growing rooms	1	52 x 6 x 13	312
3.	Packing room	1	15 x10 x 12	150
4.	Composting yard (without roof)	1	40 x 40	1600
5.	Pasteurization tunnel	1	15 x7 x 12	105
6.	Boiler room	1	10 x10 x12	100
Total			3307 sq.ft. or 310 sq. mtrs.	

In addition of above land will be required for straw storage, casing soil storage and poultry manure. Approximate land required will be around 600-1000 sq. mts.

2. Economics of the project

	Rs. lakhs
A. Land procurement and its development	2.00
B. Compost Unit (construction cost)	
i. Composting yard @ Rs.50/- per sq. ft.	0.80
ii. Pasteurization tunnel @ Rs. 400/sq.ft.	0.42
iii. Boiler room/shed @ Rs.200/- sq. ft.	0.20
iv. Water tank 10,000 litres capacity	0.20
Total B	1.62

C.	Production Facility	
i.	4 Cropping rooms including insulation @ Rs.400/sq. ft.	4.16
ii.	Corridor in the growing rooms @ Rs.100/ sq. ft.	0.31
iii.	Packing room/office @ Rs.300/sq. ft.	0.45
Total C		4.86
D.	Cost of Machinery	
i.	20 tons chilling plant, complete in all aspects including AHU's, 4 Nos (ammonia based)	6.00
ii.	Boiler 150 kg steam generation capacity	0.70
iii.	Centrifugal blower along with ducting	0.30
iv.	Steel racks in the growing rooms and iron grating in the tunnel	2.00
v.	Electric and other installations	0.50
vi.	Water pipe line and fittings	0.30
vii.	Mis. Equipments like sprayers, forks harvestings trays, etc.	0.15
Total – D		9.95
F.	Total cost of the project (A+B+C+D)	= 18.43 lakhs Or Say =Rs.19.00 lakhs

3. Recurring expenditure

G.	Total manpower required	
i.	Labourers 4 nos. @ Rs.3000 PM	= Rs. 1.44 lakhs
Expenses to incur on raw materials and energy		(Rs. in lakhs)
i.	Straw 55 tons @ Rs. 3000 MT	1.65
ii.	Poultry manure 30 tons @ Rs.450/MT	0.14
iii.	Casing soil procurement its treatment 50 M ³ @ Rs.100/ M ³	0.05
iv.	Spawn 8 qts. @ Rs. 5000/- qt.	0.40
v.	Poly bags	0.30
vi.	Energy and fuel	1.20
vii.	Gypsum, urea, wheat bran, pesticides, etc.	0.20
Total		3.94

4. Interest and depreciation

	Cost	Interest & Depression (Rs.)
On land		
15% Interest	2.00	0.30
On Building		
5% depreciation	6.48	1.29
15% Interest		
On Machinery		
10% depreciation	9.95	2.48
15% interest		
Total		4.07

5. Cost of production

1.	Raw materials	3.94
2.	Wages and salary	1.44
3.	Interest and depreciation	4.07
Total		8.57

Total production at 100% capacity utilization at 18% conversion taking 6 crops per room (6 tons compost) of 60 days duration = 26 tons (accepted 25 tons) or around 68- 70 kg mushrooms production per day.

6. Cost profit analysis

Cost of production per kg	=	Rs.34.30/- kg
Selling price @ Rs.60/kg	=	Rs.15.00
Net return in a year	=	Rs.6.43 lakhs

G. Sum Up

Capacity (TPA)	Land required (ha)	Approximate cost			Total	Cost of production (Rs./kg fresh mushroom)
		Spawn	Lab	Cultivation		
50	0.10	-		20.0	20.0	35.0
200	0.75	10.0		118.0	128.0	41.0
500	1.50	15.0		290.0	328.0	40.0
3000	5.00	62.0		1570.0	1858.0	37.5

Calculation is based on prices in 2010

Cultivation Technology of Summer White Button Mushroom (*Agaricus bitorquis*)

B. Vijay

White button mushroom (*Agaricus* spp.) is the most widely cultivated mushroom in the world, contributing around 31% of the world mushroom production. The genus has two cultivated species namely *A.bisporus* and *A.bitorquis*. The former is a low temperature species requiring $16\pm 2^{\circ}\text{C}$ for its fruiting. The later, on the other hand grows at a higher temperature ($23\pm 2^{\circ}\text{C}$). Cultivation technology of this mushroom is similar to *A.bisporus* excepting that it grows at a higher temperature.

A. Advantages of *A. bitorqis* Cultivation

- It requires 4-6°C higher temperature than *A.bisporus* for its growth and fructification. Fruiting requires a temperature of 24°C against 16-18°C in *A.bisporus*.
- It has longer shelf life.
- Its fruit bodies are large and solid, hence ideal for canning.
- It is resistant to all known mushroom viruses
- It can tolerate higher carbon dioxide concentration in the cropping room compared to *A.bisporus*.

B. Disadvantages

- It has a very slow growth rate compared to *A.bisporus*.
- It slow growth rate coupled with higher temperature range of its growth, makes it highly susceptible to pests, diseases and competitor moulds particularly false truffle.
- Due to above two reasons, this mushroom is highly sensitive and therefore, requires best quality compost (pasteurized) and strict hygiene during cultivation.

C. Cultivation Technology

The cultivation technology of this mushroom can be broadly described under four heads:

1. Compost preparation
2. Spawn and spawn run
3. Cropping
4. Post harvest management

1. Compost preparation

This mushroom requires highly selective substrate and compost prepared by short method of composting (pasteurized compost) is ideal for its cultivation (please refer chapter 7). It is difficult to cultivate this mushroom on long method compost unless strict hygienic conditions are maintained.

2. Spawning and spawn run

Once the compost is finally prepared, the spawn is mixed in the compost in a very clean environment. The optimum rate of spawn for this mushroom is 1.0 per cent of fresh weight of compost. Spawn is thoroughly mixed in the compost, then filled in bags or beds and slightly pressed with hands. Pressing too hard particularly when moisture level of compost is high, can result in anaerobic conditions that will not only inhibit the spawn run but may also kill the mycelium. The temperature of spawned compost is maintained at 28 to 30°C. If the temperature is properly maintained with high carbon dioxide concentration in the rooms, spawn run will be completed in 2 weeks time. If the bed/compost surface has been covered with newspaper sheets, they are periodically sprayed with water to keep these moist and RH is maintained at 90-95%. However, if the cover is of polythene than there is no need to spray water on bed surface. In controlled environment growing room's temperature and humidity can be maintained through air handling unit. During the spawn run very little fresh air is required that too for maintenance of temperature. Good spawn run is considered when the entire compost is impregnated by spawn and turns white.

3. Casing and case run

Like in *A.bisprous* no fruiting can be obtained if a layer of casing soil is not applied on the surface of spawn run compost. In western countries peat is largely used as casing for button mushroom. This material is not available in our country and Farm Yard Manure (FYM) and spent compost are used as substitute to peat. Both these should be at least 2 years old and completely decomposed. Leaching of these materials in water for 4-6 hours improves the quality of both these materials as this removes the toxic salts. Casing material is prepared by mixing FYM with loam soil in the ratio of 4:1 (v/v), spent compost can be used as such and pH of the casing should be 7-7.5. Like compost, casing material should also be pasteurized for cultivation of this mushroom. Moist casing soil is pasteurized in pasteurization chamber, temperature is raised to 65-70°C through introduction of live steam and this temperature is maintained for 6-8 hours. For application



Fig. 14.1. NCB 6 and NCB 13-The two strains recommended for cultivation in India

of casing layer, cover is removed from bed surface, the surface is levelled by slightly pressing with hands and a uniform layer of casing 4-5 cm in thickness is applied. Cased surface is regularly sprayed with water to keep it moist. Formaldehyde @ 0.5% can be added to water during the first spray immediately after casing to kill the contaminants that might have come during the process of casing. Care should be taken to maintain absolute hygiene during spawning, spawn run and case run. Casing should be moist at the time of application and should be saturated with water immediately after application.

Same conditions as required during spawn run are maintained during case run. Minimal fresh air is required during this period. Given the above conditions, case run will be completed in a week's time. During this stage mycelium completely colonises the casing soil and forms thick strands compared to silky strands in the compost. The quality of casing layer should be such that it is able to allow free exchange of gases even when saturated with water. It should remain soft during case run and cropping. Some casing soil is kept in sterile bags for use during cropping and stored in such a way that it is not reinfected with pests and diseases. During the entire period from spawning to end of cropping, entry of insect's pests should be prevented in cropping rooms through 28-30 mesh net.

Higher carbon dioxide concentration during case run results in quick mycelial colourization. The moisture available in the casing soil is very important hence casing should be kept wet by spraying water periodically.

Certain agronomic practices that can improve the prospects of a good crop can be practiced at the time of casing (refer chapter 9).

4. Cropping

Immediately after the case run, air is introduced in cropping rooms by opening ventilation and the temperature is brought down to 24°C. If cultivation is being done under natural conditions in seasonal growing rooms, 3-4 air changes/hour is sufficient. The casing soil is kept moist periodically by spraying water on the surface of casing soil. After these changes have been brought about, it takes about 10-12 days for fruit body initials to appear. Frequent air changes are given and temperature of room is maintained at 24-26°C. After the pinheads have been formed, direct spray of water on pinheads is avoided, however, relative humidity in the room is maintained at 85% by spraying water on floor and walls or through AHU installed for the purpose. Spraying is resumed on bed surface once the pinheads have attained the size of pea. Sometimes there is a problem of mass pinning in *A.bitorquis* that can be avoided by restricting the entry of fresh air through regulation of ventilation opening under environment controlled rooms having air handling units. The permissible speed of air over the bed is 15 cm/second, which can be increased if air is humidified. The air is forced into room through air handling units, which has an inbuilt centrifugal fan that can create an air pressure supporting 50 mm of water level. This will result in moderate pinning with majority of them developing into mature fruit bodies. This is a very critical point in cultivation of *A.bitorquis* and should be strictly adhered to.

During the first and second flush, the production is heaviest with very active mycelium and therefore, requirement of fresh air is maximum. During this stage, carbon dioxide concentration should be below 1500 ppm. Precise temperature, humidity and fresh air levels can only be maintained in controlled environment cropping rooms where

conditioned air is forced into room via circulating ducts, which has holes for directing the air downwards to floor and redistributing these between the tiers through maintenance of positive pressure. Exhausted air is removed through vents near the floor. All entry points and exhaust are covered with fly mesh to prevent the entry of insect-pests and disease propagules. Clean water should be used for spraying. Use of chemicals for control of various pests and diseases should be avoided. If at all needed safer fumigants like DDVP or insecticide like melathion can be used but not very frequently and at on set of problem during flush breaks.

Harvesting is done when the fruit body size is about 3-4 cm, and the cap is still not open. For harvesting fruit body is held lightly between thumb and forefinger and rotated slightly and lifted. Soil ridden at lower end, which has some root like rhizoids is removed with a sharp knife. The debris attract large number of insect pest and disease propagules and therefore, should be disposed off in such a way that it does not serve as an inoculum for the crop.

Mushrooms are packed in polythene bags with small pinholes to prevent anaerobic rotting and marketed. Under refrigeration (stored at 5-6°C), these mushrooms have a shelf life of 3-4 days. Compared to *A.bisporus*, this mushroom can stay in good condition for 2-3 days even at 15°C without any adverse effect on its quality. In the absence of ready market for the fresh mushroom, this mushroom can be canned or pickled. This mushroom is harder compared to *A.bisporus* and can retain its texture in cans. Its outer surface is smooth and silky compared to *A.bisporus* where fruit bodies are not so smooth. This mushroom has a shorter stipe and therefore can fetch premium price for freeze dried products also. Only disadvantage of eating this mushroom is that some of its strains like K-26 and K-32 emit chlorine like odour on eating. However, the strains released by DMR, Solan namely NCB-6 and NCB-13 do not give such odour and therefore can be grown to fetch premium price during off-season when *A.bisporus* is not cultivated.

Further Readings

1. Dhar, B.L. 1995. Production technology of *Agaricus bitorquis* In: Advances in Horticulture Vol. 13 Mushroom (K.L. Chadha and S.R. Sharma eds.), pp. 99-108.

Oyster Mushroom Cultivation

R.C. Upadhyay

Oyster mushroom commonly referred as 'Dhingri' in India, is a basidiomycetes and belongs to the genus '*Pleurotus*'. It is 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 extremely variable character influenced by the temperature, light intensity and nutrients present in the substrate. The name *Pleurotus* has its origin from Greek word, 'Pleuro' that means formed laterally or lateral position of the stalk or stem.

The oyster mushroom is one of the most suitable fungal organism for producing protein rich food from various agrowastes without composting. This mushroom is cultivated in about 25 countries of far-east Asia, Europe and America. It is the 3rd largest cultivated mushroom in the world. China alone contributes 88% of the total world production. The other major oyster producing countries are South Korea, Japan, Italy, Taiwan, Thailand and Philippines. At present India produces annually 10,000 tons of this mushroom. It is popularly grown in the states of Orissa, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh, West Bengal and in the North-Eastern States of Meghalaya, Tripura Manipur, Mizoram and Assam.

A. 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 maximum number of commercially cultivated species suitable for round the year cultivation. Moreover, variation in shape, colour, texture, and aroma are also available as per 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 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 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 it can be used in powdered form for several preparations. Fresh mushrooms have a shelf life of 24-48 h even at room temperature.

5. Highest productivity

The productivity of oyster mushroom per unit time is very high as compared to all other cultivated mushrooms. One can harvest minimum of about 500 to 700 kg of fresh oyster mushroom 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 period needed for compost preparation). Yield of this mushroom can further be increased by supplementing the substrate with suitable nitrogen source viz., soybean and cottonseed meal or by introducing high yielding cultures/strains.

The present day cultivation technology of oyster mushroom is a result of various successive steps evolved throughout the world during 20th century. A very primitive form of growing *Pleurotus* spp. was adopted by Lumberman in Europe during 19th century that involved collection of wood logs and stumps showing fructification in nature and keeping them in cool and moist places. 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.

B. The Biology of Oyster Mushroom

Visually the basidiocarps or fruit bodies of an oyster mushroom have three distinct parts - a fleshy shell or spatula shaped cap (pileus), a short or long lateral or central stalk called stipe and long ridges and furrows underneath the pileus, called gills or lamellae. The gills stretch from the edge of the cap down to the stalk and bear the spores. If a fruit body is kept on a paper directly (gills facing the paper) a dirty white or lilac deposition of powdery spores can be seen. The spore print colour may be whitish, pinkish, lilac or grey. The spores are hyaline, smooth and cylindrical. The spores are heterothallic and germinate very easily on any kind of mycological media and within 48-96 h whitish thread like colonies could be seen. The mycelium of most *Pleurotus* spp. is pure white in colour. *P. cystidiosus* and *P. columbinus* forms coremia like stalked structures (asexual spores). Basidiospores on germination forms primary mycelium. Fusion between two compatible primary mycelia develops into secondary mycelium, which is having clamp connections and is fertile. Primary mycelium is clampless and non-fertile.

C. Varieties of Oyster Mushroom

All the varieties or species of oyster mushroom are edible except *P. olearius* and *P. nidiformis*, which are reported to be poisonous. There are 38 species of the genus recorded throughout the world (Singer). In recent years 25 species are commercially cultivated in different parts of the world, which are as follows: *P. ostreatus*, *P. flabellatus*, *P. florida*, *P. sajor-caju*, *P. sapidus*, *P. cystidiosus*, *P. eryngii*,

P. fossulatus, *P. opuntiae*, *P. cornucopiae*, *P. yuccae*, *P. platypus*, *P. djamor*, *P. tuber-regium*, *P. australis*, *P. purpureo-olivaceus*, *P. populinus*, *P. levis*, *P. columbinus*, *P. membranaceus* etc. (Fig. 15.1).



Fig. 15.1. Different types of cultivated *Pleurotus* spp.

D. Cultivation

The procedure for oyster mushroom cultivation can be divided into following four steps (Fig. 15.2).

1. Preparation or procurement of spawn
2. Substrate preparation
3. Spawning of substrate and
4. Crop management

1. Preparation or procurement of spawn

The spawn preparation technique for oyster mushroom is similar to white button mushroom (*A.bisporus*). One should have a pure culture of *Pleurotus* spp. for inoculation on sterilized wheat grain. It takes 10-15 days for mycelial growth on grains. It has been reported that Jowar and Bajra grains are superior over wheat grains. The mycelium of oyster mushroom grows very fast on wheat grains and 25-30 days old spawn starts forming fruitbodies in the bottle itself. It is, therefore, suggested that the schedule for spawn preparation or spawn procurement should be planned accordingly. Sometimes the mushroom farmers are using active mycelium growing in bags for spawning fresh new oyster mushroom bags. This method can be used on a small scale. There are always chances of spread of contamination through infested straw by active mycelium spawning method so it is not advisable on large scale commercial cultivation.

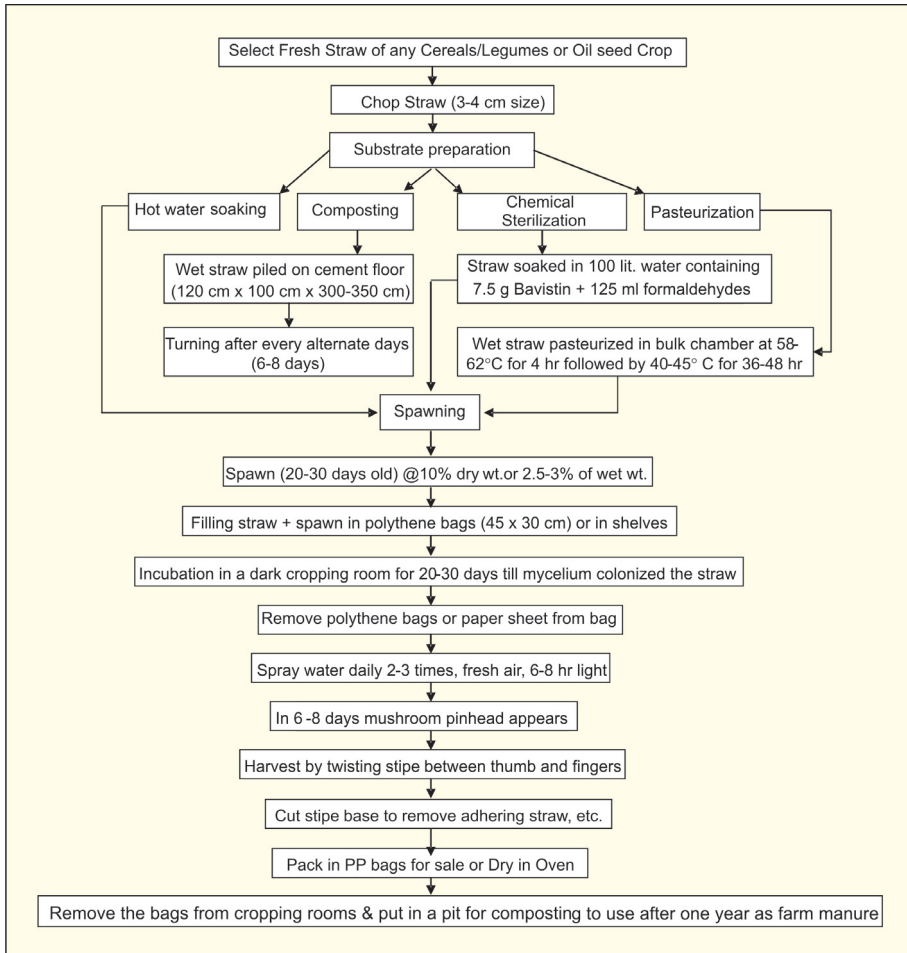


Fig. 15.2. Different steps for oyster mushroom cultivation

2. Substrate preparation

a. Substrates for oyster mushroom and their nutrition quality

A large number of agricultural, forest and agro-industrial by-products are useful for growing oyster mushroom. These by-products or wastes are rich in cellulose, lignin and hemicellulose. However, yield of oyster mushroom largely depends upon the nutrition and nature of the substrate. The substrate should be fresh, dry, free from mould infestation and properly stored. The substrates exposed to rain and harvested immature with green chlorophyll patches inhibit the growth of *Pleurotus* mycelium due to the presence of competitor moulds. Oyster mushroom can utilize a number of agro-wastes including straws of wheat, paddy and ragi, stalks and leaves of maize, jowar, bajra and cotton, sugarcane bagasse, jute and cotton waste, dehulled corncobs, pea nut shells, dried grasses, sunflower stalks, used tea leaf waste, discarded waste paper and synthetic compost of button mushroom. It can also be cultivated using industrial wastes like paper

mill sludges, coffee byproducts, tobacco waste, apple pomace, etc. The cellulose and lignin contents are important components of any substrate as far as yield is concerned. Cellulose rich substrates like cotton waste give better yields. Cellulose helps in more enzyme production, which is correlated with higher yield.

b. Methods of substrate preparation

The mycelium of *Pleurotus* is saprophytic in nature and it does not require selective substrate for its growth. The mycelial growth can take place on a simple water treated straw but there are number of other cellulolytic moulds already present on straw, which compete with *Pleurotus* mycelium during spawn run and also secrete toxic metabolites hampering its growth. There are various methods to kill undesirable microorganisms present in the straw to favour the growth of *Pleurotus* mycelium. The popular methods of substrate preparation are as follows.

i. Steam pasteurization

In this method prewetted straw is packed in wooden trays or boxes and then kept in a pasteurization room at 58-62°C for four hours. Temperature of the pasteurization room is manipulated with the help of steam through a boiler. Substrate after cooling at room temperature is seeded with spawn. The entire process takes around 3-5 days. This method is adopted on a commercial scale by Zadrazil and Schneidereit in Germany. There are various minor variations of this method adopted in Europe.

ii. Hot water treatment

The substrate (wheat straw) after chopping (5-10 cm) is soaked in hot water (65 to 70°C) for one hour or 60 to 120 minutes at 80°C or in case of paddy straw at 85°C for 30-45 minutes. After draining excess water and cooling, spawn is added. Hot water treatment makes the hard substrate like maize cobs, stems, etc. soft so that the growth of mycelial takes place easily. This method is not suitable for large-scale commercial cultivation.

iii. Chemical sterilization technique

Various species of *Trichoderma*, *Gliocladium*, *Penicillium*, *Aspergillus* and *Doratomyces* spp. are the common competitor fungi on the straw during oyster mushroom cultivation. If present on the straw during spawn run, they do not allow the growth of mushroom mycelium resulting in yield loss or complete crop failure. When wheat straw or paddy straw is treated by steeping in a chemical solution of carbendazim 50% WP (37.5 ppm) and formaldehyde (500 ppm) for a period of 16-18 h, most of the competitor moulds are either killed or their growth is suppressed for 25-40 days after spawning. The technique, which was standardized at DMR, Solan by Vijay and Sohi in 1987, is as follows: Ninety litres of water is taken in a rust proof drum (preferably of galvanized sheet) or G.I. tub of 200 litres capacity. Ten to twelve kg of wheat straw is slowly steeped in water. In another plastic bucket, Bavistin 7.5 g and 125 ml formaldehyde (37-40%) is dissolved and slowly poured on the already soaked wheat straw. Straw is pressed and covered with a polythene sheet. After 15 to 18 h the straw is taken out and excess water drained. One can use a larger container or cemented tank of 1000-2000 liters for soaking more straw. The chemicals to be added can be calculated as above. The chemical containing water can be reused once again for pasteurization of the straw.

iv. Sterile technique

It is also known as Till method. The chopped substrate after soaking in cold water is put in heat resistant polypropylene bags and sterilized in an autoclave at 20 p.s.i. for 1-2 hours followed by spawning under aseptic conditions. This method is more suitable for research work rather than on large-scale commercial production.

v. Fermentation or composting

This method is a modification of composting technique used for white button mushroom. It is most suitable for hard substrates like cotton stalks, maize stalks, leguminous stubbles, etc. Both aerobic and anaerobic fermentation of the substrate is suitable for *Pleurotus* cultivation. Composting should be done on a covered area or shed. Chop the substrate into 5-6 cm long pieces. Add ammonium sulphate or urea (0.5-1%) and lime (1%) on dry weight basis of the ingredients. Horse manure or chicken manure (10% dry weight basis) can also be used instead of nitrogenous fertilizers. Addition of lime improves the physical structure of the compost. After mixing all the ingredients sprinkle water till it is completely wet. Prepare a triangular heap of 75-90 cm but not more than 1 meter height. After 2 days of fermentation, turning of pile is done adding 1% superphosphate and 0.5% lime. The compost will be ready after 2 days of this turning. It can be spawned as such or used after pasteurization. The pasteurization of substrate can be done using the tunnels used for button mushroom compost preparation. The straw, after initial fermentation for 4 to 6 days, is filled in tunnel upto 2-3 ft. height and pasteurized at 58-60°C for 4 h and conditioned at 40-45°C for 30-36 h.

c. Substrate supplementation

The nitrogen content in most of the substrates ranges between 0.5 to 0.8% and hence addition of organic nitrogen in the straw helps in getting higher yields. Some of the common supplements are wheat bran, rice bran, cottonseed meal, soybean cake, etc. Wheat bran and rice bran should be used @ 10% while cottonseed meal, soybean cake and groundnut cake should be tried @ 3-6% on dry weight basis of the substrate. The supplements should be treated with 25 ppm carbendazim (250 mg in 10 lit. water) for 14-16 h. Supplements are thoroughly mixed with straw before spawning. Addition of supplements increases substrate temperature by 2-3°C or even more and hence supplementation during summer season is not advisable. However, during winter months though increased temperature is observed, which helps in quick spawn run. Excess nitrogen can attract mould infestation, which should be taken care of.

3. Spawning

Freshly prepared (20-30 days old) grain spawn is best for spawning. The spawning should be done in a pre-fumigated room (48 h with 2% formaldehyde). The spawn should be mixed @ 2 to 3% of the wet wt. of the substrate. One bottle spawn of 300 g is sufficient for 10-12 kg of wet substrate or 2.8 to 3 kg of dry substrate. Spawn can be mixed thoroughly or mixed in layers. Spawned substrate is filled in polythene bags (60 x 45 cm) of 125-150 gauze thickness. Ten to 15 small holes (0.5-1.0 cm dia) should be made on all sides especially in the bottom for leaching of excess water (Fig. 15.3). Perforated bags give higher and early crop (4-6 days) than non-perforated bags because of accumulation of high CO₂, which inhibits fruiting. One can also use empty fruit packing cartons or wooden boxes for filling substrate. Polythene sheets of

200-300 gauze thickness are spread in rectangular wooden or metal box, spawned substrate is filled and the polythene sheet is folded from all the four sides to make a compact rectangular box. It is tightly pressed and tied with a nylon rope. The block is incubated as such and after mycelium growth polythene sheet is removed.

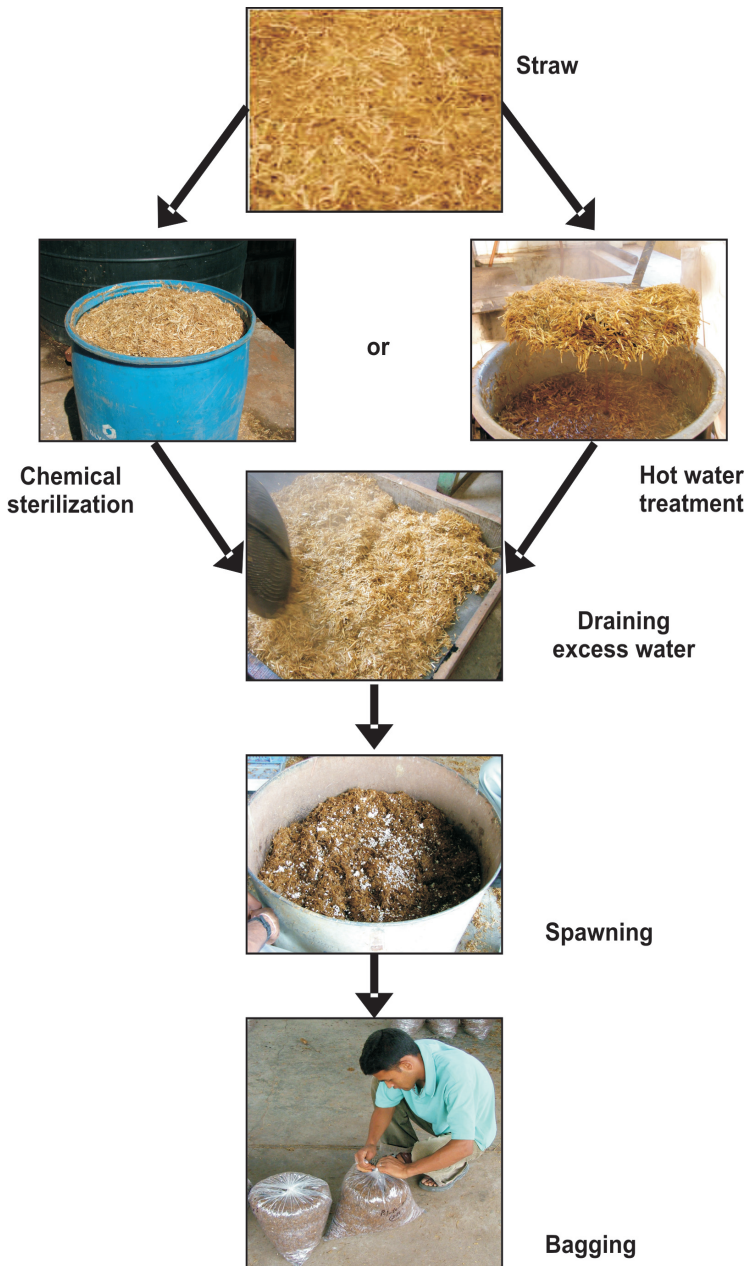


Fig. 15.3. Pictorial flow chart of oyster mushroom cultivation

4. Crop management

The spawned bags or blocks are kept in incubation room for mycelial growth.

a. Incubation

Spawned bags can be kept on a raised platform or shelves or can be hanged in cropping room for mycelial colonization of the substrate. Although mycelium can grow between 10-30°C but the optimum temperature lies between 22-26°C. Higher temperature (more than 30°C) in the cropping room will inhibit the growth and kill the mycelium. Daily maximum and minimum temperature of cropping rooms and beds should be recorded. The bed temperature is generally 2-4°C higher than the room temperature. Mycelium can tolerate very high CO₂ concentration of 15-20%. During mycelial growth the bags are not to be opened and no ventilation is needed. Moreover, there is no need for any high relative humidity, so no water should be sprayed.

b. Fruit body induction

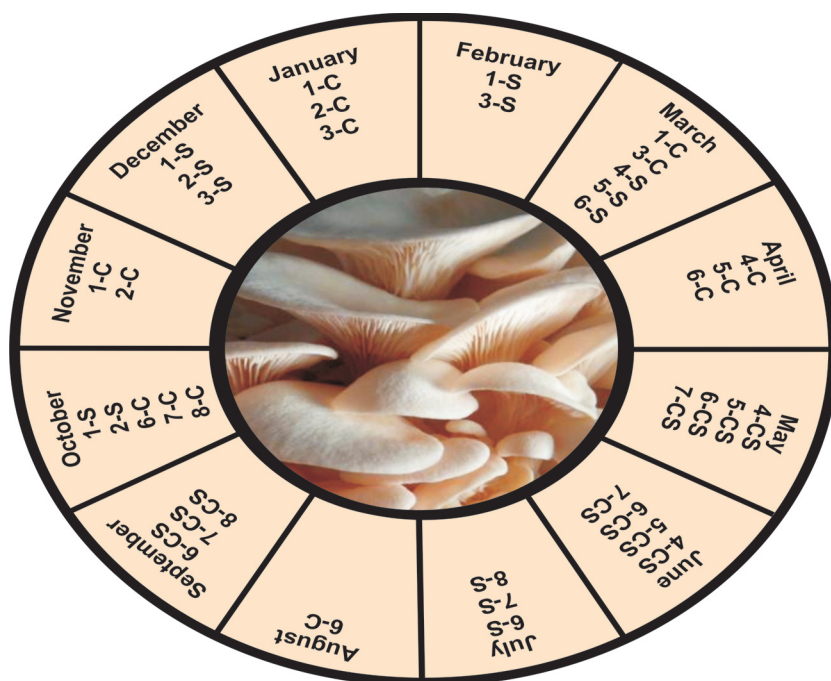
Once the mycelium has fully colonized the substrate, it forms a thick mycelial mat and is ready for fruiting. Contaminated bags with mould infestation should be discarded while bags with patchy mycelial growth may be left for few more days to complete the spawn run. In no case bags should be opened before 16-18 days except in case of *P. membranaceus* and *P. djamor* var. *roseus*, which forms fruit bodies within 10 days even in closed bags from small holes. Casing is not required in oyster mushroom cultivation. All the bundles, cubes or blocks are arranged on iron/wooden platforms or shelves with a minimum distance of 15-20 cm between each bag in the tier. They can also be hanged. The cultural conditions required for fruiting are as follows :

i. Temperature

Mycelial growth of all the *Pleurotus* spp. can take place between 20-30°C. However, for fruiting different species have different temperature requirement. Depending upon the temperature requirement of a species, they can be categorized into two groups- winter or low temperature requiring species (10-20°C) and summer or moderate temperature requiring species (16-30°C). Summer varieties can fructify at low temperature but the winter varieties will not fruitify at higher temperatures. They need a low temperature shock for inducing fruit body formation. Commercial varieties, which can be cultivated during summer are *P. flabellatus*, *P. sapidus*, *P. citrinopileatus* and *P. sajor-caju*. Low temperature requiring species are *P. ostreatus*, *P. florida*, *P. eryngii*, *P. fossulatus* and *P. cornucopiae*. We have isolated a wild species of *P. cornucopiae*, which is suitable for growing between 15-25°C. The growing temperature not only affects the yield but also the quality of produce. The pileus or cap colour of *P. florida* is light brown when cultivated at low temperature (10-15°C) but changes to white pale to yellowish at 20-25°C. Similarly fruit body colour of *P. sajor-caju* when cultivated at 15-19°C is white to dull white with high dry matter content while at 25-30°C, it is whitish brown to dark brown with less dry matter.

ii. Relative humidity

All the *Pleurotus* species require high relative humidity (75-85%) during fruiting. To maintain relative humidity, water spraying is to be done in the cropping rooms. During hot and dry weather conditions daily 2-3 spray are recommended while in hot and humid conditions (monsoon) one light spray will be sufficient. The requirement of water spray



S - Spawning; C - Cropping

1. *Pleurotus florida*, 2. *P. ostreatus*, 3. *P. cornucopiae*, 4. *P. flabellatus*,
5. *P. sapidus*, 6. *P. sajor-caju*, 7. *P. citrinopileatus*, 8. *P. membranaceus*

Fig. 15.4. Round the year cultivation of oyster mushrooms species in North West Himalayas

can be judged by touching the surface of the substrate. Spraying should be done with a fine nozzle to create a mist or fog in the cropping room. It is desirable that mushrooms are harvested before water spray. Ventilators and exhaust fans should be operated for air circulation so that the excess moisture from the pileus surface evaporates. Sometimes fruit bodies give off an offensive smell due to the growth of saprophytic bacteria on the wet pileus surface, under such conditions 0.05% bleaching powder spray at weekly interval is recommended.

iii. Oxygen and carbon dioxide requirements

The oyster mushroom can tolerate high carbon dioxide concentration during spawn run (upto 20,000 ppm or 2%) while it should be less than 600 ppm or 0.06% during cropping. Therefore sufficient ventilation should be provided during fructification. If the CO₂ concentration is high, the mushrooms will have long stipe and small pileus. Mushrooms will appear like a mouth of trumpet.

iv. Light

Unlike green plants mushrooms do not require light for the synthesis of food. They grow on dead organic plant material. Light is required to initiate fruit body initiation. For primordia formation, light requirement is 200 lux intensity for 8-12 h. Inadequate light conditions can be judged by long stalk (stipe), small cap and poor yield. The colour of the pileus is also influenced by the light intensity and its duration. Fruit bodies raised in

bright light are dark brown, grey or blackish coloured. If the light intensity is less than 100 lux the mushrooms will be pale yellowish.

v. Hydrogen ion concentration (pH)

The optimum pH during mycelial colonization should be between 6.0 to 7.0 while the pH of the water for spraying should be neither too acidic nor alkaline. Water should not contain harmful salts. Rusty iron drums and tubs used for substrate treatment or storing water for spraying delay fructification due to presence of excess iron in the water.

F. Post Harvest Practices

Mushrooms should always be harvested before water spray. The right stage for picking can be judged by the shape and size of fruit body. In young mushrooms, the edge of the cap is thick and cap margin is enrolled while the cap of 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. After harvesting lower portion of the stalk with adhering debris should be cut using a knife. 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 sun dried by spreading on a cotton cloth in bright sunlight or diffused light. The dried produce with 2-4% moisture can be stored for 3 to 4 months after proper sealing.

G. Medicinal and Nutritional Value of Oyster Mushroom

Oyster mushrooms are 100% vegetarian and the nutritive value of oyster mushroom 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 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 vegetables. A polycyclic aromatic compound *pleurotin* has been isolated from *P. griseus*, which possess antibiotic properties.

Further Readings

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Economics of Oyster Mushroom Cultivation

R.C. Upadhyay

Oyster mushroom (*Pleurotus* spp.), commonly known as “Dhingri” in India, is a lignocellulose loving fungus growing in nature on living or dead tree trunks/stumps or bark. They are easily recognized in nature due to their peculiar morphology with an eccentric short stem or stipe. Cultivation technology of oyster mushroom is very simple which does not require costly infrastructure facilities. The cultivation of oyster mushroom in India is mainly done in seasonal low cost growing rooms with very less expenditure on infrastructure. One can hardly find a big oyster mushroom growing unit in India having round the year production. There is no organized market where one can sell his produce or purchase fresh or dry oyster mushroom throughout the year. Therefore, the production of oyster mushroom on a commercial scale is rare in our country as compared to *Agaricus bisporus* (button mushroom). Theoretically each crop takes 45 days and under controlled conditions and hence there can be 8 crops per year.

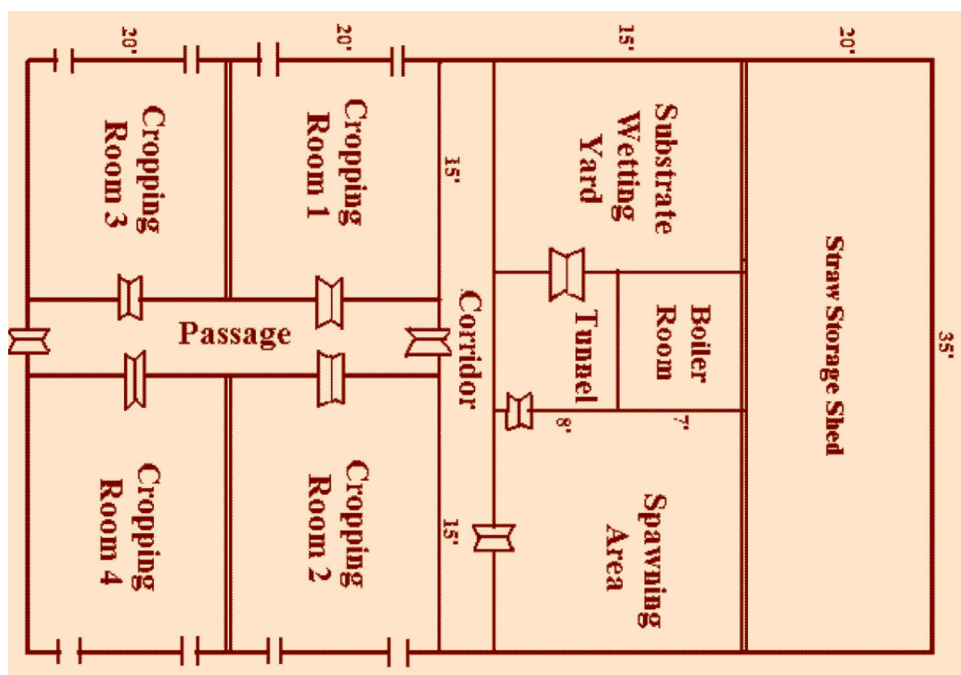


Fig. 16.1. Layout plan of an oyster mushroom unit

There are wide variations in cultivation methods, scale of production, substrates used, type of growing houses for cultivation of oyster mushrooms in different countries or even different areas of a country, hence the economics also varies considerably. The operating cost is kept low by using cheap agricultural wastes available in the locality and low cost mushroom growing rooms without any specific control of temperature, humidity and aeration.

Further, oyster mushroom can be cultivated both on fresh or fermented substrate and hence cost on substrate pasteurization can also be curtailed by avoiding use of costly boilers, pasteurization tunnel and its ancillary equipments, since quite effective pasteurization of the substrate is achieved either by immersing substrate in hot water at 60-70°C for 15-30 minutes, partial outdoor composting of the substrate for 6-8 days or steeping substrate overnight (14-16 h) in water containing 37.5 ppm carbendazim and 500 ppm of formaline in a plastic or GI drum with a lid. A mushroom grower should have sufficient knowledge of technical and economical aspects of this mushroom before taking up mushroom cultivation. Various factors like cost and availability of inputs, demand in the market and productivity affect the viability of a mushroom project. Contaminated old straw, negligence in spraying water, bad aeration, fluctuating temperature, unhygienic conditions and insufficient light may affect the total yield and economic returns. A small oyster mushroom farm with four growing rooms of 20' x 15' x 10' with a minimum capacity of 250 to 300 bags of 4 kg. wet straw requiring about 2.5 quintals of fresh substrate will form a viable unit giving a daily production of around 10 kg fresh mushroom per room (Fig. 16.1). However, it is advised that the bags should not be opened for fruiting on a

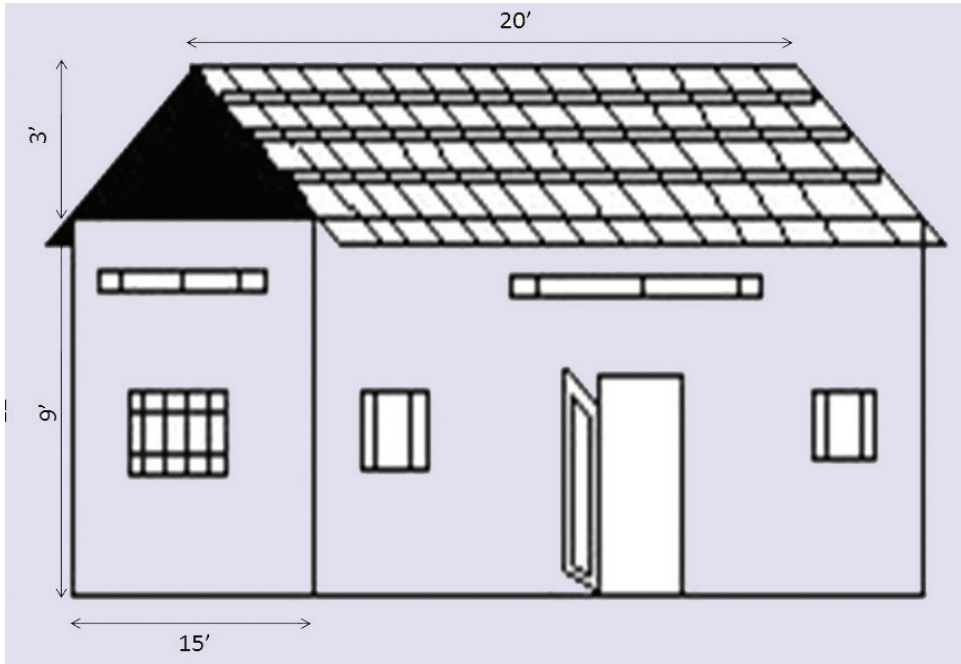


Fig. 16.2. Low cost oyster mushroom house

single day but daily 20 to 30 bags should be exposed for fruiting so that one can easily harvest and sell about 10 kg fresh mushroom daily in the market.

Although it is very difficult to give a generalized cost benefit ratio for all the regions due to variations in cost of land, labour, electricity, raw materials and market price. However, certain guidelines can be given which should be considered for calculating the cost of cultivation. The main inputs required for oyster mushroom cultivation are substrate and spawn. Cheaper substrates like paddy straw, maize and cotton stalks and leaves, corn cobs, coconut and oil palm plant wastes, banana pseudo stems and leaves, cotton industry wastes and wastes from leguminous and oil producing plants like soybean, mustard, ground nut should be used either alone or in combination to give better productivity. The farmers can further reduce the cost of mushroom production by producing spawn for their own requirement. A low cost spawn laboratory using small autoclave, inoculation chamber or laminar flow will be appropriate as the mycelium of oyster mushroom is very fast growing and in 10-12 days spawn can be prepared with little practice.

Economics of oyster mushroom cultivation by chemical sterilization technique

A. Economics of Oyster Mushroom Cultivation in Polyhouse (3.5 to 4 TPA)

(a) Non Recurring Expenditure		(Rupees)
i)	Building cost: High density polythene sheet growing room of 20' x 15' x 10' (300 ft ²) Rs 18,000 per unit	36,000.00
ii)	Sprayer pump (1 no.)	2000.00
iii)	Galvanized tubs or empty diesel drums painted inside (3 nos.)	1,200.00
iv)	Nylon ropes for hanging bags	2,000.00
v)	Thermometers (max. & minimum, dry & wet bulb thermometer & bed thermometers)	500.00
vi)	Industrial coolers (2 nos.)	20,000.00
Total non-recurring expenditure		61,700.00
(b) Recurring expenditures (cost of raw materials)		
i)	Wheat straw or paddy straw 8 q @ Rs.300.00	2,400.00
ii)	Cost of 800 polythene bags (125-150 gauze thick of 60 x 45 cm @ Rs.100/kg (12 kg)	1200.00
iii)	Cost of spawn @ Rs.50.00/kg (80 kg)	4,000.00
iv)	Labor wages for @ Rs.100.00/day for 2 persons (1 crop)	8,000.00
v)	Chemicals	
	(A) Bavistin @ 7 g for treating 10 kg straw (the solution will be reused for treating straw on the next day. Total Bavistin requirement 560 g = Rs 350	670.00
	(B) Formaldehyde 3.5 liter (100 ml for 10 kg straw) @ Rs.40.00 per litre (commercial grade)= Rs 320	
vii)	Miscellaneous charges (water, electricity, pesticides, small polythene bags for packing, etc.)	2,000.00
Total		18,270.00
viii)	(a) Building depreciation 10% + interest 15% = (Rs 9000) and Machinery depreciation 10%+ interest 15%=6425	
	Total for one year	15,425.00
	For one crop	2,570.80
Total expenditure for one crop		18,270+2,570=20,840

Expected yield (70% BE) = 600 kg fresh mushrooms	
Income from sale @ Rs. 50.00 kg	35,000.00
Net profit from one crop	14,160.00
Annual Profit from 6 crops	84,960.00

B. Economics of Oyster Mushroom Cultivation in Mud House (7 to 7.5 TPA)

(a)	Non recurring Expenditure	(Rupees)
i)	Cost of mud house (60' x 20' x 10-13') for housing 1300 bags of 6 kg wet straw (1200 ft ²)	30,000.00
ii)	Annual maintenance	3,000.00
iii)	Sprayer pump	2,000.00
iv)	Cost of tubs or drums (3 nos.)	1,200.00
v)	Thermometers	1,000.00
vi)	Bamboo and rope for making racks	3,500.00
	Total	40,700.00
(b)	Recurring expenditure: (cost of raw materials)	
i)	Wheat straw 20q @ Rs.300/qt	6,000.00
ii)	Cost of polythene bags @ 100/kg for 20 kg	2,000.00
iii)	Cost of spawn (2 q @ Rs.50.00/kg)	10,000.00
iv)	Labour wages for 60 days @ 100/ day for 2 men	12,000.00
v)	Chemicals	
	Bavistin 1.5 kg	
	Formaldehyde 20 litre	2,500.00
vii)	Miscellaneous charges	2000.00
(c)	Total recurring expenditure	36,500.00
viii)	Annual maintenance (Rs 5000 + interest 10% (Rs.4, 100) for 6 crops =1516.66 or 1600 Rs 9100 maintenance+ interest for one year	
	Total expenditure (36,500+1,600)	38,100.00
	Expected yield 70% B.E. = 1400 kg	
	Income from sale @ Rs.50/kg x 1400	70,000.00
	Net income from one crop	31,900.00
	Annual income from 6 crops	Rs 1,91,400.00

C. Economics of Oyster Mushroom Unit (95 to 100 TPA)

1. (a) Total Infrastructure Required

Facility	Unit	Size	Total area (sq.ft.)
Poly houses	8	75' x 15' x 12'	9000
Composting yard	1	40' x 40'	1600
Tunnel	1	25' x 9' x 14	225
Boiler room	1	15' x 12' x 12'	180
Store room	1	15' x 12' x 12'	180
Spawning room	1	15' x 12' x 12'	180
Packing/drying room	1	15' x 12' x 12'	180
Office	1	30' x 12' x 12'	360
Raw material shed	1	100' x 20' x 14'	2000
Total area			13,905

Total land required for the project would be around 1 acre.

1. (b) Machinery required	Total No.
Air handling units (AHU)/heavy duty coolers	8.
Boiler 150 kg/h steam generation capacity	1
Blower 800 m ³ /h capacity	1
Bamboo racks	16 sets
Drier	1

1. (c) Total power requirement of the project	HP	KW
Coolers/AHU	12	9
Water pump of AHU/Cooler	4	3
Motors of the Boiler	4	3
Heaters of the drier	24	18
Miscellaneous	10	9
Total	54	42

Economics of the project	(Rupees)
I. Fixed Capital	
A. Cost of land 1 acre	2,00,000.00
B. Civil works/buildings	
(a) Cost of construction of composting Yard 40'x40' @ Rs.50/- sq. ft	80,000.00
(b) Cost of construction of pasteurization Tunnel 25'x9'x14' @ Rs. 400/- sq. ft	90,000.00
(c) Cost of construction of spawning area, Boiler room, packing room, storeroom, Office (1000 sq.ft.) @Rs 300.00 sq. ft	3,00,000.00
(d) Cost of construction of poly houses 75' x 15' x 12', 8 Nos. @ Rs.100/- sq. ft	9,00,000.00
(e) Cost of construction of raw material Shed, 100'x 20'x 14' @ Rs.50/-sq ft	1,00,000.00
Total	Rs.14, 57,000.00
C. Plant and Machinery cost	(Rupees)
(a) Modified Heavy duty coolers 8 Nos. @ Rs. 8000/piece	64,000.00
(b) Boiler 1 No. including ducting for tunnel	1,00,000.00
(c) Bamboo racks and gratings in the tunnel	1,20,000.00
(d) Blower 1no including ducting	50,000.00
(e) Mushroom drier 1 No.	50,000.00
(f) Miscellaneous-like sprayer, pumps, Buckets, harvesting trays etc.	50,000.00
(g) Total	Rs.4, 35,000.00
Total Fixed Capital	(Rupees)
(h) A. Land	2,00,000.00
(i) B. Buildings/Civil work	14,70,000.00
(j) C. Plant and machinery	4,35,000.00
Total	Rs. 21,05,000.00

Economics of the project		(Rupees)
II. Recurring Expenditure		
A. Manpower requirement of the project		
(a) Manager-1 No. @ Rs.5000/month		60,000.00
(b) Total man-days required for substrate Preparation and spawning, 20 man days/ Outing. Total 48 outings in a year		96,000.00
Total man days required = 960.00 @ Rs.100.00/day		
(c) Labor requirement for harvesting, spraying, drying and packing total 200 mandays @ Rs.100/day	2,00,000.00	
Total		Rs.3, 56,000.00
B. Raw materials required (Rupees)		
(a) Straw 120 tons @ Rs.3000/ton		3,60,000.00
(b) Water requirement: For substrate preparation approx. 600 k lit.		1,00,000.00
For spraying, cleaning approx. 1000 k lit		2,00,000.00
(c) Polythene bags (25 q)		2,50,000.00
(d) Pesticides		10,000.00
(e) Energy and Fuel		1,50,000.00
(f) Cost of spawn: 7.5 tons @Rs 50,000/ton		3,75,000.00
(g) Selling expenses/freight etc.		50,000.00
Total		Rs.14, 95,000.00
C. Depreciation and Interest (Rupees)		
(a) Land – 15% interest		30,000.00
(b) Buildings and civil works 5% depreciation and 15% interest		2,94,000.00
(c) Machinery (10% depreciation and 15% interest)		1,08,000.00
Total		Rs.4, 32,000.00
Total Recurring Expenditure (cost of production) (Rupees)		
Raw materials		14,95,000.00
Wages and Salary		3,56,000.00
Depreciation and Interest		4,32,000.00
Total		Rs.22, 83,000.00
Total Production and Income		
Total production taking 80% B.E. of the straw		96 tons
Sale price of fresh mushrooms		Rs.50, 000/ton
Total sale		Rs.48, 00,000.00
Net Profit (Rs.48, 00,000-22,83,000)		Rs.25, 17,000.00
Cost of production/kg		Rs.26.20 /kg
Alternatively complete production can be dried and exported/sold in the local market		
Total production		96 tons
Mushroom available after drying		9.5 tons
Energy consumed in drying this much quantity of fresh mushrooms 50,000 KW	2,00,000.00*	
Sale price of dried mushrooms @ 5,00,000/ton Total sale		Rs.47, 50,000.00
NET PROFIT (Rs.47, 50,000-22,83,000)		Rs.24, 67,000.00

* If the produce is sun dried/solar dehydrated this expenditure can be saved and thus giving extra income.

Cultivation of Paddy Straw Mushroom (*Volvariella volvacea*)

O.P. Ahlawat

Paddy straw mushroom is an edible mushroom of the tropics and subtropics. It was first cultivated in China as early as in 1822. Around 1932-35, the straw mushroom was introduced into Philippines, Malaysia, and other South-East Asian countries by overseas Chinese. In India this mushroom was first cultivated in early 1940's. In India 19 edible species of *Volvariella* have been recorded but cultivation methods have been devised for three of them only viz; *V. esculenta* (Mass) Sing., *V. diplasia* (Berk and Br.) Sing. and *V. volvacea* (Bull. ex Fr.) Sing.

The optimum temperature and moisture for the growth of this mushroom are 35°C and 57-60%, respectively. It can be cultivated in North-Indian plains from July to September and in peninsular India from March to November. However, in the hilly areas during the November to January months artificial heating is necessary to raise the environmental and bed temperature but in the plains, artificial heating can be minimized by the incorporation of *Melia azadirachta indica* and *Tamarindus indicus* leaves in alternate layers.

A. Morphological Characteristics

This genus takes its name from 'Volva' means a wrapper; which completely envelops the main fruit body during the young stage. The fruit body formation starts with distinct tiny clusters of white hyphal aggregates called primordia and is followed by successive stages named as 'button', 'egg', 'elongation' and 'mature'. Differentiation can be seen first at the 'button' stage. At maturity, the buttons enlarge and umbrella like fruiting bodies emerge after the rupture of the volva. The mature fruiting body can be distinguished into the following structures (Fig. 17.1).

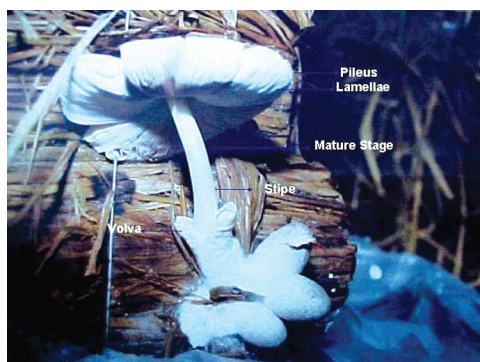


Fig. 17.1. Different structure of *V. Volvacea* fruiting body

- **Volva:** The universal veil is known as volva and it remains more or less distinct in the adult mushroom as a cup like structure at the base of the stipe.
- **Stipe:** Off-white to dull brown in colour, long, round with a smooth surface and no annulus. The stipe enlarges slightly to a bulbous base, which is encased with a distinct membranous volva.
- **Pileus:** The umbrella like fleshy structure attached to the stipe. The size of the pileus is affected by environmental factors, but generally it is around 5-15 cm broad. The 'annulus' or ring like structure on the stipe is conspicuously absent in this mushroom.
- **Gills:** The vertical, radial plates on the lower surface of the pileus are lamellae or gills. All gills are with entire margin and fimbriate edges, but the size varies from one quarter of the radius of the pileus to the full size.

The top surface of the cap is soft and smooth in texture. The colour of the fully-grown pileus is greyish white with a reddish tinge. The grey being dominant in the centre of the cap. The stipe of the umbrella tapers from the base to the apex and is solid, smooth and white in colour. The stipe is easily separable from the pileus at its junction. The gills are also free from stipe. The pileus is initially well shaped but later becomes convex to umbonate.

B. Nutritive Value

The excellent unique flavour and textural characteristics distinguish this mushroom from other edible mushrooms. The nutritive value of paddy straw mushroom is affected by the method of cropping and the stages of maturation. The proximate composition of paddy straw mushroom is given in Table 17.1. Available data reveal that on fresh weight basis it contains around 90% water, 30-43% crude protein, 1-6% fat, 12-48% carbohydrates, 4-10% crude fibre and 5.13% ash. The fat content increases with the maturation stage and the fully mature fruit body contains as high as 5% fat. The N-free carbohydrates increases from button to the egg stage, remains constant at the elongation and drops at the mature stage. The crude fibre remains at almost same level in first three stages and increases at mature stage. The egg stage contains highest level of protein, which decreases at mature stage. Ash content remains almost similar at all the developmental stages.

Contents	Composition (quantity/100g fresh mushroom)
Moisture	90.40 (g)
Fat	0.25 (g)
Protein	3.90 (g)
Crude fibre	1.87 (g)
Ash	1.10 (g)
Phosphorus	0.10 (g)
Potassium	0.32 (g)
Iron	1.70 (g)
Calcium	5.60 (mg)
Thiamine	0.14 (mg)
Riboflavin	0.61 (mg)
Niacin	2.40 (mg)
Ascorbic acid	18.00 (mg)

and increases at mature stage. The egg stage contains highest level of protein, which decreases at mature stage. Ash content remains almost similar at all the developmental stages.

The straw mushroom is known to be rich in minerals such as potassium, sodium and phosphorus. Potassium constitutes the major fraction of the major elements, followed by sodium and calcium. The levels of K, Ca and Mg remain almost same at different developmental stages, except that of Na and P, which drops at elongation and at mature stages. The contents of minor elements namely Cu, Zn and Fe did not vary much at different stages of development.

The levels of thiamin and riboflavin in paddy straw mushroom are lower than *Agaricus bisporus* and *Lentinula edodes*, while niacin is at par with these two mushrooms. At all the stages lysine is the most abundant essential amino acid and glutamic acid and aspartic acid are the most abundant non-essential amino acids (Table 17.2). Tryptophan and methionine are lowest among essential amino acids. The level of phenylalanine increases nearly one fold at elongation stage, while lysine decreases to about half of its value at the button stage. The straw mushroom is comparable to that of the other mushrooms both in terms of amino acid composition and the percentage of essential amino acids in the total amino acids. In fact, paddy straw mushroom contains high percentage of essential amino acids in comparison to other mushroom and the abundance of lysine is very important. The other three amino acids namely leucine, isoleucine and methionine are low in paddy straw mushrooms.

C. Cultivation

1. Conventional method

Different steps involved in this method are as follows (Fig. 17.2)

- Preparation of paddy straw bundles of 0.75 – 1.0 kg (80-95 cm long & 12-15 cm wide) preferably from hand threshed paddy.
- Immersing the bundles in clean water for 12-18 hours in a cemented water tank.
- Draining out of excess water by placing bundles on raised bamboo or cemented platform.
- Making bed by placing 4 bundles side by side and another four bundles similarly but from the opposite side forming one layer of eight bundles.
- Preparation of second, third and fourth layer by intermittent spawning between first and second, second and third and third and fourth layers.
- Spawning the entire surface of different layers of the beds leaving margin of 12-15 cm from edges at a space of 5 cm apart.
- Sprinkling red gram powder over the spawned surface.
- Using 500 gm spawn and 150 g of red gram powder for a bed of 30-40 kg paddy straw.
- Pressing the bed from the top and covering with clean polythene sheet for maintaining required humidity (80-85%) and temperature (30-35°C).
- Removal of polythene sheet after 7-8 days and maintain a temperature of 28-32°C with 80% humidity.
- Mushroom will start appearing after 4-5 days after the sheet is removed and will continue for next 20 days.

Table 17.2. Amino acid contents of paddy straw mushroom

Amino acid	Composition (mg/100g protein)
Leucine	3.5
Isoleucine	5.5
Valine	6.8
Tryptophane	1.1
Lysine	4.3
Histidine	2.1
Phenyl alanine	4.9
Threonine	4.2
Arginine	4.1
Methionine	0.9

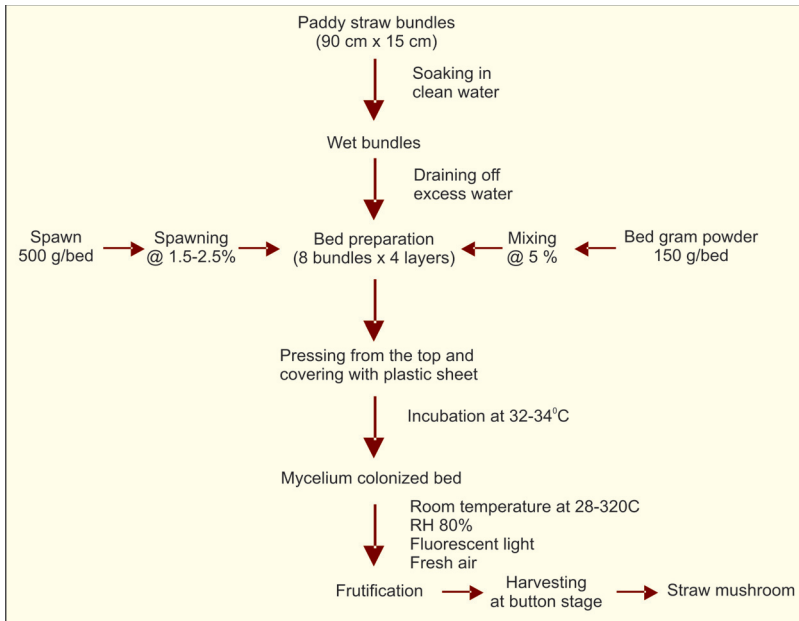


Fig. 17.2. Conventional method of paddy straw mushroom cultivation

- After crop harvest the left over substrate can be converted into manure for its use in the fields.

Note

- For hot regions the width of bed can be decreased by placing first layer of 4 bundles followed by another layer of 4 bundles from opposite side but directly on the first layer. It is to be followed by 3rd, 4th and 5th layers. The 5th layer can be of bundles or of loosened paddy straw.
- The size of beds may vary from 100 x 100 x 100 cm; 60 x 60 x 30 cm; 60 x 60 x 120 cm.
- Alternatively the beds can be prepared with the help of boxes of 80x80x10 cm and 60x40x30 cm size. In this method the material is to be chopped to a uniform length of 20cm followed by filling in box parallel to length of the box. It is followed by soaking of the material along with 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 the 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 RH of 75% for next 4-5 days, followed by lowering of temperature to 28 to 30°C with 75 to 85% RH along with introduction of fresh air. Use of superfine mist is recommended for maintaining humidity in the room. Spray fine mist of water if drying of beds is noticed, further for good harvest maintain proper aeration, temperature and humidity. This can be best achieved by controlling the ventilation/AHU's.

2. Improved cage cultivation (Fig. 17.3)

a. Material required

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

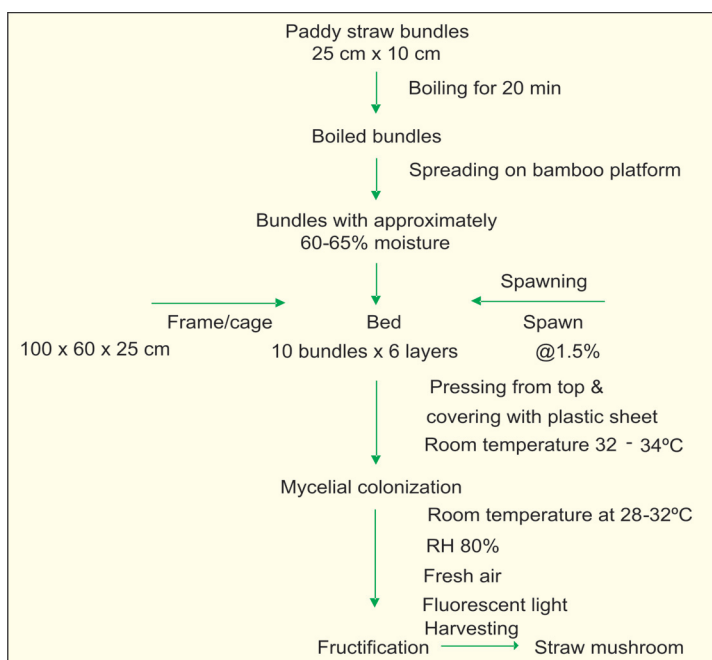


Fig. 17.3.

b. Methodology

Select dry, fresh and hand-threshed paddy straw free from moulds and leafy portion (Fig. 17.4). 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 followed by draining off excess water.
- Disinfect the cage and polythene sheet with 2% formaline or dettol solution.



Fig. 17.4. Stages of paddy straw mushroom cultivation

- Arrange ten straw bundles uniformly in the cage as the bottom layer and put some spawn grains over and inside the bundles. Put second layer of ten bundles over the first and spawn as before. Repeat this till six layers of bundles are achieved or till the entire cage is filled.
- Spray 0.1% Malathion and 0.2% Dithane Z-78 solutions all over the bed. Cover with polythene sheet and bind securely with a binding thread.
- Keep the spawned cages in a room or under a shed for spawn run. A warm place with temperature around 30°C is helpful for better spawn run.
- Remove the polythene sheet after the spawn run is complete. Maintain high humidity in the bed and room till pinheads appear.
- Pinheads appear within 10-15 days after spawning. Harvest mushrooms at the egg stage.
- Continue water spray for the next flush of mushrooms to appear within a week or so.

3. Outdoor method

The best place to cultivate paddy straw mushroom outdoor is under shade created by trees or creepers. The steps involved are as follows (Fig. 17.5).

- Prepare a raised platform either using sand or bamboo poles or wooden planks or bricks.
- Prepare bundles of 45 cm length and 10 cm width.
- Soak the bundles in running water or in 2% CaCO_3 solution.
- Prepare a layer of bundles (5 bundles x four layers) followed by spot spawning and covering spawn with gram dal powder.
- Lay 4 layers of bundles during summer months and 7 layers during rainy season.
- Topping of bed with 20 cm deep layer of rice straw followed by covering with polythene sheet.
- Remove polythene sheet after 4 days and sprinkle water carefully on 6th day. Water spray can be avoided during rainy season.

- Water should not be sprayed after appearance of mushroom pinheads.

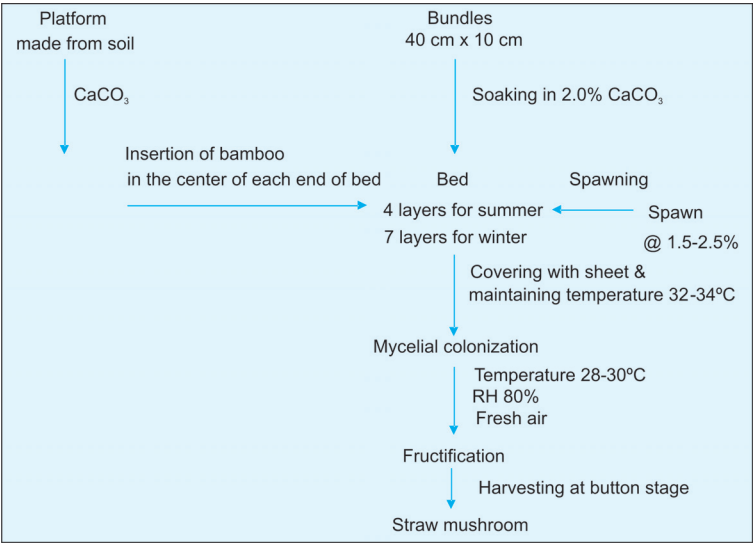


Fig. 17.5.

4. Indoor method

The indoor method can be divided into following 5 steps (Fig. 17.6 & 17.7):

a. Substrate

Cotton waste is the preferred substrate for 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 and the fine texture of cotton waste helps in retention of moisture, which minimize the water requirement at later stages of cropping and thus helps in avoiding damage to fruiting primordia.

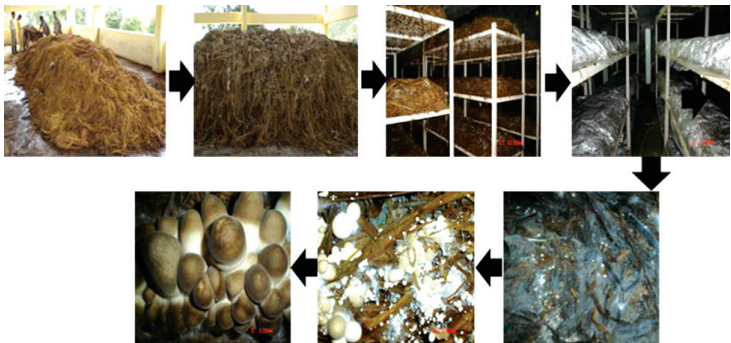


Fig. 17.6. Pictorial depiction of different stages of *V. Volvacea* cultivation using indoor method

b. Compost preparation

Substrate (cotton ginning mill waste or paddy straw + cotton ginning mill waste in 1:1, w/w ratio) is wetted for first 2 days with sufficient treading of the cotton waste so that it absorbs sufficient water. After 2 days of substrate wetting, poultry manure is added @ 5.0% to the wetted substrate and pile (1.5 m high x 1.5 m wide) is raised. However,

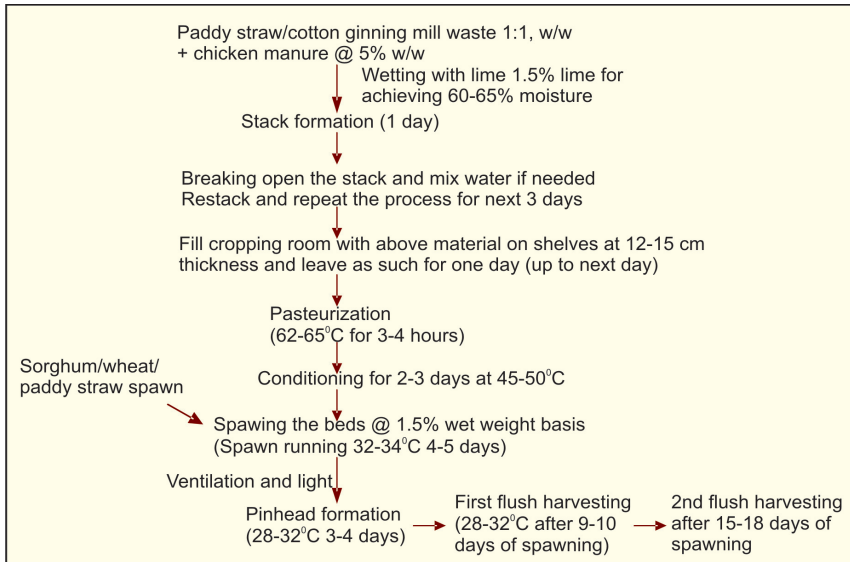


Fig. 17.7. Indoor method of paddy straw mushroom cultivation

nothing is added in cotton waste substrate. First 2 turnings are given at an interval of one day each and calcium carbonate @ 1.5% (dry wt basis) is added at third turning and the substrate is left for fermentation for next 2 days.

c. Bedding and Pasteurisation

After 4 days of outdoor composting, the compost is spread on shelves and the thickness of the substrate varies in different season from 5 to 10 cm. During summer months lesser thickness is needed, while higher in winter to preserve moisture and heat. The compost surface is made even by pressing it lightly. After 8-12 hours of compost filling live steam is introduced in the room. A temperature of 60-62°C is maintained for 4-5 hours for cotton waste compost & 65°C for 6 h for paddy straw compost. After pasteurisation, the compost is kept at a temperature of 50°C for next 24-36 h and followed by its natural cooling. The compost is spawned when substrate temperature reaches 35°C.

d. Spawning

The compost is spawned with fresh spawn @ 1.5% (dry weight) or 0.4% (wet weight) basis of the compost. The pieces of broken spawn are inserted at a depth of 2 to 2.5 cm at a distance of 12 to 15 cm apart. 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 run and at this temperature the compost will be colonized within next 4-5 days in cotton waste based compost & 5-6 days in paddy straw compost.

e. Fructification and Crop Management

During spawn running water and light are not needed but a little ventilation is required. By the end of 3-4 days fluorescent light along with little more ventilation is provided in the rooms. The plastic sheets are removed on 4-5th day, followed by little water spray on the beds. The pinhead will start appearing on 5-6th day of spawning. After another 4 to 5 days,

the first flush of mushroom will be ready for harvest. The desired conditions needed for better fructification are temperature 30°C, relative humidity 80%, fluorescent light and intermittent fresh air. The quick growth rate of this mushroom demands ample supply of water & oxygen. However, watering of the compost is not quite recommended as it lowers the temperature & suffocates the tiny primordia, which reduces the yield. Crop management to achieve the best possible combination of light, temperature, ventilation, relative humidity & compost moisture is in fact an art of judgement, experience and effort.

5. 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 (10-15 cm long pieces) in 1% CaCO_3 solution.
- Draining off of excess water by placing straw on ground.
- Piling the material and covering with plastic sheet.
- Turn the material after 1 to 2 days interval preferably when the pile temperature reaches at 50°C.
- Fill compost in 70 x 35 x 22 cm size frame, first by putting a layer of compost followed by spawning on four sides of this layer along with some wheat bran. The second layer is placed on top of the first, followed by spawning and adding wheat bran around the edges. The third and fourth layers are added like the first & second layers.

b. Arrangement of bed blocks

- Soil base is raised several centimetres, which surrounds 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.
- Plastic sheet is spread over the frame, which in turn covered by straw.
- Temperature around 33 to 35°C is maintained.

c. Harvesting of mushrooms

- Pinheads appear after 4-5 days of spawning.
- Total 9-10 days are taken for first harvest after spawning and the first flush lasts for 3 days accounting around 75% of the total yield.
- The bed blocks are watered with 0.5% CaCO_3 and covered again.
- The second flush appears after few days and this flush accounts for rest 25% of the total yield.
- 4 to 5 crops are harvested each year.

d. Spent compost

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

6. Important guidelines for obtaining healthy mushroom crop

- Compost moisture should be around 60 to 65%.
- Immediately spawn the compost as and when its temperature reaches 35°C, followed by covering the compost with plastic sheets for next 4 days. Temperature should be around 35°C during this period.
- No ventilation during first 3 days following spawning.
- Removal of plastic sheets after 4 to 6 days after spawning and sprinkling of water on bed surface followed by ventilating the cropping room.

D. Harvesting

The straw mushroom is harvested before the volva breaks or just after its rupture. These stages are called as the button & egg stages. This mushroom grows at high temperature with high moisture so it grows very fast and hence it has to be harvested twice or thrice in a day (morning, noon and evening). It usually takes 9-10 days from spawning to harvest the first crop and the first flush normally keeps on lowering 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 rooms. The next flush again remains for 2-3 days and yields less mushroom than the first flush. The second flush adds only 10 to 30% of the total crop.

Fruit bodies ready to harvest should be carefully separated from the beds/substrate base by lifting & 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, as stalks left behind on the bed/substrate will rot and may be attacked by pests and moulds leading to decrease in yield in subsequent flushes.

E. Trouble Indicators

- **Poor mycelial run:** Insufficient food in the compost, inadequately beaten or too compact compost bed or poor quality spawn.
- **Presence of contaminants:** Temperature might not have been high enough during pasteurization to kill the contaminants or the steam might not have reached upto the core of the compact compost or the use of contaminated spawn.
- **Strong ammonia smell:** Excessive use of nitrogen source or improper conditioning at Phase-II of composting.
- **Mycelium drying out:** Scarcity of water or excessive ventilation.
- **Failure to form fruiting body:** Deficiency of light, degenerated spawn or too old spawn, excessively high temperature or poor ventilation.
- **Death of young mushroom:** Degeneration of spawn, insect infestation, insufficient oxygen, excessive CO₂, sharp temperature fluctuations or diseases caused by fungi or virus.
- **Growth of *Coprinus*:** Excessive nitrogen, old and poor quality straw or excess heat of the compost bed.

Further Readings

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2. Mushroom-Cultivation, Nutritional Value, Medical Effect and Environmental Impact (Chang, ST and Miles PG, Eds.) pp 277-304. CRC Press, Boca Raton, Florida (2004).

Competitor Moulds and Diseases in Mushroom Production and Their Management

V.P. Sharma and Satish Kumar

A number of harmful fungi are encountered in compost and casing soil during the cultivation of white button mushroom. Many of these act as competitor moulds adversely affect spawn run whereas others attack the fruit bodies at various stages of crop growth producing distinct disease symptoms. At times there is complete crop failure depending upon the stage of infection, quality of compost and environmental conditions. At any phase, an undesirable growth of certain mould may adversely affects the final mushroom yield. A brief description of competitor moulds and diseases in commercially important mushrooms is given below.

A. Fungal Diseases and Competitor Moulds

1. White button mushroom

a. Competitor/indicator/weed moulds

Various moulds are encountered during button mushroom cultivation and detail description of these moulds is described in Table 18.1:

Table 18.1. Moulds encountered during mushroom cultivation and their indication

S.N.	Mould	Indication
1	False truffle	Improper pasteurization, high temperature during spawn run
2	Olive green mould	Lack of aeration during compost preparation especially during Phase-II, temperature exceeding 60°C during pasteurization
3	Brown plaster mould	Use of poor and old straw, high moisture content in compost, high temperature, less gypsum or poor quality gypsum
4	Yellow mould	Improper pasteurization, use of old chicken manure
5	<i>Sepedonium</i> yellow/ Tikki mould	Improper pasteurization, use of old chicken manure
6	Ink caps	Presence of ammonia in compost, high nitrogen in the compost, Use of old wheat straw for compost preparation/cultivation, high moisture content in the compost/ substrate
7	Cinnamon mould	Casing too wet, casing strongly disinfected with formaldehyde
8	Pink mould	Improper pasteurization
9	Lipstick Mould	Composting under too wet conditions, use of too much steam during pasteurization

S.N.	Mould	Indication
10	<i>Oedocephalum</i> mould	Ammonia and amines not completely eliminated during pasteurization and conditioning
11	White plaster mould	High pH of the compost
12	Green mould	Low pH of the compost, Use of immature spawn

i. False truffle (*Diehliomyces microsporus*)

False truffle is an impediment in the production of *A. bitorquis* (a species of button mushroom that can fruit at 25°C) in India because this fungus manifests at a temperature above 23°C. The disease is of common occurrence during February or early March in *A. bisporus* in the plains of the Northern India and during summer months in *A. bisporus* and *A. bitorquis* in hilly regions of the country. The colour of the fluffy mycelium is white to start with and turns to creamy yellow at later stages. It appears as small wefts of white cream coloured mycelium in compost and casing soil, usually more conspicuous in the layer where compost and casing mixture meet and also on casing. Gradually the mycelial growth become

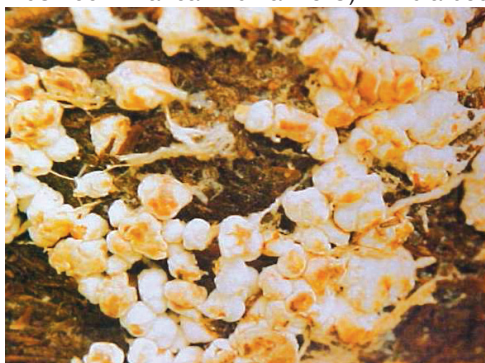


Fig. 18.1. Whitish, solid, wrinkled, rounded to irregular fungal masses of false truffle

thicker and develops into whitish, solid, wrinkled, rounded to irregular fungal masses resembling small brains (ascocarps of the fungus), looking like peeled walnuts (Fig. 18.1). They vary appreciably in size ranging from 0.5 to 3 cm in diameter. At maturity they become pink, spawn run disappears and finally disintegrate into a powdery mass emitting chlorine like odour. The fungus does not allow the mushroom mycelium to grow and compost turns dull brown. The affected patches turns soggy and disappears.

Epidemiology: Ascospores develop in truffles in 3 to 6 weeks and are released when the truffle disintegrates. Ascospore production is abundant at 25 to 30°C. Ascospore germination upto 70% has been recorded at 27°C after giving heat stimulus at 40-50°C for half an hour. The major sources of infection are casing soil and surviving ascospores /mycelium from the previous crops. Ascospores can survive for a period of 5 years in soil and spent compost while mycelium can survive for 6 months and thus serve as the major source of primary inoculum.

Control

- Compost should be prepared on a concrete floor and never on uncovered soil as during composting there is rise in temperature, which activates the ascospores present in the soil.
- Pasteurization and conditioning of the compost should be carried out carefully.
- Temperature above 26-27°C during spawn run and after casing should be avoided. During cropping, temperatures should be kept below 18°C.

- Casing soil suspected to harbour traces of spores should not be used. Young truffles must be picked and buried before the fruit bodies turn brown and spores are mature.
- Good cook out (compost temperature 70°C for 12h.) at the end of the crop should be carried out, which will kill mycelium and spores of the pathogen in the compost.
- Initial infection can be checked by treating the affected patches with formaldehyde (2%) solution.

ii. Olive green mould (*Chaetomium olivaceum*, *C. globosum*)

The earliest sign of the fungus consists of an inconspicuous greyish-white fine mycelium in the compost or a fine aerial growth on the compost surface, 7-10 days after spawning. Frequently initial spawn growth is delayed and reduced. By late spawn run, fruiting structures that look like grey-green cockle-burns 1/16 inch in diameter (Fig. 18.2), develop on straw in isolated spots of the affected compost. The compost has a musty odour. Spawn usually grows into areas occupied by *Chaetomium*, although normal spawn growth is delayed. *C. globosum* is also noticed in spawn bottles.



Fig. 18.2. Grey-green cockle-burns of olive green mould

Epidemiology: The infection usually comes through air, compost and casing soil. It appears due to improper pasteurization accompanied by high temperature in the absence of adequate fresh air in phase-II. Loading too much compost in the tunnel having high moisture and bulk density not allowing proper penetration of air during Phase-II. This results in non-selective compost harbouring *Chaetomium* and other moulds. Spores are resistant to heat and are probably not killed easily during pasteurization. High moisture in compost results in the conversion of nitrogenous compounds into amines. Unfavourable conversions often result in renewed production of anhydrous ammonia, which prompts the growth of ammonia. Sometimes, the temperature is too high in certain spots of the tunnel, or there may be less oxygen, which often results in olive-green mould appearance. Ascospores are spread by air flows, clothes and other materials used in mushroom farm.

Control

- The fermentation period of the compost should not be too short. It is essential to achieve active compost that is not too wet and has a good structure.
- Do not add nitrogen sources like, ammonium sulphate, urea, chicken manure or similar materials just before filling.
- Compost should be properly pasteurized and conditioned with ample supply of fresh air. Higher temperatures (above 60°C) for longer time should be avoided.
- Sprays of Dithane Z-78 (0.2%) is recommended for the control of olive green mould.

iii. Brown plaster mould (*Papulaspora byssina*)

It is first noticed as whitish mycelial growth on the exposed surface of compost and casing soil in trays as well as on sides in bags due to moisture condensation. This develops further into large dense patches gradually changing colour through shades of tan, light brown to cinnamon brown ultimately becoming rust coloured (Fig. 18.3). No mushroom mycelium grows on places where brown plaster mould occurs.



Fig. 18.3. Brown plaster mould

Epidemiology: Primary infection comes through air-borne bulbils or containers, compost and casing soil and workers. Its development is favoured by wet, soggy and wrongly prepared compost. Higher temperature during spawn run and cropping favours the disease development.

Control

- Composting should be carried out carefully using sufficient gypsum and not too much water.
- Peak heating / pasteurization should be for sufficient duration and at proper temperature. The compost should not be too wet before or after peak heating/ pasteurization.
- Localized treatment of infected patches with 2% formalin.

iv. Yellow mould (*Myceliophthora lutea*, *Chrysosporium luteum*, *C. sulphureum*)

Yellow moulds may develop in a layer below the casing (Mat disease), form circular colonies (Fig. 18.4) in the compost (confetti) or they may be distributed throughout the compost (Vert-de-girs). In India, *M. lutea* is reported to induce mat disease. This fungus forms a yellow brown corky mycelial layer at the interphase of compost and casing, which is difficult to detect during the impregnation of casing layer by the spawn and even during the first break. It becomes apparent when it develops its stroma like morphology and mushroom production is severely inhibited.



Fig. 18.4. Yellow mould

Epidemiology: The major source of primary inoculum is air, chicken manure and spent compost. The secondary spread is mainly through mites, flies, water splashes, picking and tools. The fungus survives easily in the form of thick walled chlamydospores. Disease severity is generally more at high moisture content and 19-20°C temperature.

Control

- Properly pasteurized short method compost should be used.

- Proper pasteurization of the casing mixture is very essential.
- Bavistin (0.05%), blitox (0.04%) and calcium hypochlorite solution (15%) is effective for the control of this disease.

v. Sepedonium yellow/ Tikki mould: (*Sepedonium* spp.)

This mould is mainly observed in the compost and is initially white in colour turning to yellow or tan at maturity (Fig. 18.5). It is generally present in the lower layers of the compost or at bottom of the cropping bags. Various types of distortions in fruit bodies are commonly observed, probably due to the production of volatile substances or toxins. These toxins inhibit the spawn and ultimately mushroom mycelium disappears from the compost.

Epidemiology: Primary sources of inoculum are soil, unpasteurized compost, spent compost, air or improperly sterilized wooden bamboos. The chlamydospore are thick-walled and resistant to heat. The fungus may also survive pasteurization temperature. Spores can spread to the compost by air currents prior to or during filling operation, during spawning operation or with unpasteurized or spent compost left in cropping room / sticking to bamboos under seasonal cultivation. Conditions favourable for button mushroom cultivation also favour the *Sepedonium* mould. Higher N content, especially in the form of chicken manure, has been reported to favour the mould development. Its appearance in the lower layers of the compost has been linked with high moisture. Chicken manure harbours very high population of *Sepedonium* spp., which serves as the primary source of inoculum in long method compost.

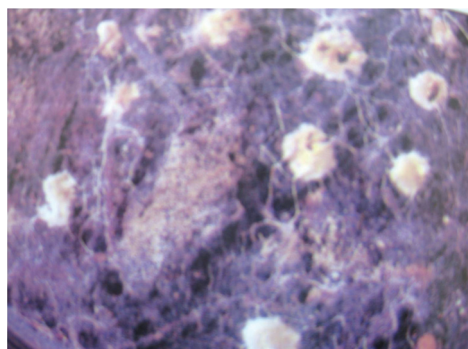
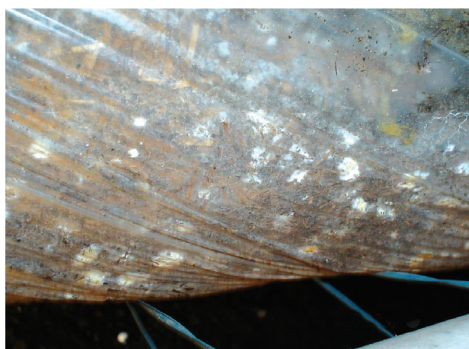


Fig. 18.5. Tikki mould

Control

- Strict temperature monitoring and control during compost pasteurization and an adequate post-crop cooking out are essential to eliminate the threat of infection.
- Preventing the entry of spores during spawning and spawn-running by installing high-efficiency air filters is essential.
- Incorporation of 0.5% carbendazim in compost and sterilizing chicken manure (for long method of composting) with 2% formalin or 0.5% carbendazim has shown good results.

- Treating finally prepared long method compost with 1.5 litre of formalin and 50 g of bavisitin per ton of ready compost and covering it with polythene sheets for 2 days prior to spawning almost eliminates the disease.

vi. Ink caps (*Coprinus* spp.)

Ink caps appear in the compost during spawn run or newly cased beds and outside the compost piles during fermentation. They are slender, bell-shaped mushrooms (Fig. 18.6). Cream coloured at first, bluish-black later and are usually covered with scales. This fungus sometimes grows in clusters in beds and has a long sturdy stem, which often reaches deep into the compost layer. Several days after their appearance ink caps decay and form a blackish slimy mass due to autodigestion.

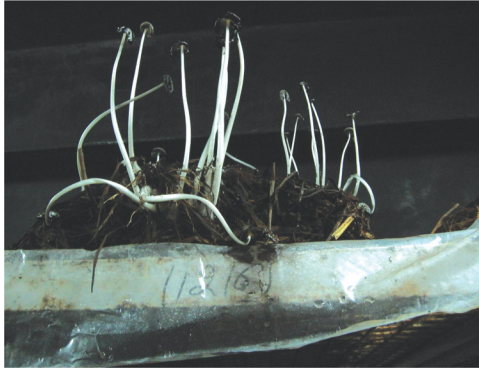


Fig. 18.6. Ink caps

Epidemiology: The infection generally comes through unpasteurized or improperly pasteurized compost or casing soil or air. Ink caps appear if the compost contains too much N, (too much chicken manure is used) or if the pasteurization period is too short. These are, therefore, genuine indicator moulds which indicate presence of NH_3 . Ink caps can also develop if insufficient gypsum is added to the compost or if peak heating has taken place at too low temperature or if the compost is too wet and poor in texture. Their incidence

is also reported when old straw is used for composting. Ink caps can directly use free NH_4^+ and can also decompose cellulose very well, in addition to lipids and lignin. They are genuine coprophilic fungi, which have an optimum pH of around 8. The large masses of spores released through inking of the caps can very easily infect freshly prepared compost.

Control

- Use properly pasteurized compost and casing soil. Avoid excessive watering. Rogue out young fruit bodies of the weed fungus to avoid its further spread.
- Prepare compost using fresh straw.
- Ammonia in the compost at spawning should be less than 10 ppm i.e. no smell of ammonia.

vii. Cinnamon mould (*Chromelosporium fulva*, Perfect status *Peziza ostrachoderma*)

Its colour ranges from yellow gold to golden brown to cinnamon brown. The mould first appears as large circular patches of white aerial mycelium on the compost or casing (Fig. 18.7). Within few days the spores are formed and the colour changes from white to light yellow or light golden brown. As the spores mature, the colour changes to golden brown or cinnamon and the colony develops a granular appearance. Later the fungus produces numerous cup-like fleshy fruit bodies on beds (Fig. 18.8).

Epidemiology: Casing soil mixture and damp wood are the source of primary inoculum. Inoculum can blow through open doors or splash from floor during cleaning. The spores

of the fungus are air-borne. Over pasteurized compost, over-heated patches during spawn run, high moisture content of the compost and excess of ammonia present in the compost favour the disease development.



Fig. 18.7. White aerial mycelium of cinnamon brown mould



Fig. 18.8. Cup-like fleshy fruit bodies of cinnamon brown mould

Control

- Casing soil should be properly sterilized by steam or formaldehyde. Newly cased beds should be sprayed with dithane Z-78 and maintain proper moisture content in casing layer.

viii. Lipstick mould (*Sporendonema purpurescens*)

The disease first appears in spawned compost as a white crystalline mould, rather nondiscernable from spawn. As the spore of the mould mature, the colour changes from white to pink, to cherry red and then to dull orange or buff. White mycelial growth is more in loose areas of casing and can colonize well conditioned compost. In crops where there is a serious virus disease, lipstick mould usually occurs as a secondary disease.

Epidemiology: Soil, casing mixture and spent compost are the sources of primary inoculum. Water splashes or pickers further disseminate it. The mould is reported to be associated with the use of chicken manure in the compost.

Control

Good hygiene is essential. Good pasteurization and conditioning of the compost will eliminate the pathogen.

ix. Pink mould (*Cephalothecium roseum*)

This mould appears as a white growth on the casing soil, which turns pink in due course. Infection generally comes through air. Mould can be checked by spraying thiram or captan (0.04%) twice on casing soil at 10 days interval.

x. Oedocephalum mould (*Oedocephalum fimetarium*)

This is a common mould observed on mushroom beds in Himachal Pradesh and incidence upto 60% has been observed in a farm at Solan during 1991. Artificial inoculation

of casing layer with *O. fimetarium* @ 5 g inoculum per 10 kg compost bag reduced the number and weight of fruiting bodies by 19.9% and 11.63%, respectively. The mould forms irregular, light silver gray patches on the compost surface during cooling before spawning. After spawning, the mould is light gray but changes to dark tan or light brown as the spores mature. Similar growth is also recorded on casing layer. *Oedocephalum* sp. in compost indicates that ammonia and amines were not completely eliminated during pasteurization and conditioning. Spraying or swabbing locally with 2% formalin controls the mould.

xi. White plaster mould (*Scopulariopsis fimicola*)

The mould appears as white patches on the compost or casing soil. These patches or mycelial mats may be more than 50 cm under favourable conditions. The white growth changes to light pink after a week of the formation of the spot. Spawn run is reduced significantly and under severe conditions complete crop failure is also recorded. The pathogen is favoured by under or overcomposting, which still retains the smell of ammonia and has high pH (>8.0). Proper composting and addition of optimum quantities of water and gypsum are recommended. Sprays of bavistin (0.1%) and local application of formalin (2%) after the removal of the mat are helpful in controlling the mould.

b. Fungal diseases

i. Wet bubble (*Mycogone perniciosa*)

Wet bubble produces two main symptoms, infected sporophores and sclerodermoid masses, which are the result of infection by *M. perniciosa* at different stages in the development of the sporophores. When infection takes place before the differentiation of stipe and pileus, the sclerodermoid (Fig. 18.9) is formed, whereas, infection after differentiation results in the production of thickened stipe (Fig. 18.10) with deformation of the gills. The disease also results into white mouldy growth on the mushrooms, leading to their putrefaction (giving foul odour) with a golden brown liquid exudates. Cross section of deformed sporophores without cottony growth showed black circular area just beneath the upper layer.

Epidemiology : *M. perniciosa* spreads primarily through casing soil but the introduction of pathogen through other agencies, like spent compost and infected trash, can not be ruled out. The infection can be air-borne, water borne or may be mechanically carried by mites and flies. Water splash is an important factor for wet bubble spread on the beds. Spread through contact also occurs readily during watering and especially during harvesting. Chlamydospores have been reported to survive for a long time (upto 3 years) in casing soil and may serve as the primary source of inoculum. The aleurospores produced on the surface of monestrous structures are probably responsible for secondary infection.

Control

- Benomyl spray @ 0.1% immediately after casing has been reported to be very effective for protecting the crop. Application of carbendazim, chlorothalonil, prochloraz manganese complex (Sportak 50 WP) @ 0.1% into casing mixture have also been recommended for the management of wet bubble. A spray of 0.8 per cent formalin on to casing surface, immediately after its application on the beds is also effective.

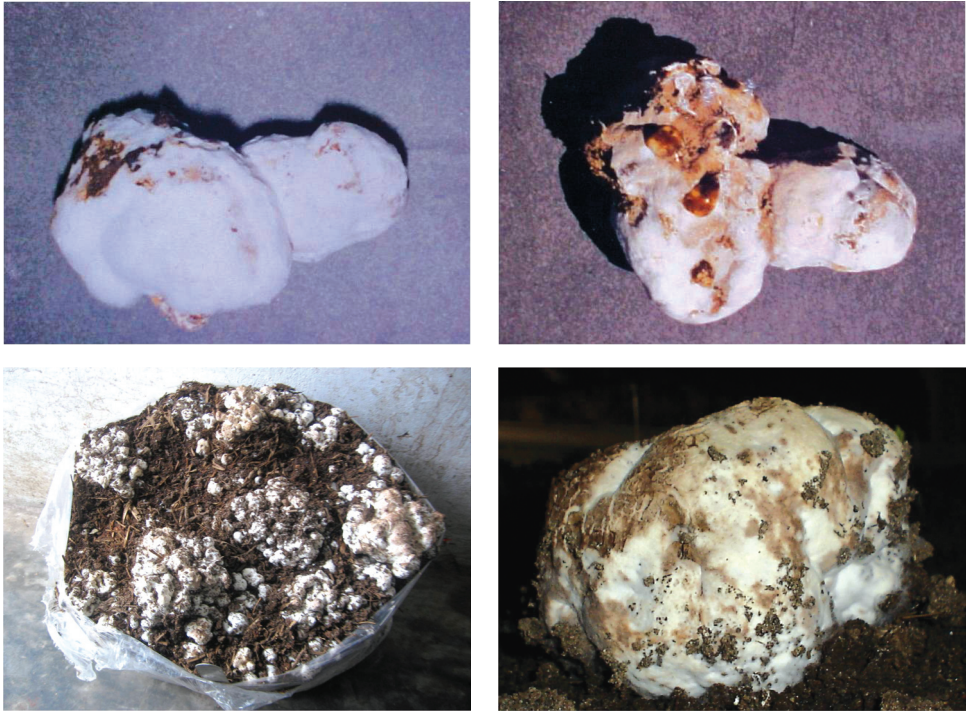


Fig. 18.9. Sclerotium (Wet bubble infection)

- Use plastic pots/ cups to cover mushroom showing wet bubble symptoms during the cropping season to prevent spread of disease.

ii. Dry bubble (*Verticillium fungicola*)

This is the most common and serious fungal disease of mushroom crop. If it is left uncontrolled, disease can totally destroy a crop in 2-3 weeks. Whitish mycelial growth is initially noticed on the casing soil, which has a tendency to turn greyish yellow. If infection takes place in an early stage, typical onion shaped mushrooms are produced (Fig. 18.11).

Sometimes they appear as small undifferentiated masses of tissue upto 2cm in diameter. When affected at a later stage, crooked and deformed mushrooms with distorted stipes and tilted cap can be seen. When a part of the cap is affected



Fig. 18.10. Thickened stipe: wet bubble infection



Fig. 18.11. Typical onion shaped mushroom symptoms of dry bubble

hare-lip symptom is noticed. On fully developed fruit bodies, it produces localized light brown depressed spots. Adjacent spots coalesce and form irregular brown blotches. Diseased caps shrink in blotched area, turn leathery, dry and show cracks. Infected fruit bodies are malformed, onion shaped and become irregular and swollen mass of dry leathery tissue.

Epidemiology: The disease is introduced (primary infection) on to the farm by infected casing soil. Spread occurs by infected equipments, hands and clothings. The fungus is soil borne and spores can

survive in the moist soil for one year. It also perpetuates through resting mycelium in spent compost. The optimum temperature for disease development is 20°C. The period from infection to symptom expression is 10 days for the distortion symptoms and 3-4 days for cap spotting at 20°C. The pathogen grows best at 24°C. High humidity, lack of proper air circulation, delayed picking and temperature above 16°C favours its development and spread. It becomes more common when cropping is extended beyond two months.

Control

Use of sterilized casing soil, proper disposal of spent compost and proper hygiene and sanitation are essential to avoid primary infection

Two to three sprays of zineb (Dithane Z-78) @ 0.15% give good control of the disease. Carbendazim (bavistin) or benomyl (benlate) or thiophenate methyl @ 0.1% spray immediately after casing also control the disease. Application of prochloraz manganese complex (Sportak 50WP) @ 0.05%, 9 days after casing is also recommended for the management of the disease. Use of formaldehyde (2%) immediately after casing is also advocated for the effective management of dry bubble.

iii. Cobweb (*Cladobotryum dendroides*)

Cobweb appears first as small white patches on the casing soil, which then spreads, to the nearest mushroom by a fine grey white mycelium. A floccose white mycelium covers the stipe (Fig. 18.12), pileus and gills, eventually resulting in decomposition of entire fruit body. As the infection develops, mycelium becomes pigmented turning a delicate pink cover. In severe attacks, a dense white mould develops over casing and mushrooms change from a fluffy cobweb to a dense mat of mycelium. The white colour can turn pink or even red with age.



Fig. 18.12. Cobweb disease on button mushroom

Epidemiology: High relative humidity and temperature encourage the disease. Spread is mainly by conidia. The pathogen is a soil inhabiting fungus and is normally introduced into the crop by soil contamination, spores, mycelium on crop debris or by farm workers. Spores can easily spread by air movement, workers hands, tools and clothing and by water splash. A high RH and temperature range of 19-22°C results in maximum yield loss.

Control

- Regular cleaning, removal of cut mushroom stems and young half dead mushrooms after each break. Controlling temperature and humidity helps in controlling the disease.
- Annual disinfection of houses and surrounding areas with 2% bordeaux mixture or with 5% formalin solution or fumigation with 2.0-2.5 L formalin and 0.5-1.0 kg chlorinated lime/100 m³ is helpful in controlling disease. Immediate spray after casing with benomyl @ 0.1% also controls the disease. Single application of prochloraz manganese complex (sporgon) at 1.5 g a.i./m² of bed 9 days after casing gives satisfactory control of the diseases.

iv. Green mould (*Trichoderma viride*, *T.hamatum*, *T.harzianum*, *T.koningii*, *Penicillium cyclopium*, *Aspergillus* spp.).

Different species of *Trichoderma* have been reported to be associated with green mould symptoms in compost, on casing soil, in the spawn bottles and on grains after spawning. A dense, pure white growth of mycelium may appear on casing surface or in compost, which resembles the mushroom mycelium. Later on mycelial mat turns to green colour (Fig. 18.13) because of heavy sporulation of causal agent, which is a characteristic symptom of the disease. Thereafter, the mould creeps to surface of casing layer and infects the new parts and developing newly borne primordia. Mushrooms developing in or near this mycelium are brown, may crack and distort, and the stipe peels in a way similar to mushrooms attacked by *Verticillium fungicola* causing dry bubble disease. Some species induce brownish lesions / spots on caps which may cover the entire cap surface under congenial conditions.



Fig. 18.13. Green mould

Epidemiology: Green mould generally appears in compost rich in carbohydrates and deficient in nitrogen. If during phase II the compost is trampled too hard in the beds, or the filling weight is too high, this can make the peak heating/ pasteurization difficult. This is certainly the case with compost, which has a short texture and which might also have too high moisture content, resulting in improper pasteurization and conditioning of compost. Frequent use of formalin also tends to promote the development of green moulds. Different sources of primary inoculum of *Trichoderma* spp. could be dust particles, contaminated clothings, animal vectors especially the mite, *Pygmephorus mesembrinae* and sciarid flies, air-borne infection, infected spawn, surface spawning, contamination

of compost by handling, machinery and equipments at the mushroom farm. High relative humidity accompanied by a low pH in the casing soil also promotes the development of *Trichoderma* spp.

Control

- Very good hygiene
- Proper pasteurization and conditioning of compost
- Sterilizing the supplements before use and mixing them thoroughly preferably after spawning
- Using the correct concentration of formalin (maximum 2%)
- Weekly sprays of mancozeb (0.2%) or bavistin (0.1%) or treatment with zineb dust gives effective control of the disease

2. Oyster mushroom (*Pleurotus* spp.)

a. Competitor moulds/weed moulds

Different fungi occurring in the substrate and competing with mushroom mycelium for space and nutrition are: *Arthrobotrys* sp., *Aspergillus niger*, *A. flavus*, *A. fumigatus*, *Alternaria alternata*, *Cephalosporium aspermum*, *C. acremonium*, *Chaetomium globosum*, *Cladosporium cladosporoides*, *Coprinus retirugis*, *C. sterguilinus*, *Coprinus* spp., *Cochliobolus specifer*, *Drechslera bicolor*, *Fusarium moniliforme*, *Momniella echinata*, *Mucor* sp., *Penicillium* sp., *Rhizopus oryzae*, *R. stolonifer*, *Stachybotrys chartarum*, *Stilbum nanum*, *Stysanus medius*, *Sclerotium rolfsii*, *Sordaria fimicola*, *Oedocephalum globerulosum*, *O.lineatum*, *Trichoderma viride*, *Trichothecium roseum*, *Trichurus terrophilus* and *Phialospora* sp. Loss in yield in different *Pleurotus* spp. by these competitor moulds has been reported upto 70%. In addition to these moulds being competitive, some produce metabolites, which directly inhibit the growth of mushroom mycelium. Most of the competitor moulds have been reported to be completely inhibited under *in vitro* and/or *in vivo* conditions by benomyl (50 ppm), carbendazim + blitox (100 ppm each) and Thiram (100 ppm). If proper pasteurization/ sterilization procedures are adopted and bags are incubated at right temperature, recommended bag size are adopted, fresh substrate with right pH after treatment is used and proper hygiene is maintained during spawning and cropping, the mould incidence can be minimized. Many of these appear either by negligence of above-mentioned attributes or if we keep the crop for prolonged period and expose the crop to too high temperature.

b. Fungal diseases

There are four fungal diseases reported on oyster mushroom from India. Their causal agents, symptoms and control measures are presented in Table 18.2.

Table 18.2. Fungal diseases of oyster mushrooms in India

Disease	Casual organism	Symptoms	Control
Cobweb	<i>Cladobotrym apiculatum</i> <i>C.verticillatum</i> <i>C.variospermum</i>	White cottony growth on the substrate (Fig. 18.14); small brown irregular sunken spots or fluffy growth on fruit bodies; soft rot and decay of sporophores emitting foul smell.	Spray bavistin @ 0.05%
Green blotch	<i>Gliocladium virens</i> <i>G.deliquescens</i>	Fruit bodies covered by mycelium and green spots; young pin-heads become soft, brown, pale yellow and decay. Mature fruit bodies show brown spots enclosed by yellow halo.	Spray @ bavistin or benomyl 0.01%
Brown rot	<i>Arthrobotrys pleuroti</i>	Fluffy growth on substrate and fruit bodies; infected tissues turn yellow, water logged and rot.	Spray bavistin @ 0.05%
Sibirina rot	<i>Sibirina fungicola</i>	Powdery white growth on stipe, gills and the primordia; primordia show brownish discolouration and soft rot and mature fruit bodies turn fragile.	Proper aeration and RH essential; spray benomyl twice

3. Paddy straw mushrooms (*Volvariella* spp.)

Paddy straw mushroom is infected by a number of destructive diseases/competitor moulds like *Mycogone perniciosa*, *Scopulariopsis fimicola* and *Verticillium* spp. in other countries. In India, large number of competitor moulds and few diseases has been reported on this mushroom. *Chaetomium* spp., *Alternaria* sp., *Coprinus* spp. and *Sordaria* sp. are the most commonly observed contaminants. A 'button-rot' disease caused by *Sclerotium* sp. and bacterial 'button-rot' have also been recorded. Combination of insecticide, fungicide and antibiotic (Malathion 0.025% + Dithane Z-78 or benomyl 0.025% + tetracycline 0.025%) are recommended for the management of pests and diseases. Several other competitor moulds namely, *Coprinus aratus*, *C. cinereus*, *C. lacopus*, *Psathyrella* sp., *Penicillium* spp., *Aspergillus* spp., *Rhizopus* sp., *R. nigricans* and *Sclerotium* spp. have been reported from the substrate. Partial sterilization of the straw and sprays on the beds with captan and zineb (0.2%) has been recommended for reducing the damage. *Rhizoctoria solani* has been recorded on the substrate, which reduces the sporophore formation and causes malformation of fruiting primordia. Considering the rate of growth of paddy straw mushroom and short cropping cycle, disease normally do not reach unmanageable proposition.



Fig. 18.14. Cobweb of oyster mushroom

4. Other mushrooms

Sporadic attempts have been made to cultivate few other mushrooms like giant mushroom (*Stropharia rugoso-annulata*), black ear mushroom (*Auricularia polytricha*), shiitake (*Lentinula edodes*) and white milky mushroom (*Calocybe indica*) in different parts of the country and the competitor moulds/diseases recorded on them are briefly mentioned below:

Mycogone rosea was observed parasitizing *S. rugoso-annulata* under natural conditions. The main symptoms are white cottony growth on gills, light brown spots on stipe and deformity of the sporophores. *Cladobotryum verticillatum* has been reported on *Auricularia polytricha* producing white fluffy growth on substrate and fruit bodies resulting in 9-96% yield loss. Carbendazim (0.05%) spray has been reported to be effective for controlling the disease. *Trichoderma viride*, *Trichoderma* sp., *Aspergillus* spp. and *Fusarium* sp. are commonly recorded as competitors during the cultivation of winter ear mushroom. During the cultivation of *C.indica*, several competitor moulds namely, *Aspergillus niger*, *A. flavus*, *A. fumigatus*, *Rhizopus stolonifer*, *Mucor* sp., *S. rolfsii*, *T. viride*, *T. hamatum*, *Fusarium* spp. and *Coprinus* spp. have been isolated from the substrate.

B. Bacterial Diseases

Bacterial diseases have been reported to infect *A. bisporus*, *A. bitorquis*, *Pleurotus* sp., *Volvariella* sp., *Lentinula edodes*, *Flammulina velutipes* and *Auricularia* sp. The bacterial pathogens induce varieties of symptoms like blotch, mummy, pit, drippy gill, soft rot, yellowing, etc. The bacterial blotch of button mushroom is most important and the same is described here:

Bacterial blotch (*Pseudomonas tolaasii*): Bacterial blotch of white button mushroom is characterized by brown spots or blotches on the caps and in more severe cases, on the stipes. The most characteristic symptom of bacterial blotch is the occurrence of dark brown areas of blotches on the surface of the cap. These may be initially light in colour but may eventually become dark brown. Severely affected mushrooms may be distorted and the caps may split where the blotch symptoms occur. The enlargement of the spots on the cap surface is dependent upon environmental conditions and is favoured by temperature of at least 20°C together with the presence of water film. The bacterial blotch spots are slimy.

Epidemiology: Casing and dust are the primary source of inoculum for the blotch pathogen into a mushroom house. Even after pasteurization the bacterial pathogen is present in most casing materials. Occurrence of the disease is associated with the rise in the bacterial population on the mushroom cap rather than in the casing. Bacteria present on mushroom surface reproduce in moist conditions especially when moisture or free water film persists for more than 3 hours. Once the pathogen has been introduced at the farm, it may survive between crops on the surfaces, in debris, on tools and on various other structures. When the disease is present on the farm, its secondary spread may take place through workers, implements, ingredients, mushroom spores, debris, etc. Sciarids and mites are also important carriers of the pathogen besides water splashes.

Control

- Manipulation of relative humidity, temperature, air velocity and air movement are of great significance in managing the disease. Temperature above 20°C and relative humidity of more than 85 per cent should be avoided. Additional ventilation and air circulation after watering can ensure quick drying of mushrooms. Temperature fluctuations at higher relative humidity leading to water condensation must be avoided.
- Application of bleaching powder @ 0.15% is effective in managing the disease.

C. Viral Diseases

Viruses infect button, oyster, shiitake, paddy straw and winter mushrooms, however; dieback of button mushroom is the most serious disease.

1. Die back

Mycelium does not permeate or hardly permeates the casing layer or disappears after the normal spread. Mushrooms appear only in dense clusters, maturing too early. Mycelium isolated from diseased fruit bodies shows a slow and degenerated growth as compared with healthy mycelium. The delayed appearance of the pinheads in the first flush and formation of fruiting primordia below the surface of the casing layer can be an important indication of the disease. These mushrooms appear above the casing soil with open pilei. Symptoms on sporophores are highly variable and they include slow development, abnormal mushrooms, watery stipes, brown stipes and drum stick type fruit bodies. Several viruses of different shapes and sizes are associated with die back disease. In India, viruses measuring 29 nm and 35 nm in diameter have been found to be associated with a virus disease of button mushroom. Transmission of viruses takes place through mycelium and spores.

Management

- At the termination of the crop, cook out of the compost for 12 hours at 70°C and to remove the compost quickly
- Spray the wood with 2 % sodium pentachlorophenate and 1.0 % sodium carbonate
- Disinfect doors, little holes in the floor, shutters, racks, floors and walls with formalin (2 %). Also clean the compost yard and surroundings with formaldehyde
- Use of proper filters during phase II operation of the composting
- Immediately after spawning, spray malathion@ 0.05% and cover the compost with paper. Spray 1 % formalin weekly on the newspaper sheets during spawn run
- Quickly remove cuttings/litter and destroy

The entire farm and its surroundings should be maintained very clean. In the working corridor formalin (2%) should be sprayed. Machines, refrigerator and other utilities should be disinfected with formalin (2%) solution.

D. Abiotic Disorders

Besides the biotic agents, which adversely affect the mushrooms, there are a large number of abiotic agents which create unfavourable environment for the proper growth of

mushrooms resulting in the quantitative as well as qualitative losses. These abiotic agents include temperature, relative humidity, low or high moisture in the substrate, pH, CO₂ concentration in the room, wind velocity and fumes. Some of the most common abnormalities generally encountered during button mushroom cultivation are as under.

1. *Agaricus bisporus*

a. Storma

Stroma or sectors / sectoring are noticeable aggregations of mushroom mycelium on surface of spawned compost or the casing. Discrete aerial patches of white mycelium form a dense tissue layer on the substrate surface. Stroma can easily be peeled from the surface of compost or casing. Stroma appearing on the compost in small-localized patches can coalesce into larger areas. After casing, stroma may form on the casing above a patch of compost-borne stroma or on casing where stroma does not exist in the compost. Stroma on casing develops in advance of pinning but rapidly putrefies once watering begins. Mushrooms can develop on stroma, but this is somewhat unusual. Stroma and sectors are related to the genetic character of the spawn but are sometimes induced if spawn is mishandled or exposed to harmful petroleum based fumes or chemicals or certain detergents during preparation, storage, transit or at the farm. Production practices during cropping also affect the appearance of these abnormalities but specific relationship has not been elucidated. Excessive CO₂ with high water content in the compost and prolonged spawn run period may also result in stroma. Large patches of stroma of 8 to 12 inches are often removed from the compost or casing surfaces with the hope that next growth of spawn will be normal and bear mushrooms.

b. Weepers / Strinkers / Leakers

Mushrooms described as being 'Weepers' typically exude considerable amount of water from mushroom cap. When small water droplets exude from stem or cap, the mushrooms are called leakers. These water droplets may be few in number and relatively isolated from each other or may be sufficiently numerous to cover the mushrooms. A weeping mushroom can dissolve into white foam. Water collects on the casing surface beneath a weeper and the area develops a putrid odour becoming a 'stinker'. Factors that induce a mushroom to become a weeper are not known but low-moisture compost (less than 64%) coupled with high moisture casing is where weepers are frequently seen. The combination of these two conditions often foster weeper mushrooms prior to and during the first break. In some strains it may also symbolize the degeneration of the strain.

c. Hollow core and brown pith

These two disorders seem to affect cream strains much more than other strains, although off-white strains can also have hollow core. When the bottoms of the stems are trimmed after harvesting, a circular gap is seen in the centre of the stem. This hole may extend the length of the stipe or it may be shorter. When the hollow cut end portion is brown in colour the sale price is considerably reduced. This abnormality seems to be related to watering and water stress.

d. Purple stem / Black leg / Storage bum

Cut stems of the mushrooms develop a deep purple colour within few hours of harvest or after being in cold storage overnight. At times colour is closer to black than purple and it occurs in all strains smooth white, off-white, cream and brown. Generally mushrooms from 3rd break to the end of the crop are most susceptible. Conditions that predispose mushrooms to this phenomenon are unknown but the frequency and the amount of water applied before harvest seems to affect its occurrence.

e. Rose comb

As the name indicates pinkish gills form large lumps and grow on the cap in an abnormal manner giving the appearance of the comb. These abnormal gills appear at various places on the fruit body and give it swollen or spongy appearance. Such mushrooms are not marketable. The abnormality is caused by smoke or gases or vapours of kerosene oil, petrol, diesel paint or oil products etc.

f. Scales or crocodiles



Fig. 18.15. Scaling in mushrooms

On the top of the cap, scales arise due to high velocity of air coupled with low RH. Strong vapours of formaldehyde or pest control products in excess can also cause the outer layer of the skin to tear off. The scale symptoms reduce the value of the mushrooms (Fig. 18.15).

g. Long stemmed mushrooms

Mushroom with long stems and small caps that may look like drum sticks can indicate virus diseases but it is often the result of high CO₂ concentration. With the improvement of aeration such conditions can be corrected (Fig. 18.16).



Fig. 18.16. Long stemmed mushrooms

h. Brown discolouration

Browning of small pin heads or half grown mushrooms is very common on seasonal mushroom farms. This may be caused by high temperature, sprinkling water with high pressure (maximum pressure is 0.4 atm), highly chlorinated or excessive use of formalin for spray.

i. Mass pinning

In many instances symptoms of mass pinning or pinning below the casing are observed, especially during seasonal cultivation. Sudden fall in temperature, excessive aeration or early lowering of CO₂ concentration than recommended can lead to such

symptoms. Many of the abiotic disorders are strain specific and some high yielding strains may be more sensitive.

2. Oyster mushroom

As compared to white button mushroom, there are few physiological disorders recorded in oyster mushrooms. Reduced light in the cropping room results in longer and thicker stipes and pileus is partly reduced. Insufficient ventilation (1-2% carbon dioxide) and low light exposure induce bunched growth of mushrooms.

General guidelines

Initial inoculum load, density, the rate at which the disease develops/spreads and the time of infection determines the control measures to be applied. The following preventive and/or eradication control measures are adopted for the management of diseases:

- **Ecological**-by manipulations of environmental factors such as temperature, humidity and ventilation
- **Biological**-by incorporation of biocontrol agents and organic amendments
- **Chemical**-by use of safe and minimum doses of specific fungicides, antibiotic, etc

A close relationship exists between crop management practices and some endemic disease problems like dry bubble, brown blotch and truffle. Biological agents are being increasingly tried throughout the world but with a limited application on commercial scale. Sanitation and hygienic measures are most essential to manage the disease particularly under Indian conditions although under certain situations use of chemicals is inevitable.

Sanitation and hygiene

Hygiene covers all the measures, which are necessary to minimize the possible incidence of the pests and pathogens. Thus, hygiene and sanitation go hand in hand at all stages of mushroom growing. Farm hygiene is the best defense for a mushroom grower against mushroom pests and diseases particularly during the present time, when use of chemicals on food crops is being discouraged.

Based on the critical observations during all the stages of mushroom production, the following steps should be adopted as a routine practice for successful mushroom cultivation.

- The location of mushroom unit should be away from chemical industries and should be free from toxic fumes or gases
- Floor for the preparation of compost should be cemented/tiled and covered with a roof.
- Substrates used for compost preparation should be fresh, protected from rain and mixed in exact proportion.
- Pasteurization and conditioning of the compost should be for optimum duration at right temperatures as over/under pasteurization may produce poor quality compost and invite disease problems.

- Do not allow free access of persons working in composting yards to spawning and other cleaner areas without changing the dress and foot-dip.
- Spawn should be fresh and free from all contaminants.
- Spawning area must be washed and disinfected with 2% formalin.
- The fresh air should be filtered before it enters the growing rooms to exclude all particles of 2 micron and above.
- Casing mixture should be properly sterilized (65°C for 5-6 hours).
- Casing mixture should be stored in a clean and disinfected place. All the containers, equipments and machinery used for casing should be thoroughly washed and disinfected.
- Picking should start from new or cleaner crop towards older crops.
- Waste from picking, trash, stems, unsaleable mushrooms should be carefully collected not allowing to fall on the floor and be disposed off carefully.
- Avoid surface condensation of water on developing mushrooms.
- Add bleaching powder (150ppm) at every watering to manage bacterial disease.
- Remove heavily infected bags from the cropping rooms or treat the patches by spot application of 2% formalin or 0.1% Bavistin.
- Maintain optimum environmental conditions in the cropping rooms to avoid abiotic disorders.
- Control insect-pests well in time to avoid the spread of pathogen by them.
- At the end of crop, cook out at 70°C for 12 hours is very essential to eliminate all pests and pathogens.

Use of chemicals

Some of the most common fungicides recommended for the control of major fungal pathogens of mushrooms and used in mushroom industry are:

- Benomyl (Benlate 50 wp)- For control of *Cladobotryum*, *Mycogone*, *Trichoderma*, *Verticillium*, mix 240 g/100 m² with casing or dissolve in water at 240 g/200 litres/100 m² during first watering.
- Carbendazim (Bavistin) same as for benomyl.
- Chlorothalonil (Bravo or Repulse) - to control *Mycogone* and *Verticillium*. Apply as spray 2 week after casing and repeat after 2 weeks later @ 200 ml in 100-200 litre water/100 m².
- Prochloroz Manganese (Sporgon)- to control *Mycogone*, *Verticillium*, *Cladobotryum*, give a single application of 300g/100litres/100m², 7-9 days after casing. For double application, use 113g/100litres/100m², 7-9 days after casing and repeat again between second and third flushes. For triple application, use 57g/100litres/100m², 7-9 days after casing and after first and third flushes (presently sporogon is not available in India).
- Thiabendazole(Tecto)- to control *Cladobotryum*, *Mycogone*, *Verticillium*, Apply at the same rate as Benomyl.
- Zineb- to control *Dactylium*, *Mycogone*, *Geotrichum* and *Verticillium*, Use 350 g/ 100 m² every week after casing. For wettable powder, 1 kg/1000 litres @ 5 litre/ 100 m² after casing and between flushes.

As a general practice, cook out of compost, fumigation of cropping rooms after cropping with formaldehyde and spray with copper fungicides helps in removing primary inoculum. Similarly it may be appropriate to spray 0.5% formalin or 0.1% bavistin just after casing to check the primary inoculum. The chances of infection are much higher at these stages as there is lot of movement of air, materials and persons and all are potential carrier of diseases.

Further readings

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2. Rai, R.D., Upadhyay, R.C. and Sharma, S.R. 2005. Frontuers in mushroom biotechnology., NRCM, Solan, pp. 430.

Biology and Management of Insect Pests and Mites of Mushrooms

Satish Kumar and V.P. Sharma

Like the field crops, mushrooms are attacked by several pests. Sciarid flies, phorid flies, cecids, springtails, mites and nematodes are important pests of cultivated mushrooms throughout the world. These pests damage the crop right from spawning to harvesting of the crop. Mushrooms being an indoor crop, provide a suitable habitat for the insect-pests where pests remain protected from the vagaries of the weather. Moreover, maintenance of optimum temperature and humidity in the cropping rooms, provides ideal conditions for the maximum activity and population build up of the pests. Under Indian conditions, most of the growers cultivate mushrooms seasonally and hardly pay any attention to hygiene and sanitation aspects. These seasonal farms lack air handling units and fresh air is introduced by keeping the doors of cropping rooms open daily for 2-3 hours. As a result, a large number of mushroom pests gain easy access into these farms. Mushroom flies, besides spreading various mushroom diseases, take heavy toll of the crop every year. Therefore, measures should be taken to prevent the entry of insect pests, mite and nematode into the cropping rooms. However, chemical method of pest control should be taken as last step.

A. Sciarid Fly

Sciarids, the small fungal gnats, are mosquito type flies. Colour of flies varies from brown black to black. Body length varies from 1.5 to 3.5 mm depending upon the species (Fig. 19.1). Antennae are long (14 annuli) which are held characteristically erect. These flies are known to breed in all the organic matters, leaf moulds, rotten vegetable matters and wild fungi, which act as primary source of inoculum for the pests. Sciarids are pests of mushrooms throughout the world and damaging stage of the pest is larvae. Larvae feed on compost, mycelium and mushrooms. Through on consumption of compost by the larvae, pH of the substrate changes, which slows down the growth of mushroom



Fig. 19.1. Sciarid fly

mycelium. As the infestation by the larvae is often in groups, bare patches without mushrooms can be seen on the beds. After the sporophore formation, larvae enter the mushrooms, start feeding and make tunnel within a stipe. Eventually they reach the pileus and feed vigorously.

When larval attack occurs at pin head stage, further development of pinheads completely stops and pin heads eventually die. Adult sciarids consume minute quantity of water and other liquids but do not feed on mushrooms. *Agaricus bisporus* is more susceptible than *A. bitorquis*. Flies also transport spores of the pathogenic fungi, virus infected fungi, nematodes and mites. Sciarid infestation can cause upto 50% reduction in crop. Under prevailing conditions at Punjab sciarids are known to cause more than 60% infestation. Sciarids were also recorded damaging shiitake mushroom.



Fig. 19.2. Sciarid larva

Single female lays about 100-170 eggs singly or in clusters in the spawned compost and casing material. Freshly laid eggs are round to oval in shape. Maximum egg laying occur at a temperature range of 14-25°C. Egg laying above 30°C is very less. The newly hatched larvae have distinct black head. As the larvae hatch they move away from hatching site to feed and usually feed on mycelium. Larvae prefer to feed in moist areas and tend to move away from dry areas. Fully grown larvae are dirty white

with visible longitudinal black streaks. Larvae are 5-8 mm in length (Fig. 19.2). The larval period is of 16 days at 18°C. They then go in to resting/ developmental stage called pupation. In this stage larvae may appear dead but in fact they are undergoing changes within the larval skin. Just after pupation, colour of pupa changes to yellowish brown. Male pupa is comparatively smaller than the female pupa. The mean pupal period is of 6 days at 18°C. Pupa is 4 mm in length and 1-15 mm in width. There is tendency of pupa to move towards casing surface. As it moves the pupal case breaks and the adult stage emerges. Adults always emerge in the morning between 5:30-7:00 AM. The adult runs about and within 30-60 minutes its wings are fully expanded. The adults are positively phototactic in morning and evening hours. Males generally crawl on the bed surface while females rest on surface of walls. Mating occurs almost immediately after adult emergence. On an average adult longevity is 2-3 days. These flies have been found to stay in the cropping rooms throughout the year. Temperature affects the duration of life cycle to great extent. Life cycle is completed in 28 days at 20°C.

B. Phorid Fly

These are small hump backed black or light to dark brown flies measuring 1.9-2.0 mm in size (Fig. 19.3). These flies are diminutive of house flies. Antennae are



Fig. 19.3. Phorid fly

inconspicuous. Wing venation is reduced. They move rapidly with jerky movements. Adult phorids are most common in early summer and are attracted to light and swarm near windows and doors of the cropping rooms. Mating swarms of phorids are commonly found outside mushroom houses, once mated the females are attracted to mushroom houses by odour of actively growing mycelium. Unspawned compost and fully grown mature compost are not so attractive to ovipositing phorid flies.

A single female lay about 50 eggs at a time beneath the surface of compost or the casing. The eggs are whitish, slightly curved, 0.3 mm long. Eggs hatch in about 5-7 days at 20°C. The newly emerged larvae are nearly transparent. The mature larva is dirty white and measures 3.3-4 mm in length with pointed head and blunt rear end (Fig. 19.4). Larvae feed on mushroom tissue and move upward into the cap forming tunnels in stipe (Fig. 19.5). The infested mushroom turns brown along the tunnel in the stipe. Attack at pinning stage restricts the further development of pin heads. Larvae also feed on mushroom mycelium in compost and casing soil. In case of button mushroom phorids can cause up to 46% loss in yield. Phorid flies are less harmful than sciarid flies if we compare damage per larva. In oyster mushrooms, particularly during rainy season 100% loss in yield has been reported.



Fig. 19.4. Phorids larva



Fig. 19.5. Infected mushroom fruit body

At 18°C larval cycle will be completed in about 14 days followed by pupal stage. Pupa is about 2-3 mm long, yellowish brown to dark brown having respiratory horns on the thorax. Developmental period from egg to adult is 14.6 days. Lower temperature increases the generation time. Adults mostly emerge in the morning. Male and female flies survive for 2.5 and 3.0 days, respectively. Adults are positively phototactic during morning and evening hours. Male are more active than females. Phorid flies are also known to transmit various diseases of mushrooms. Phorids also act as vectors of mites.

1. Management

a. Physical methods

i. Hygiene and sanitation

Hygiene is the primary method of pest control in mushroom farming. It is the foundation upon which success of all other control techniques depends. The objectives of any hygiene programme includes exclusion of pests and diseases from production cycle, elimination of pest and pathogens and destruction of pest and disease present in a crop

at its termination. Such measures help to reduce the contamination level and ensure clean start for subsequent crops. Sanitation focuses on elimination or killing a pest. Routinely removing stumpage from the rooms, where the crop is growing, is a sound sanitary practice. Sanitary practices are designed not only to remove mushroom pests but to kill significant crop threats.

ii. Screening of doors and ventilators

Mushroom flies can easily pass through ordinary wire screen and enter the mushroom house to breed on spawned compost and mushroom beds. Screening of doors and ventilators with nylon net of 35 meshes or more can effectively check the entry of flies in the cropping rooms.

iii. Light trap

Polythene sheets coated with sticky material and attached to a fluorescent tube light in each cropping room help in controlling adult flies. Insects are attracted to white light above 15°C and to yellow light at lower temperature. Use of light trap (15 W yellow bulb and polythene sheet coated with mustard oil) is very effective for monitoring as well as for the management of the flies.

iv. Poison baiting

Poison baiting with Baygon diluted with water (1:10) with addition of little sugar is an effective method of fly control in cropping rooms. Solution of Leafpep and Electra (1:10) with addition of sugar is also effective.

v. Cookout

The most heavily contaminated area on a farm is the older crops about to be terminated. Elimination of pests that have built up within the crops is one of the essential step in any effective control programme. Temperature of 70°C held for 2-3 hours effectively kills all stages of pest and pathogens.

vi. Disposal of spent compost

The spent compost and casing material contain the insects, mites and nematodes. Dumping the spent compost and casing material in moist and shady places helps it to become ideal substrate for breeding of pests. Putting this material in the compost pit and covering it with at least 10 cm thick layer of manure helps in checking the fly breeding.

b. Chemical methods

i. Treatment of compost and casing material

For treatment of compost, Lindane 20 EC @ 20 ml per 1000 kg of straw after dilution in water is thoroughly mixed at the last turning. If flies are observed before casing, 15 ml of Lindane diluted in water is mixed well in 100 kg of ready to use casing material. Other chemicals, which have been used in treatment of compost and casing effectively, are given in Table 19.1.

Table 19.1. Insecticides for treatment of compost and casing mixture

S. No.	Chemicals	Compost	Casing
1.	Diflubenzuron	0.005% 10 mg/kg	0.01% 35 mg/kg
2.	Cyromazine	-	5 g/ton
3.	Methoprene	380 mg a. i./m ² (200 ml aqueous solution)	-
4.	Diazinon	25 ppm	-
5.	Diazinon	0.5-1 g	After spawn, casing and pinning
6.	Malathion	0.01%	

c. Curative methods

- When mushroom flies are noticed in cropping rooms, spray 30 ml Nuvan 76 EC at 0.01% concentration (1.33 ml/ 10 liters of water) on the walls. Close the doors and ventilators for 2 hours after spraying. Avoid direct spray on mushroom beds. Observe minimum interval of 48 hours between spray and picking of mushrooms
- Flies can be killed by application of Permethrin dust (10 g a.i./kg), without any residue problem
- Malathion (2-3 g/m²) and Diazinon (0.5-1 g/m²) can be applied between flushes and near harvest. Malathion (0.01%) can also be sprayed on beds 7 days after spawning
- Malathion (0.01%) spray on the beds 7 days after casing
- Spray of Decis (0.05%) on walls, floors and galleries effectively to check the adults

Continuous application of the above chemicals result in the development of resistance in insects. Therefore, care should be taken to rotate the chemicals.

C. Cecid Fly (Gall Midges)

Adult cecid is dark brown, tiny midge 0.7-1.5 mm. Larvae are spindle shaped, 1.5-2.8 mm white or orange in colour (Fig. 19.6). Cecid flies have two types of development. In the sexual type, the adult flies mate and the female lay eggs, which hatch into larvae. In the paedogenetic type of reproduction mother larvae bear larvae, which increase in size and without fertilization become mother larvae. Larvae feed on mycelium and make vertical grooves in the stipe. They feed on the outside of stipe at the junction of stipe and gills. Presence of bacteria on the skin causes brown discolored stripes on the stipe and gills. Delicate gill tissues break down to produce tiny pustules of black

**Fig. 19.6.** Cecids

fluid. Young larvae also feed on exuding sap. Cecids can cause up to 50% spoilage of mushroom. Initial infestation probably arises from infested casing soil. Larvae being sticky, its spread is caused by trays, tools, shoes and clothes of workers.

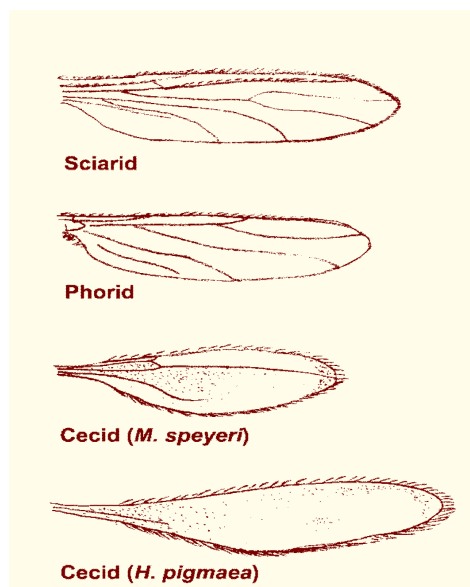


Fig. 19.7. Wing venation of mushroom flies

1. Management

Prophylactic measures are the same as in case of sciarids and phorids.

a. Chemical control

- Sudol (4%) is only commonly used disinfectant, which is used for washing floors is effective against larvae.
- Application of Chlorfenvinphos, Fenitrothion, Fenthion at 1.0 g a.i./m² on beds immediately after spawning and before casing gives satisfactory control.
- Peppering of Diazinon granules @ 50 ppm a.i. in compost gives complete control of *H. pigmaea*.

The distinguishing characters of mushroom flies and summary of economic

threshold level (ETL) for various aspects at different times and location on mushroom farms are given the following Table 19.2 and Table 19.3, respectively.

Table 19.2. Distinguishing characters of mushroom flies

Attribute	Sciarid	Phorid	Cecid
Shape	Like mosquito	Like small house fly	Rarely visible
Size	1.5-5.0 mm	1.9-3.0 mm	0.7-1.5 mm
Colour	Brown black to black	Black to light brown	Dark brown
Antennae	Long with 14 annuli	Inconspicuous	Inconspicuous
Wings (Fig. 19.7)	Fused costa and subcosta	Reduced venation	Subcosta faint
Larvae (Head)	Round black	Pointed head	Spindle shaped
(Length)	5-8 mm	3-4 mm	1.5-2.8 mm

Table 19.3. Summary of economic threshold level (ETL) for various aspects at different times and location on mushroom farms

Pest	Situation	ETL	Comments
Sciarids	Outside spawning/ casing area Spawn run <2 weeks after casing 1 st flush	5 adults in trap or live adult sciarid Any live adult Any live adult	These adults have either flown in from elsewhere or escapes from older rooms As above First generation from infestation at casing
	>2 nd flush	>20 per trap per week or 10-20 live adults per room	Limited control possible of larvae in beds
Phorids	Outside spawning/ Casing area	Any live adult	Carriers of pygmy mites
Cecids	Tray timbers 4 th flush	Any live resting stage Any live larvae	Poor cook out High number in peat or carry over in timbers
	5 th flush	Any live larva	Low, moderate number in peat

D. Springtails

Adults springtails are silver grey to ground colour with light violet band along the sides of body with black ocellular fields present on the head. Body length including appendages is 0.7-2.25 mm. Abdomen is 4-6 segmented. Antennae is 3-6 segmented (Fig. 19.8). Single female of *S. iricolor* lays about 15.8 eggs at mean temperature of 22.5°C. Freshly laid eggs are smooth, spherical, white and measure 0.19 mm. Mean incubation period is 4.9 days at 30°C.



Fig. 19.8. Springtails

Eggs hatch in 30 days at 30°C. Newly hatched insects are white except for an area of dark pigments surrounding the ocelli (eyes). At each moult, size of the insect increases. Adults live up to 78 days at 26°C. The insect remains active throughout the year.

Springtails damage oyster, button, shiitake and milky mushrooms. They feed on mycelium in compost resulting in disappearance of mycelium from spawned compost. They also attack fruiting bodies of button mushroom and cause slight pitting or browning at feeding sites. In oyster and shiitake they feed on gills resulting in destruction of gill linings. *Seira iricolor* scrap the spawn grains making them naked. They also congregate at the base of stipe and eat-out the mycelial strands.

1. Management

Springtails enter in mushroom houses along with the organic matter. Measures to minimize their infestation are

- a. Cleaning of surroundings and inside of mushroom house
- b. Proper pasteurization of compost and casing material
- c. Proper disposal of spent compost
- d. Raising the crop above the floor level
- e. Disinfect the composting yard and empty growing room with 0.05% malathion
- f. Mixing Diazinon 30 ppm (15 ml diazinon 20 EC after dilution with water) in 100 kg of compost at the time of filling
- g. For controlling infestation during spawn run and cropping period spray malathion or dichlorvos at 0.025-0.05% and observe the waiting period of 2 and 5 days in case of dichlorvos and malathion, respectively

E. Mites

Cultivated mushrooms are infested by several groups of mites. Fifty-four species of mites have been reported from various parts of the world, of which 16 species have been found to be economically important. Cultivated mushrooms are generally infested with mites belonging to Acaridae, Pyemotidae, Eupodidae, Ascidae, Digamseididae, Scutacaridae, Tydeidae, and Macrochelidae.

The mites pass through eggs, larva, resting larva, protonymph, resting protonymph, deutonymph and resting deutonymph to become adults (Fig. 19.9). Single female lays

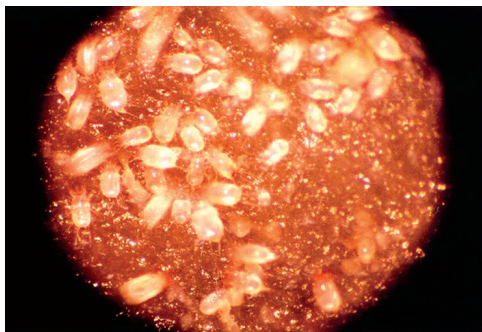


Fig. 19.9. Mites

40-60 eggs in her life time. *T. dimidiatus* completes its life cycle in 17-24 days. The initial infestation of mites in mushroom houses comes through raw material used for the preparation of mushroom beds. *T. dimidiatus*, a major pest of mushroom throughout the world is often present in large numbers in hay, straw, grains and similar materials used for preparation of mushroom compost. Occasionally phorid flies also transport mushroom mites.

Symptoms/damage caused by the mites vary with the species. *T. dimidiatus* hollows out tiny buttons while in large mushrooms it makes cavities of various sizes on stalk and caps. *T. berlesei*, *T. mycophagus* and *T. longior* make holes on caps. *Caloglyphus keameri* and *Oppia nitens* make deep pits on stalk and cap while in some cases buttons are completely hollowed out after tunneling within the stipe. *Tyrophagus putrescentiae* feeds on mycelium and sporophore resulting in small irregular pits on stalk and caps. *Pygmephorus* sp (Red pepper mite) feeds on mycelium below the casing layer. The red pepper mite feed on weed moulds. Their presence thus, indicate poor compost infested with weed fungi like *Trichoderma*. These mites are also known to cause allergic reactions to humans.

1. Management

The following measures are helpful against mites:

- a. Proper pasteurization of compost and casing material
- b. Proper hygiene and sanitation
- c. Disinfection of mushroom houses by spraying 0.1% dicofol
- d. Burning sulfur in the empty rooms @ 200-250 g/1000 cu. ft.
- e. Cooking out at 70°C for 1-2 hours, after each crop
- f. Sterilization of empty trays
- g. Disposal of spent compost in pits at least one mile away from mushroom house
- h. Applying Propargite (Omite 590 EC) at 0.88 and 0.66 g a.i/m² at spawning and casing
- i. Spraying beds with chlordenvinphos, fenitrothion, fenthion, trithion or metasystox (1.0 g a.i/m²) immediately after spawning and before casing
- j. Spraying diazinon 20 EC (1.5-2.0 ml/10 lit. of water) in the compost or Dicofol (0.1%) in mushroom beds, or drenching mushroom houses and all their premises with diazinon is also effective

Further Readings

1. Mushroom Pests and Diseases Control by Fletcher, J.T., White, PF and Gaze, RH. Intercept Ltd. 149pp
2. Manual on Mushroom Cultivation by Peter Oei, Tool Publications, The Netherlands 245pp
3. Advances in Horticulture, Vol. 13 Mushrooms (Chadha, KL and Sharma SR eds), MPH, New Delhi 621pp.

Nematode Pests of Mushrooms and Their Management

Satish Kumar and V.P. Sharma

During different phases of button mushroom production, a large number of nematodes are encountered along with insect-pests and mites. The term nematode (nema = thread + oides = resembling) indicates the external appearance of the organisms (Fig. 20.1). Nematodes are microscopic (upto 1 mm) and can swim easily in the surface film of water in casing and compost. Mycelium of the fungi is favourable source of food for nematodes. Nematodes are one of the most dangerous pests of button mushroom, which once enter the beds cannot be eradicated completely, until and unless crop beds are destroyed and disposed off completely.

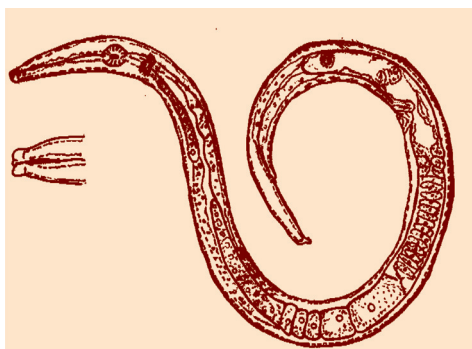


Fig. 20.1. Nematode

Their presence in the beds simply means very poor yield or total crop failure. A number of instances of crop failure due to nematodes have been reported during the last two decades. Compost preparation using long method where no pasteurization is done, improper pasteurization in short method, seasonal cultivation under unhygienic conditions and lack of awareness about cultivation practices are some of the factors responsible for easy access of nematodes in cropping beds. In early days wooden trays because of their repeated use and inadequate sterilization were an important source of nematode infestation. Generally three types of nematodes viz., myceliophagous, saprophytic and predatory are encountered in mushroom beds.

A. Myceliophagous Nematodes (Fungal Feeders)

In all, 21 nematode species have been reported to be harmfully associated with mushroom cultivation from various parts of the world. Among these, twenty species belong to four genera (*Aphelenchoides*, *Aphelenchus*, *Paraphelenchus* and *Seinura*) of order Aphelenchida and the only Tylenchid is *Ditylenchus myceliophagus* (Table 20.1). In India, occurrence of eight species of *Aphelenchoides* and *D. myceliophagus* have been recorded from mushroom beds.

Table 20.1. Pathogenicity of myceliophagous nematodes associated with mushrooms

Nematode species	Pathogenicity
Tylenchida	
<i>Ditylenchus myceliophagus</i> *	+++
Aphelenchida	
<i>Aphelenchoides agarici</i> *	+++
<i>A. asterocaudatus</i> *	—
<i>A. bicaudatus</i>	+++
<i>A. composticola</i> *	+++
<i>A. cyrtus</i>	+
<i>A. dactylocerus</i>	++
<i>A. helophilus</i>	—
<i>A. limberi</i>	++
<i>A. minor</i> *	—
<i>A. myceliophagus</i> *	—
<i>A. neocomposticola</i>	++
<i>A. parietinus</i>	—
<i>A. sacchari</i> *	+++
<i>A. saprophilus</i>	++
<i>A. spinosus</i>	—
<i>A. subtenuis</i>	—
<i>A. swarupi</i> *	++
<i>Aphelenchus avenae</i>	++
<i>Paraphelenchus myceliophthorus</i>	++
<i>P. pseudoparietinus</i>	—
<i>Seinura winchesi</i>	++

* Species reported from India, +++ Highly pathogenic, ++ Pathogenic, + Found to multiply on mushroom, -Pathogenicity not studied

1. Nature of damage

Myceliophagous nematodes have needle like structure (stylet) in their mouth parts. The stylet is hollow inside and can be moved forward and backward by the contraction and relaxation of the muscles. The nematodes secrete variety of strong enzymes. These enzymes act immediately after ejection and help in penetration of stipe and to convert the cell contents in assimilable forms. The nematodes have very fast rate of multiplication (50-100 fold/week). Rate of multiplication is faster during spawn run period (22-28°C) than the cropping period (14-18°C). Beyond 30°C these do not reproduce. It has been found that initial infestation with 3 nematodes of *D. myceliophagous*/100 g of compost can entirely destroy the mycelium with in a period of 70 days. These nematodes survive in a state of anabiosis (a restoring to life from a death like condition) for up to two years, if the compost is dried gradually but they die if the compost is dried rapidly.

2. Source of nematode infestation

Button mushroom is highly susceptible to nematode attack during entire cultivation process. The common source of nematode contamination are damp wheat straw,

manures, FYM, garden soil, spent compost, platform soil, irrigation water and contaminated implements. Sometimes flies, particularly sciarids carry the nematodes from one bed to another.

3. Symptoms

Since the growers are reluctant to disturb the beds after casing, the early symptoms of nematodes attack are generally overlooked and yield reduction is the first effect noticed by them. Following symptoms of nematode attack appear in infected beds in succession:

- a. Mycelial growth is sparse, patchy and mycelium turns stingy
- b. The compost surface sinks
- c. Whiteness of spawn-run slowly changes to brown
- d. Mushroom flushes are poor and delayed
- e. Alternate high and poor yield in successive flushes
- f. Browning of pinheads
- g. Decline in yield
- h. Complete crop failure
- i. White fungal growth over casing in patch areas

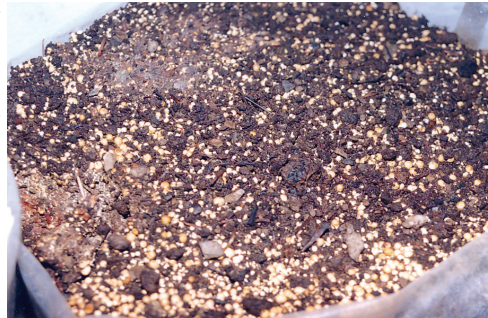


Fig. 20.2. Death of pin heads

B. Saprophagous Nematodes

These nematodes lack the stylet. Buccal cavity is short and wide. These are generally clumsy looking worms with round caudal or clavate ends. The only nematode order that represents saprophages in mushroom cultivation is *Rhabditida*. The genera of common prevalence are *Acrobeoides*, *Caenorhabditis*, *Cephalobus*, *Diplogaster*, *Panagrolaimus* and *Rhabditis*.

1. Nature of damage

There are different schools of thoughts regarding the nature of damage caused by saprophytic nematodes. According to some workers, these nematodes invade the mushroom beds only after the invasion of myceliophagous nematodes. These nematodes secrete some enzymes and toxins, which increase the pH of compost and hampers spawn run. These are also known to create unhygienic conditions or sometimes they may carry harmful bacteria on their body surface. Recently it was found that saprophytic nematodes *Caenorhabditis elegans* can damage the sporophore of *A. bisporus*, if the population reaches 300-500 nematodes/g of casing mixture. Some of the typical symptoms produced by these nematodes are:

- a. Distorted, notched and kidney shaped mushroom
- b. Violet colour of gills
- c. Browning of sporophores

Many of the hybrid strains are sensitive to saprophagous nematodes. However, further investigation to prove their exact role in mushroom cultivation is still needed.

C. Nematode Management

Keeping in view the nature of the crop, limited availability of safe and potent nematicides, residue problems and other hazards of nematicides, it is better to prevent entry of nematodes into the beds rather than controlling them afterwards. So far there is no curative measure available, which can be adopted during cropping stage. Hence, only control measure is to follow an integrated approach.

1. Prophylactic measures

- a. Cropping should be done in purposely built mushroom houses with proper ventilation using properly pasteurized compost made by short method
- b. Strict hygienic and sanitation measures should be followed throughout the cropping period
- c. Composting yard must be cemented to prevent the direct contact of compost with the soil. It must be disinfected with 2% formalin, 24 hours earlier to compost preparation
- d. All the instruments, walls, floors and galleries should be disinfected with 4% formalin
- e. Composting ingredients should always be stored in clean area
- f. Cleanliness should be maintained inside and in surroundings of mushroom farms
- g. Casing mixture should be properly pasteurized
- h. Manures used for composting should be thoroughly broken and allowed to decay properly
- i. In long method of composting, covering compost with double PVC sheet for 24 hours after third turning gives effective control of nematodes
- j. Foot dips must be installed in front of each cropping room
- k. Irrigation water should be clean
- l. No person or worker should be allowed to enter into the farm without proper disinfection of his/her hands and feet
- m. All the cropping rooms should be fly proof and only recommended insecticides should be sprayed for the control of flies
- n. In long method chicken manure may be avoided. Neem cake can be added

2. Chemical control

Mushrooms, being indoor crop, provide little scope for pesticidal usage. Short life of the crop and deleterious effect of pesticides on mycelium and residue problems further limits the scope of pesticide application. Many chemicals have been tested but most of these show detectable amount of toxic residue. However, some of the chemicals, which can be used during composting itself are effective in checking nematode population especially long method of composting. Dichlorvos (0.04%) under polythene cover for 3-4 days was found to be most effective for control of *A. composticola* and *Rhabditis* sp. Fenamiphos EC at 20 mg/kg incorporated in compost is a practical preventive measure. Thianozin @ 80 ppm (0.008%) in compost and its spray on the bed surface during spawn run effectively controls the nematodes without any detectable residue on mushrooms.

3. Biological control

Since the use of chemicals for the management of nematodes has many constraints, only alternative left is to exploit biological means. Various microorganisms, plant-parts and extracts have been exploited for the management of nematodes. Research on the use of bacteria, fungi, mites and nematodes for their control is going on. However, maximum work has been done on nematode trapping fungi such as *Arthrobotrys oligospora* and *A. superba*, which are known to reduce the nematode population and increase the yield. Fungus, *A. robusta* has been recommended against mycophagous nematodes. This fungus is available commercially as Royal-300 strain Anti polis in France. *Candelalretta musiformis* isolated from spent compost has been found highly effective in checking nematode multiplication. Fungus *A. irregularis*, is highly effective against *A. composticola*.

A large number of plants have been found to possess nematicidal properties. Incorporation of dried leaves of *Azadirachta indica*, *Cannabis sativa*, *Eucalyptus tereticornis* and *Ricinus communis* at 3 kg/100 kg of dry wheat straw, enhanced the population of thermophilic fungi, mesophilic antibiotic producing fungi and at the same time reduced the population of *A. composticola* below economic injury level. Karanj leaves mixed in compost also reduces the nematode population. Addition of neem leaf powder @ 2% on w/w basis of compost has been recommended for controlling nematodes. Incorporation of neem cake @ 5% on w/w basis of compost at spawning has been reported to hamper the multiplication of *A. composticola*.

So far there is no strain of *A. bisporus*, which is resistant against nematodes. However, *A. edulis* is resistant to the nematode *D. myceliophagus* and *A. bitorquis* (K-30) to *A. saachari* but susceptible for *D. myceliophagus*.

4. Physical control

Use of heat is the most successful method of nematode control in mushroom cultivation. It is recommended that to make compost nematodes free, air and bed temperature in the pasteurization room must be maintained at 60°C at least for 2 hours and cook out of mushroom house at 70°C for 5-6 hours or 80°C for 30-60 minutes is necessary. Used trays and handling tools must be disinfected by dropping in formalin or cresylic acid. Dipping of the appliances in boiling water for 1-2 minutes is sufficient for complete destruction of nematodes. Finally, spent substrate should be disposed off completely. The nematode, *D. myceliophagus*, can withstand drying for up to 3 years and this makes the disposal of all spent compost very important, as dry infested debris is a potential source of trouble. Lowering down the room temperature to 13°C during cropping period retards the pathogenicity of these nematodes.

D. Action Points

- a. Observe strict hygiene throughout the farm
- b. Ensure that the temperature during peak heat is satisfactory
- c. Make sure that casing ingredients are stored and mixed in clean area and casing is properly pasteurized
- d. Make sure that all spent compost is removed from the farm
- e. Properly clean the cropping rooms after every crop

Further Readings

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Recycling of Spent Mushroom Substrate

O.P.Ahlawat

Mushroom growing is an eco-friendly activity as it utilizes the waste from agriculture, poultry, brewery, etc. and in turn produces a quality food with excellent and unique nutritional as well as medicinal attributes. The spent mushroom substrate (SMS) left after final crop harvest is a matter of concern as it creates various environmental problems including ground water contamination and nuisance (Fig. 21.1). Compost is considered “spent” when one full crop of mushroom has been taken or when further extension of cropping becomes unremunerative. In the past, considerable efforts have been directed towards profitable utilization of SMS as manure and in mitigation of environmental pollution.



Fig. 21.1. View of road side disposal of SMS

A. Traits of Spent Mushroom Substrate

The traits and composition of SMS vary in different mushrooms because of difference in types of substrate used and their subsequent utilization by mushrooms. SMS normally

Table 21.1. Different uses of SMS from different mushroom

Application	SMS of			
	<i>Agaricus bisporus</i>	<i>Pleurotus spp.</i>	<i>Volvariella volvacea</i>	<i>Lentinula edodes</i>
Reclamation of soil	√	-	√	-
Organic-mineral fertilizer	√	-	-	-
Manure for horticulture	√	-	√	-
Bioremediation	√	√	√	√
Disease management	√	-	-	-
Animal feed	-	√	-	-
Re-growing of mushrooms	√	√	√	√
Biogas production	-	√	√	-
Briquettes for boiler	√	√	√	-
Rehabilitation of industrial sites	√	-	√	-
Vermicomposting	√	√	√	-

contains 1.9-0.4-2.4% (N-P-K) before weathering and 1.9-0.6-1.0 (N-P-K) after decomposition for 8-16 months. It contains much less heavy metals than sewerage sludge, which precludes its classification as a hazardous substance. SMS obtained from various sources usually have 1.9 to 8.3 mmhos/cm conductance. However, chloride used to be one of the major inorganic anions in SMS and it varies from 1.5 to 7.5 kg/1000 kg in fresh SMS, while 0.3 kg/1000 kg in well rotten SMS. SMS has an initial pH in the range of 7.0-7.30, which increases during weathering. The volume of SMS also decreases (shrinkage) over the time. The fresh SMS obtained from various sources vary in its density: 0.198 g/cm³ with a range of 0.15 to 0.24 g/cm³ in U.K., 0.475 g/cm³ in Ireland and 0.24 to 0.62 g/cm³ in USA.

B. Recycling of Spent Mushroom Substrate for Different Purposes

As mushroom production is increasing, so is the SMS generation, which calls for management of this so-called waste. Fortunately, SMS has many positive attributes still left for its potential uses. The material has been found to be a good nutrient source for field and horticultural crops because of its nutrient-status. Besides, it has a high cation exchange capacity (a measure of the amount of nutrients a medium can hold) and has a slow mineralization rate that held in retaining its quality as an organic matter (Fig. 21.2 & Table 21.1). SMS can be used for organic-farming and can also be utilized for undermentioned means.

1. Reclamation of soil
2. Organic fertilizer
3. Manure in horticultural crops
4. Bioremediation of contaminated soil and water

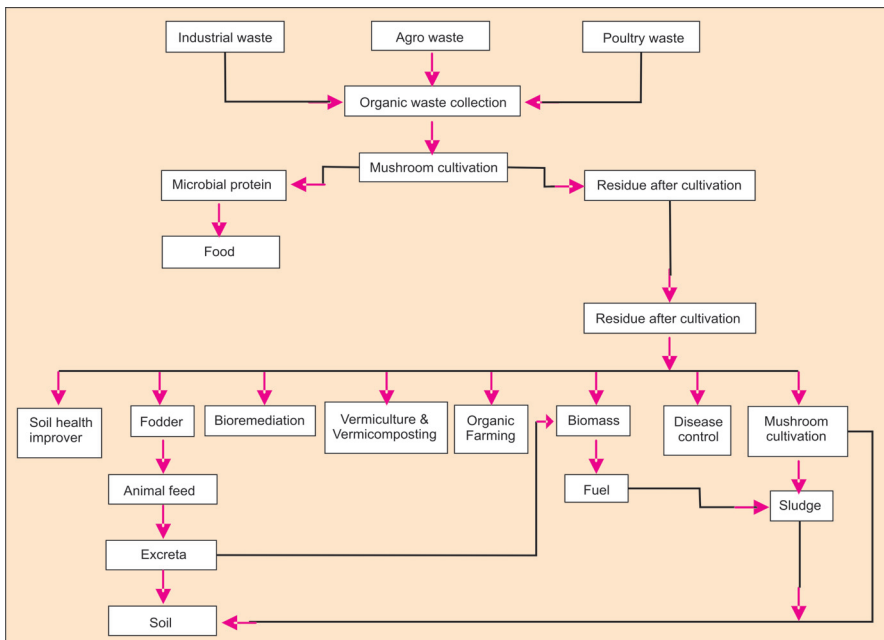


Fig. 21.2. Recycling of spent mushroom substrate

5. Diseases management of crop plants
6. Re-growing of mushrooms
7. Animal feed
8. Biogas and steam production in boilers
9. Others
10. Integrated use of SMS

1. Reclamation of soil

Addition of SMS in nutrient poor soil helps in improvement of soil health by improving its texture, water holding capacity and nutrient status. SMS incorporation in soil does not have any adverse effect on its alkalinity but leads to an increase in pH as well as the organic carbon content. The phosphorus and potassium requirements of crop plants can be fulfilled by incorporating 5% of SMS by volume, while nitrogen requirement can be fully met by incorporating 25% of SMS by volume. SMS incorporation also helps in quick establishment of turf and ryegrass.

2. SMS as organic fertilizer

SMS is still nutrient-rich and contains about 80% of the total nitrogen in bound form with high molecular weight fractions of lignin and humic substances. Nitrogen release from the compost is very slow, therefore, addition of some easily available form of nitrogen may be required. Conversion of SMS into an organic-mineral fertilizer seems to be an alternative way of using SMS for soil amelioration and plant nutrition. The organic-mineral fertilizers prepared with three different formulations having, 2, 7 and 10% nitrogen and each supplemented with 2% phosphate (P) and 2% potassium (K) gave yield of spinach equal to the standard fertilization. In addition, the organic-mineral fertilizer also results in improved quality and dry matter of spinach as compared to mineral fertilizer.

3. Horticulture

Suitable treatments like rapid salt leaching and decomposition in open for two to three years make SMS more suitable for either complete or partial substitution of growing medium for flowers, vegetables, fruits, saplings, ornamental shrubs and other horticultural plants (Fig. 21.3 and 21.4). The SMS being rich in N, P and K acts as a good growing medium for vegetables like cucumber, tomato, broccoli, tulip, cauliflower, pepper, spinach, etc. but the response varies with different levels of SMS incorporation. SMS incorporation @ 25% and 37.5% with the growing medium supports the growth of lettuce, marigold and tomato. However, the aged SMS is preferred over the fresh one. Vegetables like tomato, *Cucurbita pepo*, *Capsicum annum*, spring broccoli, autumn broccoli, aubergines, sweet corn cv Seneca gold, snapbeans (*Phaseolus vulgaris*) cv. provinder and *Pennisetum glaucum* cv. HGM-100 also give more yield on incorporation of SMS in soil. Not only the yield but SMS incorporation in soil also improves the firmness and ascorbic acid content in tomatoes.



Fig. 21.3. Healthy crop (tomato) using SMS



Fig. 21.4. Healthy crop of brinjal (a), onion (b), pea (c) and wheat (d) using SMS based manure

The nursery crop of *Cornus sericea* and *Forsythia intermedia* cv Lynwood also showed good response to SMS incorporation in the growing medium. Besides vegetables, green house and nursery crops, the woody ornamental and forage nursery crops including *Cotoneaster dammeri* cv. Coral Beauty, *Deutzia gracilis*, *Cornus alba*, *Argenteo marginata*, *Forsythia intermedia* cv. Lynwood, *Juniperus sabina* cv. Blue Danube, *J. virginiana* cv. Hetzii, *Potentilla fruticosa* cv. Red ace, *Ligustrum vulgare*, *Rosa indica* cv. John Franklin, *Weigela* cv. Bristol Ruby and *W. florida* cv. Variegata also showed good growth at different levels (33, 67 & 100%) of SMS mixed with bark. In addition to the above mentioned plants, SMS incorporation in soil also increases the total spear FW and number/m² growing medium in white asparagus and total weight gain in mountain persimmon as well as non astringent persimmon. SMS incorporation @100, 200 and 400 tonnes (fresh weight)/acre in nutrient poor soil like silty dry loam shows positive effect on the silage and grain yield of cash crops.

4. Bioremediation of contaminated soil and water

The uncontrolled release of industrial wastes in open and the poor availability of pretreatment facilities are the important factors contributing towards the environmental pollution. The degradation of various chemicals in environment depends upon the prevailing physical and chemical conditions and the nature of microorganisms thriving within the system. SMS has the ability to chemically adsorb the organic and inorganic pollutants, and in addition, it also contains diverse category of microbes having capability to biologically break down the organic xenobiotic compounds present in the soil and

water. The mixing of pentachlorophenol (PCP) contaminated soil with aliquots of spent sawdust cultures of shiitake mushroom, supplemented with nutrient solution of glucose, thiamine and mineral salt, results in disappearance of about 44.4-60.5% of PCP with in 21 days of incubation. The SMS also has the decontamination potential of land sites used for disposal of hazardous wastes.

The microbes, especially actinomycetes (*Streptomyces* sp. and *Thermomonospora* sp.) present in SMS also have strong PCP catabolizing capabilities, which contribute towards decreased level of PCP in contaminated soil after incubation with SMS. The incorporation of 5% w/w SMS in soil having 0.0005% alachlor concentration, enhances the alachlor disappearance and protects the garden pea cv. Taichung from root injury.

The limestone, gypsum, organic matter and “bulk” that constitute SMS make it an ideal choice for passive treatment of coalmine drainage. The water quality from such drainage can be improved by creation of wetland out of SMS. The supplementation of artificial wetland constructed out of SMS with carbon source improves its life for years. The flow rate with which water is passed through such wetlands has direct effect on the out going water quality. The SMS also has a role in stabilization of abandoned mines, pipeline construction and commercial/industrial sites.

5. SMS for disease management

The actinomycetes, bacteria and fungi inhabiting the SMS not only play a role in its further decomposition but also exert some antagonism to the pathogens surviving and multiplying in soil. The organic amendment of soil with SMS helps in restricting the root knot infestation of tomato plant by *Meloidogyne incognita*. The extract from SMS also inhibits the conidial germination of *Venturia inaequalis*, causal agent of apple scab; *Cochliobolus carborum*, causing disease on maize and *Sphaeropsis sapinea*, causing disease on red pine. The weekly/biweekly application of spreader/sticker amended SMS extract, starting from green tip to petal fall of apple tree reduces the scab- affected leaf area on apple plants.

6. SMS for re-growing of mushrooms

The respawning of button mushroom spent compost together with the addition of Spawn mate (delayed-release nutrient) and Bonaparte peat (adsorbent material) results in good yield of second button mushroom crop. The residual compost so obtained can be reused for raising the tomato seedlings. Similarly, the shiitake SMS supplemented with 10% wheat bran and 10% millet can be utilized for *Pleurotus sajor-caju* cultivation but it required air-drying, grinding, supplementation, pasteurization and spawning.

The higher yield (BE-79%) of *P. sajor-caju* could be obtained by supplementing the spent shiitake base medium with 12% soybean and 1.0% calcium carbonate. Increase in both biological efficiency and mushroom size showed positive correlation with increasing levels of calcium carbonate addition to the basal medium. The use of anaerobically fermented SMS as casing material gives mushroom yield at par with that of the peat based casing material with additional advantage of less bacterial blotch infection.

7. SMS as animal feed

Cellulose made available after *Pleurotus* spp. (Oyster mushroom) cultivation can act as energy source for animals as they have sufficient quantity of enzymes/ microbes in

rumen, which can degrade it further. Besides availability of cellulose, oyster mushroom cultivation also improves protein value and digestibility of the substrate. The oyster mushroom SMS can substitute about 30% of the total feed without affecting the growth of animals.

Another way of increasing the protein content of SMS of *Pleurotus ostreatus* and *Lentinula edodes* is by synchronous saccharification and fermentation by *Aspergillus* species (*A. candidus* 362) and a yeast strain (*Endomycopsis fibuliger* 253). The protein content in *P. ostreatus* and *Lentinula edodes* grown SMS increases from 24.1 to 32.3% and 28.4 to 36.7%, respectively (Table 21.2). It also increases the *in vitro* digestibility of total crude protein by 70%.

Table 21.2. Effect of pilot-scale solid-state fermentation on chemical composition spent compost medium

	Media with 35% spent compost of			
	<i>Pleurotus ostreatus</i>		<i>Lentinula edodes</i>	
	Control	Fermented	Control	Fermented
Crude Protein (% DW)	24.1	32.3	28.4	36.7
Crude Fibre (% DW)	14.8	10.2	13.3	9.8
Crude ash (% DW)	6.5	9.0	6.5	9.3
<i>In vitro</i> crude protein digestibility (% DW)	64.2	67.8	68.7	70.1

DW - dry weight

(Source: Zhang *et al.*, 1995)

8. SMS for biogas and steam production

As indicated above, SMS obtained after oyster mushroom cultivation can be utilized further as cattle feed and the waste of cattles, i.e. cow dung can be used for producing biogas, and the sludge accumulated in biogas tank can be used as casing material for button mushroom. Again the SMS thus generated can be reused as manure for raising the crop. The use of SMS for biogas production has multiple benefits, such as possibility to utilize feed stocks of high moisture content, ability to be scaled to suit family as well as community needs, effluent (sludge) with properties of a good manure can replace chemical fertilizers, and can give indirect economic benefits to the users. The increased susceptibility and nitrogen contents of spent substrate are reported to be the reasons behind higher percentage of gas yield. Solids from biogas digester act as good manure for nursery raising as well as for the vegetable crops.

9. Others

Recently, SMS has also found uses for many other activities, which includes its use as the feeding material for vermicompost, in briquettes making for their use in boiler for steam generation, preparation of casing soil by anaerobic fermentation for 1-2 years, rehabilitation of the mining sites, biodynamic compost preparation and as fertilizers. In case of vermicompost preparation, the SMS from paddy straw, oyster mushroom and button mushroom has been found suitable. Fresh as well as 15-20 days old rotten SMS from white button, oyster, milky and paddy straw mushrooms is an acceptable material for the worms to multiply and convert it in to manure for field crops. The SMS either alone or in different combinations with FYM, agricultural and vegetable farming wastes

(depending upon the availability) is a good medium for effective vermicomposting following the standard protocol (Fig. 21.5.) The time period for vermicomposting using SMS varies between 2 to 2.5 months.



Fig. 21.5. Vermicompost preparation using SMS

Use of SMS also helps in stabilization of the abandoned mine sites, pipeline construction sites and commercial/ industrial sites. Depending upon the rate of application, it can also supplement the requirement of nitrogen, phosphate, potash and calcium carbonate required for permanent stabilization by vegetation. It can be used as mulch for seed germination. SMS can be compressed and used for making briquettes on drying. These briquettes have found uses as the source of energy in commercial scale steam boilers at some of the commercial mushroom-growing units. Organic manure preparation using the biodynamic composting process, which involves mixing of some additional source of nutrients, biocatalysts, maintenance of optimum moisture and aeration, is also one of the alternate way of SMS reuse. However, the most common use in mushroom cultivation is as casing material and it can be converted in to a quality casing material by its decomposition under anaerobic conditions for 1-2 years and mixing of 1.0% calcium carbonate before its application as casing soil.

10. Integrative use of SMS

Different components of agriculture can be integrated together involving mushroom cultivation as the central activity. First of all, the agricultural waste can be used directly for oyster mushroom cultivation, from which oyster mushroom and SMS will be the main products. The mushroom can be used for human consumption, while the SMS can be fed to animals. The excreta and the cow dung from animals will become a feeding material for biogas production and the sludge from the biogas plant will in turn work as the casing material for button mushroom. After harvesting the button mushrooms, the

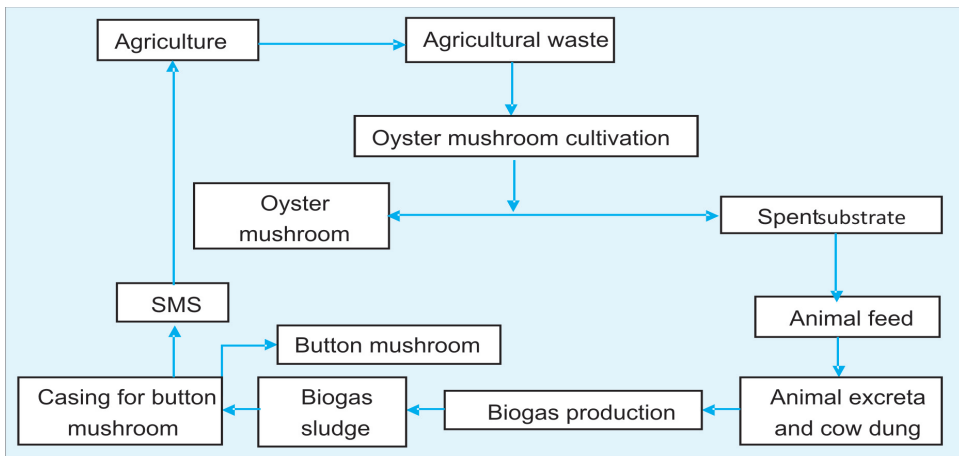


Fig. 21.6. Integrated use of agricultural waste with mushroom cultivation as central activity

remaining SMS can be decomposed and used as manure for different crops and ultimately the cycle completes itself (Fig. 21.6).

C. Conclusion

The major hurdle in SMS exploitation as an organic manure comes from 10 to 100 folds increase in salt concentration in soil and water, elevation in the concentration of ammonium, nitrate, chloride, sulphate, calcium, magnesium, sodium and potassium in ground water. The soil as well as ground water also contain more dissolved organic carbon, dissolved organic nitrogen and nitrate with no pesticide residue. The spent mushroom substrate also varies in pH (7.3 -8.2), conductivity (1410-2380 mmhos/cm³), carbon: nitrogen ratio (9-15:1), nitrogen availability (organic and inorganic) and in nitrate N to ammonia N ratio.

The overall cropping results have shown that SMS requires some early treatments like desalting/prolonged leaching and composting as the desalted or composted SMS has shown several advantages over fresh. The SMS quality parameters like its conductivity, load of heavy metals and phosphate should be given due consideration before using it in the field. So in the era of growing environmental awareness and strict legislations, exploitation of SMS for the management of environment, agriculture and production of recyclable energy, requires strict watch on its physical, chemical and microbiological properties. The diversified uses of SMS in managing agriculture, environment and energy generation may lead to a change of its name from spent mushroom substrate to 'used mushroom substrate'.

Further Readings

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Postharvest Handling of Fresh Mushrooms

G.C. Wakchaure

Mushrooms are a rich source of good quality protein, having most of the essential aminoacids, minerals and vitamins with low calories. Though around 20 genera of mushrooms are being cultivated for commerce throughout the world, only four types, viz., white button mushroom (*Agaricus bisporus*), oyster mushroom (*Pleurotus* spp.), milky mushroom (*Calocybe indica*) and paddy straw mushroom (*Volvariella volvacea*) are grown commercially in India with the white button mushroom contributing about 85% of the country's production against its global share of about 31 per cent.

The production of mushroom is done throughout the year by the environmentally controlled units, but the seasonal growers come into play during the winters and the supply at the local market exceeds causing less profit due to fall in price and spoilage due to market surplus. Mushrooms are highly perishable and get spoiled due to browning, wilting, liquefaction, loss of texture, aroma, flavour, etc, making it unsaleable. Most of the mushrooms, being high in moisture and delicate in texture, it cannot be stored for more than 24 hours at the ambient conditions prevailing in the tropics. Researchers, who studied spoilage of fresh mushrooms, earlier believed the primary cause to be the enzymatic reactions in the living tissue. Later, it was suggested that spoilage might be caused by the action of bacteria on the mushroom tissue and browning of mushrooms was due to a combination of autoenzymatic and microbial action on the tissue. Sound postharvest practices have since been developed to extend the shelf life of fresh mushrooms.

As far as processing technologies are concerned, sun drying of mushrooms is one of the simplest and oldest methods followed by the growers from the time immemorial. Due to the difficulties in drying of some of the mushrooms, new preservation technologies like canning, pickling, mechanical and chemical drying (freeze drying, fluidized bed drying, batch type cabinet drying and osmotic drying) and irradiation treatment of mushrooms have been developed to improve the shelf life and consumption of mushrooms.

During the recent years, there has been an increased emphasis on the quality of fresh vegetables including mushrooms, which is reflected in the price of the produce. In India, the mushroom market is largely the contribution of small and marginal farmers with limited resources, who are dependent on local market for the sale of their produce. The rate of respiration of the harvested mushrooms is high in comparison to the other horticultural crops and this results in a shorter postharvest life.

Many short-term storage measures are followed to retard the deterioration in quality at the level of mushroom grower till it reaches the consumer. By following proper packing, cooling and transportation, the shelf life of mushrooms can be extended.

A. White Button Mushroom (*Agaricus bisporus*)

White button mushroom still dominates the Indian and International market and a lot of work has been done to minimize the loss in quality of the mushrooms.

1. Washing

Washing, is normally done to remove soil particles, however, it leads to decline in shelf life and spoilage by bacteria. Small growers wash in solution of reducing agents to retard the browning caused by polyphenoloxidases. Hence, various anti-microbial as well as reductant compounds are used in washing mushrooms to extend the shelf life.

Oxine, a stabilized form of chlorine dioxide, was very effective in controlling bacterial growth and colour deterioration when used at a level of 50 ppm or higher with a two minute or longer wash period at 12°C. The use of sodium hypochlorite (100 ppm) and calcium chloride (0.55%) with oxine (100 ppm) resulted in increased antibacterial effectiveness. Use of calcium chloride and oxine also resulted in lower cap opening and firmer mushrooms during storage. Washing fresh mushrooms in water containing sodium sulphite solutions results in lower bacterial numbers and an improved initial appearance, but more rapid bacterial growth and browning occurred during subsequent storage compared to unwashed controls. Mushrooms washed in hardwater (150 ppm calcium carbonate) reduced bacterial growth and there was less colour deterioration during storage. Washing mushrooms in a solution consisting of oxine (50 ppm), sodium erythorbate (0.1%), and calcium chloride (0.5%) resulted in significantly lower bacterial populations and less colour deterioration during the storage. Based on experiment done at this organization and its co-coordinating centers, it has been found that washing of mushrooms in 0.05% potassium metabisulphite improved the initial whiteness, which lasted longer during the storage. Even though many farmers are adapting this approach of washing, but selling clean unwashed properly packed mushroom may be a better option, as many people prefer mushroom not just because of health benefit, but also considered it a more chemical free food.

2. Modified atmosphere packaging (MAP)

Modified Atmosphere Packaging is a method by which a modified atmosphere is created in a sealed package of a fresh product by respiratory gas exchange, namely oxygen (O₂) intake and carbon dioxide (CO₂) evolution. When the rate of gas permeation through the packaging material equals respiratory gas exchange, equilibrium concentrations of O₂ and CO₂ are consequently established. The equilibrium depends on: temperature, respiration rate of specific product, product weight, O₂ and CO₂ permeabilities of the packaging material, free volume in the package and film area. Thus modified atmosphere packaging (MAP) helps in extending the shelf life and maintenance of quality of perishable produce by way of creation of appropriate gaseous atmosphere around the produce packed in plastic films. In this technique, the natural process of respiration of the produce in conjunction with the restricted gas exchange through a polymeric film such as low density polyethylene (LDPE), normal and oriented polypropylene (PP) is used to control the in-pack oxygen and carbon dioxide. General

principle of MAP for vegetables and the conceptual model of the MAP for mushroom are given in the Fig. 22.1(a) & (b), respectively.

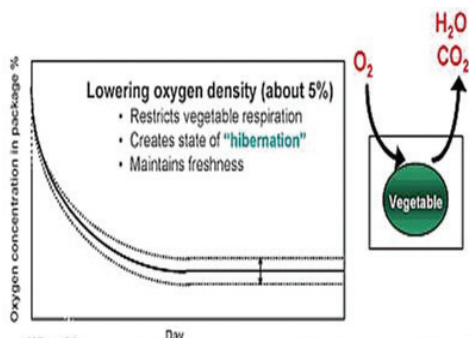


Fig. 22.1(a). Principle of MAP

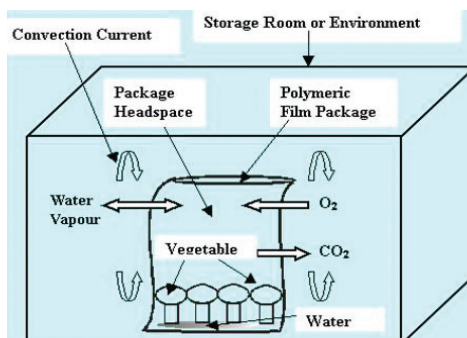


Fig. 22.1(b). Conceptual model of MAP

Modified atmosphere can be created by two methods: active and passive modifications. In passive modification, the product is just sealed in a polymeric package and due to the respiration of the fresh product and permeation of gases into the package, the atmosphere is modified. In active modification, air is flushed into the package initially, so that the steady state atmosphere is reached quickly after packaging. In passive modification, it takes a long time to reach the steady state conditions within the package.

Modified atmosphere packaging (MAP) of mushrooms has been shown successfully to delay senescence and maintain quality after harvest. Shelf life of mushrooms can be increased by over wrapping them with PVC films. Thickness of 100 gauge polythene bags with 0.5% venting area are recommended for packing mushroom in case of refrigerated storage. For transporting mushroom to long distance, polystyrene or pulp-board punnets should be used instead of using polythene bags (Fig. 22.2). The punnets are over-wrapped with differentially permeable Poly Vinyl Chloride (PVC) or poly acetate films. They create modified atmosphere in punnets producing an atmosphere of about 10% CO_2 and 2% O_2 . The optimum atmosphere for storage of mushrooms is found to be 2.5-5% CO_2 and 5-10% O_2 .



Fig. 22.2. Pulp board punnet with over wrapped polyethylene sheet

In modified atmospheric packaging, the packaging material plays a vital role in modifying the inside atmosphere around the product and the product quality as well. Among the various packaging materials viz., polyvinylidene chloride coated, oriented nylon, anti-fogging, wrap or vacuum packing film, the antifogging film maintained the quality of mushrooms for 24 days. The best packaging material polyethylene extends the shelf life of fresh mushrooms to 15 days under MAP conditions.

In modified atmospheric packaging, the shelf life of the product can further be extended by supplementing some chemicals in addition to modifying the atmosphere inside the package. The various supplementary packaging materials viz., activated carbon, sorbitol, chitosan, potassium permanganate can be used in MAP for maintaining the quality of oyster mushrooms at ambient temperature. A study was conducted in Finland about the washing and use of a humidity absorber (Silicagel) in the packages during the modified atmosphere and it was found that washing in chlorinated water and incorporation of dehumidifiers decreased the microbial contamination and increased shelf-life in *Agaricus bisporus*. Sorbital maintained the best colour in mushroom when it was packed and stored along with fresh mushroom trays over wrapped with PVC films.

3. Modified humidity packaging

Most polymeric films used in conventional packing have lower water vapour transmission rates relative to transpiration rates of fresh produce. This leads to nearly saturated conditions within packages. The high in-package-relative-humidity (IPRH) can cause condensation of water vapour within a package and allow microbial growth. This may either increase or decrease the spoilage depending on the product, depending on their transpiration coefficients and water potentials.

To obtain the desired IPRH, there are two possible approaches: perforation of the package, which precludes the possibility of achieving modified atmosphere conditions within the package, and use of in-package water absorbing compounds like calcium chloride, which can maintain the required RH. MAP in combination with MHP further improved the shelf-life of fresh mushrooms. An IPRH of 87-90% is desirable for best colour in mushrooms during storage.

4. Controlled atmospheric storage

In this method, the oxygen and carbondioxide concentrations are altered inside the package and respiration rate gets altered. Controlled atmospheric package reduces brown discolouration (enzymatic browning) and the shelf life is extended.

The calcium chloride added to the irrigation water improves the yield and colour of the canned mushroom product. Mushrooms exposed to lower airflow rates in the growing room remain whiter than those exposed to higher airflow rates. Addition of proprietary form of stabilized chlorine dioxide (oxine, 200 ppm) to preharvest watering applications on mushrooms had lower incidence of blotch and mushrooms retained whiter colour during storage. Commercially available food grade moisture absorbers such as montmorillonite clay and silica gel can be used to extend the shelf life of mushrooms in packs. Mushrooms treated with honey (0.5 and 1 percent) for 18 hours, air dried to remove surface moisture, packed in 100 gauge polythene pouches with 0.5% venting area, increased the shelf life by more than a week over control at 3-5°C and 2-3 days at ambient temperature.

5. Packing & packaging

The mushrooms are packed for transporting them to the market. While a good package sells a product, a mediocre package can interfere with sale of an otherwise excellent product. For the local markets in India, mushrooms are packed in retail packs of 200 g or 400 g in simple polythene packs of less than 100 gauge thickness. Large

quantity packing of mushrooms is done using polythene or pulp-board punnets, which will withstand long distance transport (Fig. 22.2). These punnets are over-wrapped with differentially permeable PVC or polyacetate films. These over-wrappings help in creating modified atmosphere in punnets with 10% CO₂ and 2% O₂ and mushrooms maintain their fresh look for 3 days at 18°C.

Table 22.1. Types of container materials used for various types of packaging

Material	Size (mm)	Capacity (kg)
Plastic punnets	130 x130 x 72	0.40
Cardboard chips	305 x 125 x 118	1.82
Plastic tray	330 x 280 x 145	2.30
Expanded polystyrene	400 x 333 x 167	4.56

In the recent years controlled atmosphere packaging (CAP) and modified atmosphere packaging (MAP) are catching up fast for all types of fruits & vegetables. These packaging techniques have to be effectively used for packing mushrooms to have improved shelf life. If simple polythene bags are used, it is important to make desired number of holes for proper humidity control.

6. Pre-cooling or refrigeration

The temperature of the button mushroom after picking varies between 15-18°C, and it rises steadily during the storage due to respiration and atmospheric temperature. This heat causes deterioration in quality. Hence, the heat should be removed immediately after the harvest and the temperature of mushrooms should be brought down to 4-5°C as quickly as possible. The choice of the cooling system depends upon the quantity to be handled, which may be a refrigerator for a small grower to a cold room with all facilities for a commercial grower. Using evaporative cooling, hydro-cooling, forced-chill air, ice bank or vacuum cooling systems, mushrooms can be cooled up to 2-4°C. The conceptual diagrams of principle of hydro-cooling and evaporative cooling for fresh vegetables are given in Fig. 22.3(a) and (b), respectively.

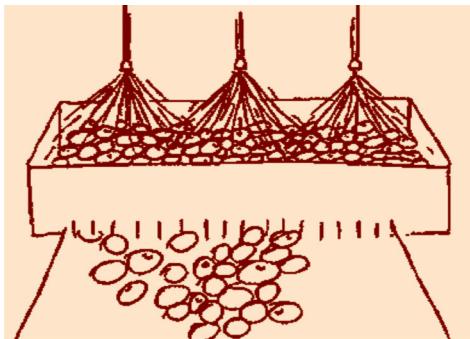


Fig. 22.3(a). Principle of hydro-cooling

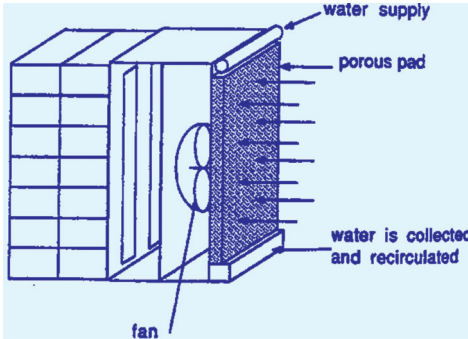


Fig. 22.3(b). Principle of evaporative cooling

The temperature of the mushrooms increases through respiration after picking and the respiratory rate increases with the increase in the storage temperature. It has been estimated that mushrooms at a temperature of 10°C have 3.5 times higher respiratory

capacity than those at temperature of 0°C, which necessitates immediate shifting of mushrooms to the refrigerated zone.

The size and shape of the packs also play an important role in cooling room. Packs with more than 10 kg mushrooms or with 15 cm thick layers of mushroom causes problem. Vertical flowing of air is more suitable for cooling. The mushrooms should not be stored in the same cooler along with fruits as the gases produced by fruits e.g. ethylene cause discoloration of mushrooms. This forced-chill air-cooling system is time consuming and vacuum cooling is becoming more popular.

7. Vacuum cooling

In vacuum cooling, the water in cell walls and interhyphal spaces of mushrooms is evaporated under low pressure and the evaporative cooling lowers the temperature from ambient to 2°C in 15 to 20 minutes. Vacuum cooling is a uniform and faster process, where mushrooms are subjected to very low pressure and water evaporates giving off the latent heat of vaporisation, thus cooling itself. The vacuum-cooled mushrooms have superior colour than conventional-cooled mushrooms. The major drawback of the system is the high capital cost; and an inevitable loss of fresh weight during the process of cooling. Filling and emptying the cooling chamber introduces another operation and expenses into the marketing chain.

Air spray moist chillers can also cool the mushrooms rapidly. The temperature can be lowered by 16-18°C in an hour without any moisture loss.

8. Ice-bank cooling

With a view to reduce the weight loss during the conventional vacuum cooling, ice bank cooling of mushrooms is now in vogue in some countries wherein a stack of mushrooms is passed through forced draft of chilled but humidified air from the ice-bank. Principle of the ice-bank cooling is shown in the Fig. 22.4.

9. Steeping preservation

This method is simple and economical and the mushrooms can be preserved for short period by steeping them in solution of salt or acids. The common practice is that cleaned mushrooms are washed in water or chemical added water and filled in large

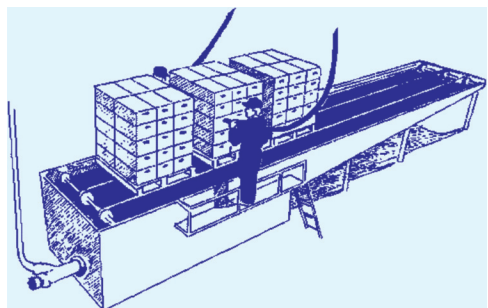


Fig. 22.4. Ice bank cooling

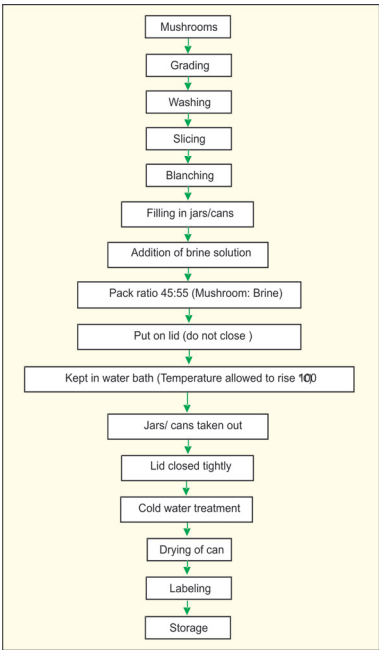


Fig. 22.5. General flow chart for steeping preservation

plastic containers. Blanching in brine solution for 5 minutes is generally done before filling them in cans. Brine solution is then added into the cans or containers. Steeping of water blanched mushrooms in 1% potassium meta bisulphite (KMS) along with 2% citric acid (overnight), before drying improves color, texture and reconstitution properties. General flowchart of steeping preservation is shown in the Fig. 22.5.

Solution consisting of 2% sodium chloride, 2% citric acid, 2% sodium bicarbonate and 0.15% KMS is used for steeping preservation of blanched mushrooms for 8-10 days at 21-28°C. Chemical solution of 2% salt, 2% sugar, 0.3% citric acid, 0.1% KMS and 1% ascorbic acid is also used for steeping preservation of mushrooms. It helps to extend shelf life of mushrooms.

10. Canning

Canning is the technique by which the mushrooms can be stored for longer periods up to a year and most of the international trade in mushrooms is done in this form. The canning process can be divided into various unit operations namely cleaning, blanching, filling, sterilization, cooling, labelling and packaging. In order to produce good quality canned mushrooms, these should be processed as soon as possible after the harvest. In case a delay is inevitable; mushrooms should be stored at 4 to 5°C till processed. The mushrooms with a stem length of one cm are preferred and are canned whole, sliced and stems and pieces as per demand. Well graded fresh mushrooms white in color, without dark marks on either caps or stems are preferred for canning. Whole mushrooms are washed 3-4 times in cold running water to remove adhering substances. Use of iron free water with 0.1% citric acid prevents discoloration. Thereafter blanching is normally done to inhibit polyphenol oxidase enzymes activity and to inactivate microorganisms. It also removes the gases from the mushroom tissue and reduces bacterial counts. The mushrooms are blanched in stainless steel kettles filled with a boiling solution of 0.1% citric acid and 1% common salt. The blanching time ranges from 5-6 minutes at 95-100°C. The mushrooms after blanching are filled in sterilized tin cans (A-2½ and A-1 tall can sizes containing approximately 440 and 220 g drained mushroom weight, respectively). Brine solution (2% salt with 0.1% citric acid or 100 ppm ascorbic acid) is added to the mushroom-filled cans after bringing its temperature to 90°C. After filling, the cans are exhausted by passing them in exhaust box for 10-15 minutes, so that temperature in the centre of cans reaches up to 85°C. Then the cans are sealed hermetically with double seamer and kept in upside down position. After exhausting of cans, sterilization of cans is needed. Sterilization is the process of heating the cans up to 118°C to prevent the spoilage by microorganisms during storage. The cans cooled immediately after sterilization process to stop the over-cooking and to prevent stack burning. Cooling can be done by placing the cans in a cold-water tank. Thereafter the clean and dry

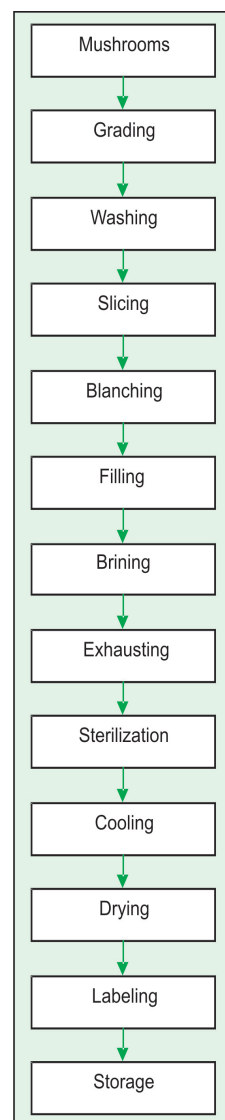


Fig. 22.6. Flow chart (Canning)

cans are labeled manually or mechanically and packed in strong wooden crates or corrugated cardboard cartons. The cans are stored in cool and dry place before dispatching to market. In a hot country like India, where the ambient temperature is high during the several months in a year, basement stores are useful, especially during the summer months. General flowchart of canning preservation is shown in the Fig. 22.6.

11. Radiation preservation

Low doses of gamma radiation can be used to reduce the contamination and extend the shelf life of mushrooms. Irradiation should be given immediately after harvest for optimum benefits. Irradiation can potentially delay the maturation i.e. development of cap, stalk, gill and spore and also reduces the loss of water, colour, flavour texture and delays the quality losses. Cobalt 60 is used as a common source of gamma rays. A dose of 10 KGy (Kilo Gray) will completely destroy microorganisms.

An enhancement in shelf-life of *Agaricus bisporus* upto a period of 10 days can be achieved by application of gamma ray close to 2 KGy and storage at 10°C. Irradiation reduces the incident of fungal and bacterial infection. The loss of flavour components is noticed in irradiated mushrooms. The cap opening is also delayed by irradiation. Aminoacids in fresh mushrooms are preserved by gamma irradiation. Irradiation at low levels proved better than irradiation levels of 1 & 2 KGy. The permissible doses for such preservation have not been worked out in our country. Even for export, it will be necessary to follow the standards of importing country.

12. Transport

The effect of pre-cooling and packing will be partially negated if the product is later stored and transported in a hot environment. Mushrooms, therefore, need refrigerated transport. To keep the mushrooms cool during transport to short distances, the polypacks of mushrooms can be stacked in small wooden cases or boxes with sufficient crushed



Fig. 22.7(a). Boxes for bulk transport



Fig. 22.7(b). Refrigerated van for bulk transport

ice in polypacks (over-wrapped in paper) (Fig. 22.7a). For long distance, transport of large quantities in refrigerated trucks is essential though it is costlier (Fig. 22.7b).

B. Oyster Mushroom (*Pleurotus Spp.*)

The oyster mushrooms are harvested and the straw adhered to mushroom is removed and are packed in polythene bags of less than 100 gauge thickness with perforations having vent area of about 5%. Though these perforations cause slight reduction in

weight during storage, it helps in maintaining the freshness and firmness of the produce. Rough handling should be avoided

Storage of oyster mushroom at very low temperatures especially in non-perforated polypacks results in condensation of water with increased sliminess and softening of the texture. Cooling with positive ventilation is desirable i.e. cold air should be directed through the packed produce. For transporting 'dhingri', the fruitbodies are stacked in trays or baskets. Few polypouches containing crushed ice are kept along with mushrooms. The tray is then covered with thin polythene sheet with perforation. The prepacked polythene packs with perforations may also be transported in this way.

C. Milky Mushroom (*Calocybe indica*)

Milky mushroom is the new introduction from India to world and its production is catching up fast in different parts of the country during the summer months and the mushroom has revolutionized the so called off-season mushroom growing. Fresh mushroom market is largely catered by seasonal growers who do not have cold-chain storage and transport facilities. They sell the produce in highly localized market. This mushroom has very good shelf life of 3-4 days without loss of color and appearance. Washing, packaging, pre-cooling and refrigeration, transports and storage of fresh milky mushroom, if needed, are almost same as for the button mushroom.

D. Paddy Straw Mushroom (*Volvariella volvacea*)

This mushroom is packed in polythene bags. As low temperature storage causes frost injury and deterioration in quality, the best way of storage is at 10-15°C in polythene bags with perforations. Mushrooms packed in bamboo baskets with an aeration channel at the center and dry ice wrapped in paper placed above the mushrooms, is in practice for transportation in Taiwan. Packing in wooden cases for transport by rail or boat is practiced in China. In general the shelf life of this mushroom is very less and mushroom are sold on the day of harvest.

E. Drying of Mushrooms

Drying is perhaps the oldest technique known to the mankind for preservation of food commodities for long duration. It is the process of removal of moisture from the product to such a low level that microbial and biochemical activities are checked due to reduced water activity, which makes the products suitable for safe storage and protection against the attack by microorganisms during the storage. Mushroom contains about 90% moisture at the time of harvesting and are dried to a moisture level down below 10-12 per cent. At a drying temperature of 55-60°C, the insects and microbes on the mushrooms will be killed in few hours, which gives us the dehydrated final product of lower moisture content with longer shelf-life. The temperature, moisture of the mushroom and humidity of the air affect the color of the dried product. Dehydrated mushrooms are used as an important ingredient in several food formulations including instant soup, pasta, snack seasonings, casseroles, and meat and rice dishes. Dried mushrooms can be easily powdered and used in soups, bakery products, etc. Mushroom dried at higher temperature loose texture, flavor, color along with reduced rehydrability.

Most of the mushrooms except the button mushroom have been traditionally dried for long-term storage e.g. oyster, shiitake, paddy straw, *Auricularia* etc. In case of button

mushroom, it is the blackening and irreversible change of texture, which often discourages the use of this otherwise simple technique of preservation. Recently with advances in drying technologies, various drying methods such as solar drying, fluidized bed drying (Fig. 22.8), dehumidified air- cabinet drying (Fig. 22.9), osmo-air drying, freeze-drying (Fig. 22.10), cabinet drying (Fig. 22.11) and microwave drying are efficiently used for almost all types of mushrooms.



Fig. 22.8. Fluidized bed dryer



Fig. 22.9. Dehumidified air dryer



Fig. 22.10. Freeze dryer



Fig. 22.11. Cabinet dryer

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Cultivation of Shiitake (*Lentinula edodes*)

V.P. Sharma, Satish Kumar and S.R. Sharma

Lentinula edodes, commonly called as shiitake is the 2nd largest mushroom cultivated in the world after *Agaricus bisporus*. It is liked by the consumers for its unique taste, flavour and medicinal properties. *L. edodes* is mainly cultivated in Japan, People's Republic of China, Taiwan, S. Korea and United State of America. Preparation of shiitake spawn, cultivation on synthetic logs and on wood logs is described here.

A. Spawn Preparation

Mainly wheat grain spawn is used in synthetic log cultivation whereas; sawdust spawn and wood plug spawn are used in wood log cultivation. Wheat grain spawn is prepared as described in Chapter 5. Saw dust spawn is prepared using any of the following formulae:

a.	Saw dust	65%	b.	Saw dust	78%
	Wheat bran	15%		Sucrose	1%
	Used tea leaves	20%		Wheat bran	20%
	Water content	65%		Calcium carbonate	1%
				Water content	65%
c.	Saw dust	800 g			
	Rice bran	200 g			
	Sucrose	30 g			
	Potassium nitrate	4 g			
	Calcium carbonate	6 g			
	Water	2 litres			

Saw dust after proper sieving to remove bigger size wood particles and other impurities, is thoroughly mixed adding water. Normally one or two drops of water should ooze out when pressed between the fingers. It is then filled into either empty spawn bottles or in polypropylene bags. One inoculation hole is made into the centre of the substrate with the help of a rod. The spawn containers are plugged with non-absorbent cotton and covered with aluminium foil. These are then autoclaved at 20 p.s.i. for 2 hours. The actively growing mycelium (10 days old) culture is inoculated aseptically and incubated for 30 days at $24 \pm 2^{\circ}\text{C}$. Contaminated bottles are discarded.

Wood plug spawn is prepared by inoculating mycelium on small wedge shaped or either small cylindrical wood pieces. When the fungal mycelium impregnates the wood pieces, they are ready for inoculation.

B. Synthetic Log Cultivation

This method is practiced in Taiwan, Mainland China, Singapore, New Zealand, USA, Finland, Netherlands, Germany, Philippines, Sri Lanka, Thailand and India.

1. Substrate preparation

The commercial cultivation can be carried out on sawdust of broad leave trees mainly tuni, mango, safeda, oak, maple and poplar. Some of the common formulations are as under

i.	Saw dust	80%	ii.	Saw dust (Maple and birch 60:40)	80%
	Rice bran	20%		Millet	10%
	Water content	65%		Wheat bran	10%
iii.	Hard wood	89.8%	iv.	Hardwood	32.8-
	Rice bran	10%		saw dust	34.2%
	CaCO ₃	0.2%		Rice bran	2.7-5.2
	Water content	60%		Corn powder or millet rice	1.4-2.6%
v.				CaCO ₃	0.2-0.3%
				Water content	59-62%
	Corn cobs	40 kg	vi.	Sugar cane bagasse	50 kg
	Saw dust	10 kg		Rice bran	12.5 kg
	Wheat bran	12.5 kg		Gypsum	1.5 kg
	Cane sugar	1 kg		Potassium Sulphate	15 g
	Pectin	15 g		Urea	15 g
	Urea	20 g		Magnesium Sulphate	10 g
vii.	Rice straw	50%	viii.	Saw dust	80 kg
	Wheat straw	20%		Wheat bran	20 kg
	Wheat bran	19 kg		Cane sugar	1.3%
	Saw dust	20%		CaCO ₃	1.5%
	CaCO ₃	1 kg		Citric acid	0.2%
				CaSO ₄	0.5%

Water should be adjusted to 60-65% and pH to be adjusted to 5.5-6.0 using gypsum and lime. Soluble ingredients (citric acid, sugar, sulphates, etc.) are usually dissolved first in water before mixing; saw dust has to be soaked at least for two days and rice straw for three hours. All the ingredients are thoroughly mixed. At our institute formula No. (viii) is commonly used.

2. Filling and sterilization of bags

Fill the bags (1.5 to 2 kg) immediately after mixing and wetting the substrate (Fig. 23.1). Otherwise fermentation and contamination may start. Polypropylene (heat resistant) bags are used for filling. The bags are first loosely filled and later by putting the pressure, cylindrical shape is given to the bags. Some growers make holes for later inoculation before semi-sterilization; other will make holes after the heat treatment. Two 15 mm diameter, 20 mm deep holes are punched on opposite sides with an auger. The holes

are covered with 33 mm square adhesive medical tape. The time between mixing the supplements and sterilization should be less than six hours to avoid fermentation. Bags can also be provided with iron/plastic ring and plugged with non-absorbent cotton. Sterilization is carried out in an autoclave at 22 psi for 1½-2 hours.



Fig. 23.1. Bags filled with substrate

3. Spawning and spawn running

Spawning is carried out by removing the cotton plugs. Grain spawn is introduced @ 3% under aseptic conditions (Fig. 23.2 & 23.3) The bags are placed in cropping rooms where these are generally incubated in a 4 h / 20 h light/ dark cycles at 23-25°C. Spawn run (Fig. 24.4) may take 60-80 days or more depending upon the strain and environmental conditions. During the period it goes through mycelial growth, mycelial coat, mycelial bump and browning stage.



Fig. 23.2. Inoculation of sterilized bags



Fig. 23.3. Inoculated bag



Fig. 23.4. Spawn run in shiitake

4. Mycelial coat formation

A thick mycelial sheet/ coat will develop (Fig. 23.5) on the surface of the substrate. This will occur 7-8 weeks after inoculation.

5. Mycelial bump formation

Bumps are clumps of mycelium, commonly formed on the surface of most strains after 9-10 weeks (Fig. 23.6). These bumps can turn into mushroom primordia at a later stage but most of them abort. Fluctuating temperatures and high CO_2 promotes bump formation.



Fig. 23.5. Mycelial coat



Fig. 23.6. Mycelial bump

6. Pigmentation

Some aeration should be provided when the bumps have formed for this phase to occur. After longer spawn runs (more than 60 days) the surface of the colonized substrate may begin to turn brown, some exudates may be there during spawn running.

7. Coat hardening phase

Remove the plastic when bags have partially (half or one third) turned brown. The coat will gradually become hard (Fig. 23.7). While outside of the substrate should be hard, the inside should be softer and moist. The core of the substrate has moisture of about 80%.

8. Fruiting

For induction of fruiting suitable temperature, high RH, good ventilation and cold water/ shock treatment are required (Fig. 23.8).

A schedule of various parameters as given below (Table 23.1):

- i. The temperature range for fruiting is strain dependent.
- ii. A dry period after harvesting will prevent contamination.
- iii. The artificial logs may be given a water bath to restore high moisture content of the substrate.

Table 23.1. Various cropping parameter

Stages/ Activity	Days	Temperature °C	Light intensity (Lux)	Humidity (%)
Incubation	50-120	20-30	500-1000	65-70
Induction	2-4	10-20	500-1000	85-95
Fruiting	7-14	12-18		60-80
Rest	7-21	20-30	None	65-70
Induction	2-4	10-20	500-1000	85-95



Fig. 23.7. Coat hardening



Fig. 23.8. Pin head formation

9. Harvesting

Hold the stalk of the mushroom and break them from the substrate. Don't tear them from the surface. Harvest the mushrooms at an early stage (Fig. 23.9). Don't water the scars left after harvesting for 3-4 days. Normal yields are 15-30% of the wet weight of the substrate.

C. Cultivation on Wood Logs

L. edodes grows in nature on the dead wood of a number of hard wood broad leaf trees mainly *Quercus* spp., *Castanopsis* spp., *Elaeocarpus* spp., *Lithocarpus* spp., *Betula* spp. and *Carpinus* spp. The generalized cultivation technique is as follows:

1. Log preparation

L. edodes mycelium is saprophytic and wood rotting. As indicated above it mainly grows on dried wooden logs of different trees (Table 23.2) absorbing nutrients from the

cambium. Although it grows on any size and age of logs, but the log with 9-18 cm diameter and from 15 to 20 years old tree are most suitable. The time of falling or cutting the trees is also equally important. The most suitable period is from autumn (December-January) to early spring when the logs contain highest amount of carbohydrates and other organic substances. Moreover, the outer protective layer bark is also tightly attached with the woody portion. The logs should contain a moisture content of 44-55% at the time of felling. If the moisture content of the log is less than 20% then there will be no growth. On the other hand if the moisture contents is more than 60% with a pH of 7-8, it will easily be contaminated with other moulds. The pH of the logs should be between 4.5-5.5. The felled logs are left as such for 25-45 days, which results in the lowering of the moisture contents to 40-45%. If the moisture content is optimum and further drying will result in excessive moisture loss, the logs are immediately inoculated,



Fig. 23.9. Mushrooms ready to harvest

Table 23.2. Trees suitable for wood log cultivation of shiitake

Sr.No.	Scientific Name	Common Name
1.	<i>Carpinus laxiflora</i>	Hornbeam
2.	<i>Castanea crenate</i>	Japanese
3.	<i>Castanopsis cuspidata</i>	Shii
4.	<i>C. sieboldii</i>	Shii
5.	<i>Ostrya virginiana</i>	Ironwood
6.	<i>Quercus abla</i>	White oak
7.	<i>Q. acutissima</i>	Oak
8.	<i>Quercus spp.</i>	Oak
9.	<i>Salix nigra</i>	Black willow
10.	<i>Betula lutea</i>	Sweet birch
11.	<i>B. nigra</i>	Red birch
12.	<i>Alnus serrulata</i>	Hazel alder



Fig. 23.10. Holes made on logs for spawning

2. Spawning the logs

For spawn inoculation, small holes of 1 x 1 cm and 1.5 to 2 cm deep are made on the logs with the help of a drilling machine (Fig. 23.10). The holes are made at a distance of 20-30 cm (long axis) and 6 cm between each row. The holes between two rows are alternate in position. Saw dust spawn is filled in the holes or wood plug spawn is inserted. The sawdust spawn should be kept soft and not tightly pressed. The holes are sealed with paraffin wax. The

spawning should mostly be done in aseptic conditions. Shiitake mycelium grows between 5 to 30°C but the most optimum temperature is 20-26°C. Low temperature (14-20°C) is favoured during spawning logs, so that there are minimum chances of contamination.

3. Crop management

Inoculated logs are kept in open at a place where the physical conditions are most favourable for the mycelial growth. The logs are kept in a flat pile so that there is minimum light exposure. The pile should be covered with either straw, or gunny bags to prevent excessive water loss of the logs. The vegetative growth in the logs will be completed within 8-12 months depending upon the culture strain and the type of wood used.



Fig. 23.11. Shiitake growing on wood logs

The logs do not require watering during incubation. Keep humidity low (60-70%) to prevent contamination if the plastic is removed too early or too late, yields will be affected. Deformed fruit bodies during the first flush are a sign of a too short spawn run or high CO₂ during incubation.

For fruit body induction this mushroom requires, temperature shock of temperature drop, high humidity and enough light. The logs for fruiting are either sprayed with cold water or immersed in a tank of cold water. If the logs are immersed in cold water, then during summer they should be kept for 24 hours in cold water (15-18°C) while during winter they should be kept for 2-3 days at 10-15°C.

The logs are then leaned against the supports. The cropping area is kept moist to maintain high relative humidity. The temperature should be 15-20°C and humidity around 80-90%. Fruit bodies are harvested by first pressing and then twisting (Fig. 24.11). Mushrooms are harvested up to 3 times and after a rest for 30-40 days, logs are again watered to get more mushrooms. It can be repeated up to 3-4 times per year and these logs will produce crop up to 3-8 years.

D. Features of Wood Log and Synthetic Log Cultivation

Comparison of features of wood log and synthetic log cultivation of shiitake is summarized in Table 23.3.

Table 23.3. Wood log versus synthetic log cultivation

Features	Natural Logs	Synthetic logs
Substrate	Wood logs only	Saw dust, bagasse, sugarbeet residue, cotton seed hulls, peanut hull , corn cobs
Time for first harvest	8-12 months	80 –100 days
Production Period	3 -8 years	8 months
Production	10-15 kg/ 100 kg log	80-145% BE
Management	Difficult	Easy
Quality of Product	Excellent	Poor

Systematic flow chart of cultivation of shitake mushroom is given in Fig. 23.12.

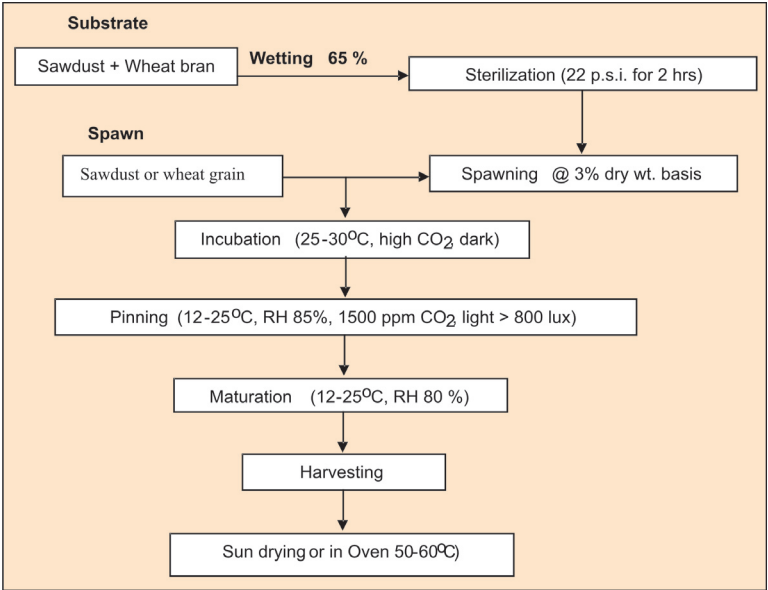


Fig. 23.12. Flow chart of cultivation of shiitake mushroom

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Cultivation of Specialty Mushrooms - *Auricularia*, *Flammulina*, *Calocybe* and *Agrocybe*

V.P. Sharma and Satish Kumar

Specialty mushrooms is a term given to a group of mushrooms, which are less common in a particular area or country. The following genera may be grouped under specialty mushrooms (Table 24.1).

Table 24.1. Genera of specialty mushrooms

S. No.	Scientific name	Common name
1.	<i>Pleurotus</i> spp.	Oyster mushroom, dhingri
2.	<i>Volvariella volvacea</i>	Paddy straw mushroom, tropical mushroom, chinese mushroom
3.	<i>Lentinula edodes</i>	Shiitake, black forest mushroom, shiang - g
4.	<i>Auricularia</i> spp.	Black ear, wood ear, Jew's ear, ear fungus
5.	<i>Calocybe indica</i>	White milky mushroom
6.	<i>Flammulina velutipes</i>	Winter mushroom, velvet stem, enokitake
7.	<i>Agrocybe aegerita</i>	Black poplar mushroom
8.	<i>Pholiota nameko</i>	Nameko, viscid mushroom
9.	<i>Coprinus lagopus</i>	Ink caps, Dung mushroom, shaggymane
10.	<i>Oudemansiella canarii</i>	-
11.	<i>Tremella fuciformis</i>	Silver ear, white jelly fungus
12.	<i>Dictyophora duplicata</i>	Bamboo sprouts, flower of the fungi, veiled lady mushroom, king of the dried foods

Pleurotus, *Volvariella* and *Lentinula* have been separately dealt elsewhere in this book. Scope and present status of other specialty mushrooms is being discussed in this chapter.

A. Scope of Specialty Mushrooms

Varied agroclimatic conditions and availability of agricultural and industrial wastes in India offer great opportunities for cultivating specialty mushrooms on commercial scale. The following merits amply demonstrate their potential in India.

- An ever-increasing public appetite for new and different foods will continue to fuel an expansion in the specialty mushroom market. Historical developments in the cultivation of mushrooms amply demonstrate this trend.

- Mushrooms add flavour, eye appeal to our food and are also good source of proteins, fiber, vitamins and minerals.
- Specialty mushrooms have been traditionally used in China and Japan for medicinal and tonic purposes since time immemorial.
- The Indian sub-continent is endowed with a variety of vegetation and climate, suitable for growing different mushrooms throughout the year. Cultivation of different mushroom will help in developing integrated farming system for different eco-regions.
- Export Potential: Mushrooms are comparatively a new entrant on the list of important export items in India.

B. Cultivation of Wood Ear Mushroom

The two main species cultivated commercially are: *Auricularia polytricha* and *A. auricula*. Latter is thin and light in colour whereas former is darker, thicker and long haired. The cultivation is undertaken as follows:

- Take good quality wheat straw
- Soak it overnight for 16-18 h and drain out excess water
- Mix 4-5% wheat or rice bran on wet weight basis
- Fill 2 kg substrate per polypropylene bag and autoclave at 15 p.s.i. for 1-2 h
- Spawn the substrate after cooling @ 2% aseptically and incubate at 25-30°C for spawn run for 20-25 days
- Cross cut or give slits and hang the bags for fruiting at 25°C with 85-90% RH
- Daily spray water, give 1 h diffused light and provide sufficient aeration

1. Harvesting

Harvesting is done by slight twisting. Mushrooms harvested from wood logs have longer hair, more tough texture, less attractive colour and longer production period than from straw bags. In 3-4 flushes, one can harvest 1.0-1.4 kg fresh mushrooms/kg of dry straw. The fruit bodies can easily be sun dried with dry matter of 8-12 per cent. This mushroom retains its characteristic crispness on cooking (Fig. 24.1).



Fig. 24.1. Wood ear mushroom cultivation in bag

2. Management

Proper hygienic conditions are necessary because addition of wheat/ rice bran may attract moulds in the absence of proper sterilization. Presence of high-level of carbon dioxide results in development of abnormal fruit bodies. The absence of light also produces abnormal under developed mass of fruit bodies. Under very humid conditions cobweb has been found to attack this mushroom.

C. Cultivation of *Flammulina velutipes* - The Winter Mushroom

Sawdust of broad leaf trees supplemented with rice bran / wheat bran is commonly used as substrate for cultivation of this mushroom. Rice bran/wheat bran provides many of the essential nutrients. Much of the lignin, cellulose, and monosaccharides are provided by the sawdust. Saw dust is wetted thoroughly with water for 16-18 h. Generally, equal quantity of saw dust is poured in equal quantity of water. After wetting, 5 per cent wheat bran is added in the saw dust and mixed thoroughly.

1. Containers

This mushroom can be grown in a variety of containers like polypropylene bags, plastic bottles, vinyl bags, filter bags, jars, etc.

2. Filling

Two kg substrate (wet) is filled in polypropylene bags. The bags are plugged with non-absorbent cotton using a neck ring.

3. Sterilization

The filled bags are sterilized in the autoclaves for 1½ hour at 15 p.s.i.

4. Inoculation

The bags are inoculated with wheat grain based spawn after cooling. Saw dust spawn can also be used and growers may purchase from specialized spawn makers. Sawdust spawn is prepared by mixing ten parts of saw-dust with one part of rice bran and enough water to provide a certain degree of humidity.

5. Incubation (Spawn run)

The bags are placed/ arranged in incubation rooms where mycelium can grow favourably. The optimum temperature for the mycelial growth is between 22-25°C, so the temperature of incubation



Fig. 24.2. Spawn run bags

room is kept between 20°C and 23°C under the normal commercial cultivation conditions. Mycelium colonizes the whole bag in 20-25 days (Fig. 24.2).

6. Fruiting induction

When mycelium spreads to 90% of the bag space, the plug is pulled off, the neck of the bag is unfolded and the surface of the media is made smooth for fruiting (Fig. 24.3). Bags are then placed in dark at a temperature of 10 -14 °C and the humidity is maintained at 80 -85%.



Fig. 24.3. Bags ready for fruit body induction



Fig. 24.4. Initiation of primordia

Moisture level in the bags is important for fruiting. Good fruit bodies are formed by adjusting 80-85% humidity in the room and by maintaining correct moisture content in the substrate. Primordia are formed in 10-14 days after reducing the temperature to 10-14°C (Fig. 24.4). The initiation of fruit bodies starts in dark but light is necessary for further development. At the time of fruit body formation, temperature of cropping room should be lowered to 8-12°C with relative humidity from 80-85 per cent.

7. From primordia to fruit bodies

At 10 -12°C, the fruit bodies grow rapidly, but they are slender, long and of poor quality. For this reason, the growth of fruit bodies is controlled by lowering the temperature to 3-5°C and providing air movement (3-5 m/sec), which encourage stiff, white and drier fruit bodies (Fig. 24.5 & 24.6). This control is continued for 5-7 days from the period when the cap's differentiation is observed to the period when the length of the stem reaches 2 cm.

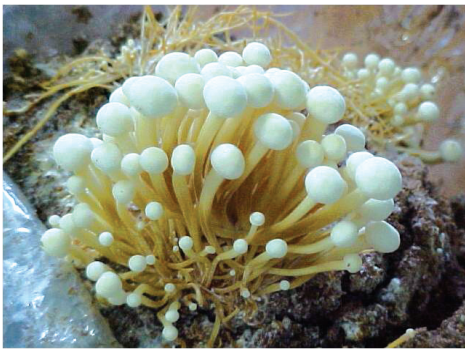


Fig. 24.5. Developing primordia



Fig. 24.6. Slender, long fruit bodies

8. Harvesting

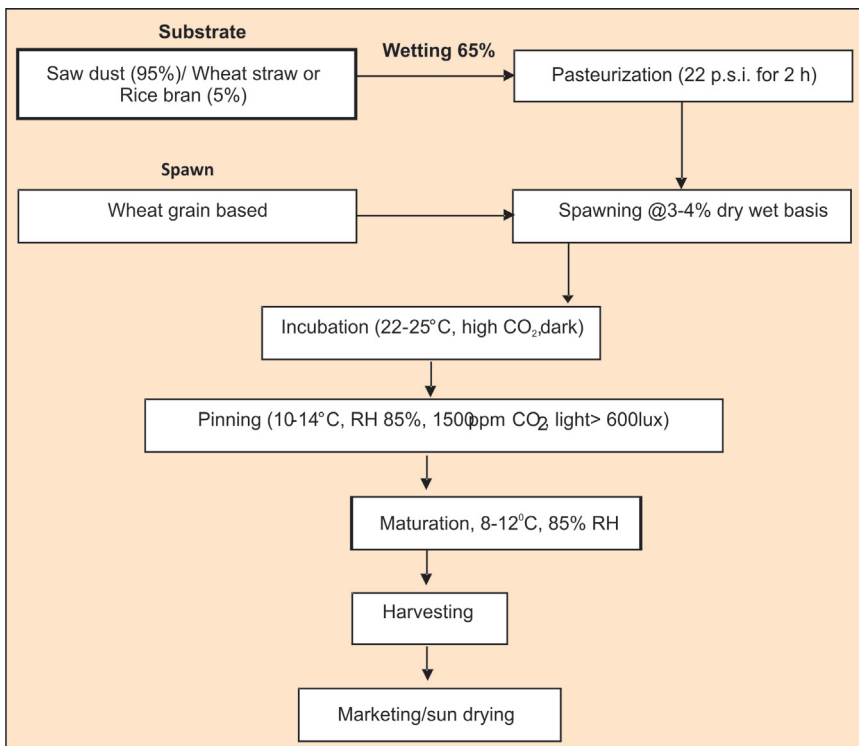
When the fruit bodies are 13-14 cm long, fruit bodies are pulled up from the bag and packed. It takes about 50-60 days from the initial fruiting to the crop. The first flush usually amounts to 200-240 g/ bag (800g dry) and second flush yields 160-180 g/ bag (Fig. 24.7 & 24.8). The flow chart of *Flammulina* production is given in Fig. 24.9.



Fig. 24.7. Cultivation in polypropylene bags



Fig. 24.8. Crop ready to harvest

Fig. 24.9. Flow Chart of *Flammulina* production

C. Cultivation of Milky Mushroom (*Calocybe indica*)

Milky mushroom (*Calocybe indica*) like paddy straw mushroom is suitable for cultivation in tropical and subtropical regions of the country. This variety is new introduction to world mushroom family from India. During last decade it has become a major variety for cultivation in South India and during last 2-3 years its cultivation has become popular in North as well, particularly in Haryana. Its high biological efficiency, better keeping quality, simple cultivation technique and white attractive colour are major factors for its popularity.

1. Substrate and its preparation

The mushroom can be grown on a wide range of substrates. Substrates exposed to rain or harvested prematurely (green colour) are prone to various weed moulds, which may result in crop failure. It can be grown on straw of paddy/wheat/ragi/maize/bajra, cotton stalks and leaves, sugarcane bagasse, cotton and jute wastes, dehulled maize cobs, tea/coffee waste, etc., However, cereal straw (paddy/wheat), which are easily available in abundance are favoured.

Straw is chopped in small pieces (2-4 cm size) and soaked in fresh water for 8-16 hours. This period can be reduced when pasteurization is to be done by steam. Main purpose of soaking is to saturate the substrate with water. It is easier to soak if straw is first filled in gunny bag and dipped in water.

2. Pasteurization/sterilization

Pasteurization/sterilization can be achieved by any of the following ways.

a. Hot water treatment

Water is boiled in wide mouth container and chopped wet straw filled in gunny bag is submersed in hot water for 40 minutes at 80-90°C to achieve pasteurization. This is very popular method particularly with small growers.

b. Steam pasteurization

Wet straw is filled inside insulated room either in perforated shelves or in wooden trays. Steam is released from a boiler and temperature inside substrate is raised to 65°C and maintained for 5-6 hours. Air inside the room should be circulated to have uniform temperature in the substrate.

c. Steam sterilization

Substrate is filled in polypropylene bags (35x45cm, holding 2-3 kg wet substrate) and sterilized at 15 psi for 1 hour. Once pasteurization/sterilization is over straw is shifted to spawning room for cooling and spawning.

d. Chemical sterilization technique

Technique defined for oyster mushroom (straw soaked in solution having 75 ppm bavistin and 500 ppm formalin) can also be used. In South India many farmers are using this technique. However in 5-10% of bags, spawn run may not be complete and *Coprinus* appears in such cases.

3. Spawning and spawn running

Spawning methods are similar to that mentioned for oyster mushroom. However, layer spawning is most commonly used in milky mushroom. Higher spawn dose of 4-5% (wet wt. basis) is used. After spawning bags are shifted to spawn running room and kept in dark where temperature between 25-35°C with 80% RH is maintained (Fig. 24.10). It takes about 20 days for substrate to get colonised and after that bags are ready for casing.

4. Casing

Casing means covering the top surface of fully colonised bags, with pasteurized casing material. Pond soil/soil (75%) + sand (25%), Coir pith + soil, FYM + soil can be used as casing material. However, soil (75%) + sand (25%) is generally preferred as casing material. Casing thickness is between 3-4 cm. Casing provides physical support, moisture and allows gases to escape from the substrate. Casing material, pH adjusted to 7.8-7.9 with chalk powder, is sterilized in autoclave at 15 p.s.i. for one hour or chemically treated with formaldehyde solution (2%) about a week in advance of casing. Treated casing is covered with polythene sheet to facilitate the action of formaldehyde and also to avoid its escape in the atmosphere. Soil is turned at an interval of 2 days so that at the time of casing, it is free from formalin fumes. For casing, bag's top is made uniform by ruffling top surface and spraying with carbendazim (0.1%) + formaldehyde (0.5%) solution. Casing material is sprayed with above chemicals to saturation level. Temperature 30-35°C and RH 80-90% are maintained thereafter for entire cropping cycle. (Fig. 24.11).



Fig. 24.10. Spawn run bags



Fig. 24.11. Cased bags

5. Cropping

It takes about 10 days for mycelium to reach to top of the casing layer, thereafter fresh air is introduced and minimum 3-4 air changes per hour are required. Light should be provided for maximum duration during entire cropping period. These changes in environment result in the initiation of fruiting bodies within 3-5 days. Mushrooms with 7-8 cm dia. (Fig. 24.12) are harvested by twisting, cleaned and packed in perforated polythene/polypropylene bags for marketing.

6. Crop management at different stages of cultivation

a. Substrate preparation

Substrate is a major source of weed moulds and disease causing organisms. Hence substrate should be of good quality and is chopped and soaked at a distance from bag filling/spawn running and cropping area. The workers chopping straw should not be involved in bag filling and spawning.

b. Bag filling, spawning and Spawn run

Bag filling and spawning area should be sprayed with formaldehyde (1%) twice in a week. For large scale production, it is advisable to have hepa filtered air circulation in

spawning area. Spawn running area should be sprayed with formaldehyde 0.5% (5ml/ litre of water) and malathion 0.1% (1 ml/ litre of water) once in a week.

c. Casing and cropping

Carbendazim (1 g) + formaldehyde (5ml) in 1 litre of water is sprayed before casing. Repeat spray on the casing soil and in the room again after a week. Malathion (0.1%) should further be sprayed on next day of casing to protect the crop from files. The fungicides or insecticides should not be sprayed on mushrooms.



Fig. 24.12. Mature milky mushroom crop

If any patch of mould is noticed, do spot treatment with formaldehyde (4%, 40 ml/litre) by soaking cotton in the solution and applying on and around infected spots. Before removal of bags/ disposing spent substrate, formaldehyde (2%) should be sprayed.

d. Water management

This is very important for a good and healthy crop. During rainy season controlled watering is required and watering once in a day may be enough. During winter watering twice may be sufficient. However during summer as water loss is high, it becomes very difficult to maintain required RH and moisture of the substrate. During such period one should spread sand on floor (around 6" thick) and use mist sprayer 3-4 times and frequently check the moisture of the casing by touch. Watering should also be adjusted to maintain RH (80-85%) inside cropping room.

7. Economics of milky mushroom production (50kg/day)

The cost of production depends upon the cost of raw material, yield/unit, production level and the wholesale price. At present the wholesale price in different parts of the country is between Rs. 45-60/kg. The information given below is a model to workout cost of production for a medium size mushroom production unit keeping in view an average yield. One has to keep in mind the above factors while working out the cost of production (Table 24.2 & 24.3).

Table 24.2. Annual expenditure

S.No.	Item	Quantity (kg)	Cost (approx.)
1.	Paddy straw	36500	54,750.00
2.	Spawn	4600	2,30,000.00
3.	Polythene bags for growing	500	38,500.00
4.	PP bags for packing	500	38,500.00
5.	Casing material	—	10,000.00
6.	Thread ball		2,000.00
7.	Formaldehyde	50 litres	3,750.00
8.	Bavistin	2.5kg	2,000.00
9.	Melathion/Nuvan	2 litres	1,600.00
10.	Bleaching powder	50kg	1,000.00

S.No.	Item	Quantity (kg)	Cost (approx.)
11.	Labour (Rs.3,000/-month)	3 Nos. (12 months)	1,08,000.00
12.	Water		2,400.00
13.	Electricity		3,400.00
14.	Transport		10,000.00
15.	Rent of building/Shed		12,000.00
16.	Miscellaneous expenditure		12,000.00
Total			5,29,900.00 or 5,30,000.00

Table 24.3. Annual fresh mushroom production (kg)

Fresh mushroom produced (kg) (50%)	= 18250.00	(100%)	= 36,500.00
Self consumption	= 180.00		= 180.00
Wastage	= 180.00		= 360.00
Balance for sale	= 17890.00		= 35,960.00
or	17900		or 35,950.00
Realization @ Rs.45/kg	= Rs.8,05,500.00	@ Rs.45/kg	= Rs. 16,18,200.00
Net annual profit (Sale realization - Cost of production)	= Rs. 8,05,500.00 - 5,30,000.00		
	= 2,75,500.00		= Rs. 16,18,200.00 - 5,30,000.00
Cost of production/kg	= Rs.30 /kg		= 10,88,200.00
			= Rs.14.74 or Rs.15/kg

D. Cultivation of *Agrocybe aegerita*, The Black Poplar Mushroom

Agrocybe aegerita, commonly known as black poplar mushroom grows mostly on poplar and willow wood from spring to autumn. *A. aegerita* has unique flavour, high nutritive value and many medicinal values. However, yield potential of this mushroom is very low. It can be grown on a variety of substrates as mentioned for milky mushroom cultivation. Substrate has to be sterilized in the autoclaves.

The cultivation is undertaken as follows:

- Soak good quality wheat straw overnight for 16-18 h and later remove the straw and drain out excess water
- Mix 4-5% wheat or rice bran on wet weight basis
- Fill 2 kg substrate in each polypropylene bag and autoclave at 15 p.s.i. for 1-2h
- Spawn the substrate after cooling @ 4% aseptically and incubate at 25-30°C for spawn run for 20-25 days (Fig. 24.13)

**Fig. 24.13.** Spawn run bags**Fig. 24.14.** Developing primordia**Fig. 24.15.** Ready to harvest

- Cross cut or give slits and hang the bags for fruiting at 25°C with 85-90% RH
- Spray water daily, give 1 hr. diffused light and provide sufficient aeration

One bag (2 kg) yields about 500-600 fresh mushrooms. The average diameter of the pileus is 2 cm and average weight is about 3.0-2.5 g. The fruit bodies can be stored for 10-12 days in a refrigerator at 4°C. The fruit bodies are easily sun dried with dry matter of 8-12 per cent (Fig. 24.14 & 24s.15).

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1. Chang, S.T. and Hayes, W.A. 1978. The biology and cultivation of edible mushrooms. Academic Press, New York. 819 p.
2. Rai, R.D., Singh, S.K., Yadav, M.C. and Tewari, R.P. 2007. Mushroom biology and biotechnology. NRCM, Solan. 388 p.

Cultivation of Medicinal Mushroom- *Ganoderma lucidum*

V.P. Sharma and Satish Kumar

Mushrooms once considered mysterious forms, are quite well known not only for their edibility, but also for their medicinal properties. Some mushrooms are edible, others are non-edible and a few are poisonous. Some are hallucinogenic, others luciferous, some are beautiful and others unsightly. Of the 15000 known species, 2000-3000 are safe for human consumption and about 300 of them are medicinal mushrooms. Oriental countries like China, Japan and Korea have been pioneer in traditional knowledge about medicinal properties of mushrooms. Mushrooms are increasingly being evaluated in the west for their nutritional value, acceptability and pharmacological properties. There are approximately 700 species of higher Basidiomycetes (including edible species) that have been found to possess significant pharmacological activities.

Ayurveda is the oldest system of medicine in India that describes medicinal uses of several plants and very few mushrooms and wood rotting fungi. Some of the clinically used drugs such as aspirin, digitoxin, progesterone, cortisone, morphine, vincristine, vinblastine, taxol and several others are derived directly or indirectly from higher psslants. Clinically important and well recognized drugs of fungal origin are penicillin, griseofulvin, ergot alkaloids and cyclosporine.

With the renewed interest in traditional medicine, the nutraceutical aspects of the mushrooms are being valued more and the exploitation of this potential is limitless. Many pharmaceutical substances with potent and unique properties have been extracted from mushrooms. They produce unique anticancer medicines. These are actually dietary supplements. Mushrooms can be profitably grown on agricultural and horticultural wastes and hence ameliorate the environment. The mycorrhizal association helps in regeneration and establishment of seedlings at hostile sites. This aspect of mushroom benefit has been extensively researched during the previous four decade and gainfully employed in producing healthy seedlings quickly. Several genera and species of Basidiomycetes are known to be the sources of several metabolites and enzymes.

Medicinal mushrooms have an established history of use in traditional oriental medicine. Many traditionally used mushrooms belonging to genera, *Auricularia*, *Flammulina*, *Ganoderma*, *Grifola*, *Lentinula*, *Trametes* (*Coriolus*) and *Tremella* have been demonstrated to possess significant medicinal properties. *Ganoderma lucidum* is the most popular medicinal mushroom in China and has been used for a wide range of health benefits, from preventive measures and maintenance of health to regulation and

treatment of chronic as well as acute ailments. It is known for managing cancer in combination with conventional therapy and also for its anti-HIV effect.

Ganoderma lucidum and related species have the longest historical usage for medicinal properties dating back at least four thousand years. In Japan, it is called Reishi and in China and Korea, it is variously called Ling Chu and Ling Zhi (Mushroom of immortality). Traditionally it has been used widely in the treatment of hepatopathy, chronic hepatitis, nephritis, hypertension, arthritis, insomnia, bronchitis, asthma and gastric ulcer. Scientific studies have confirmed that the substances extracted from the mushrooms can reduce blood pressure, blood cholesterol and blood sugar level as well as inhibit platelet aggregation. *Ganoderma* species are famous tonic in Chinese medicines. They are widely distributed in India on tree trunks. For 4000 years *G. lucidum* has been used as a part of Chinese and Japanese medicine especially for the treatment of most of the human ailments. Extracts from fruit bodies and mycelia of *G. lucidum* occurring in South India were found to possess *in vitro* antioxidant activity

Reishi (*Ganoderma lucidum*) is pharmacologically as well as commercially the most important medicinal mushroom in the world with current global trade of about two billion dollars; trade in India has crossed Rs.100 crores annually through imports from Malaysia and China. Directorate of Mushroom Research has developed cultivation technology of Reishi, which is described here:

True-to-the-type genuine DNA-fingerprinted cultures are available in the DMR's Mushroom Gene Bank.

Reishi can be grown seasonally in the low cost growing rooms preferably polyhouses and also in the environmentally controlled cropping rooms. As the mushroom is intended to be used exclusively as medicine, it has to be grown organically; seasonal farmers have to put up polycover on the top and sides of the thatched huts and utmost hygienic conditions have to be maintained to prevent diseases and pests as no toxic chemical is to be used.

Reishi is grown on the sawdust of the broad-leaved trees (mango, poplar, coconut, sheesham). Sawdust, obtained from the sawmills, is amended with 20% wheat bran and is wetted to a level of 65% moisture. One per cent of calcium sulphate (gypsum) and One per cent of calcium carbonate (chalk powder) are added per kg sawdust to get a pH of 5.5. The mixed substrate (700 g dry wt; 2.1 kg wet wt) is filled in polypropylene bags the



Fig. 25.1. Developing fruit bodies of *Ganoderma*

mouth of which is then plugged with cotton after putting a plastic ring like wheat grain spawn pack of mushrooms in polybags.

The bags are then sterilized in autoclave at 22 p.s.i. for 2 hours. After cooling, the substrate is spawned with wheat grain or saw dust spawn @ 3% on the dry weight basis, as it is comparatively a slow growing fungus. Spawn-run (incubation) is done at 28-35°C in the closed rooms (high carbon dioxide) and darkness. After the complete spawn run (bags white all over), which takes about 25 days, polythene top is cut at the level of the substrate totally exposing the top side and proper conditions for fruiting or pinning (temp. 28°C, 1500 ppm CO₂, 800 lux light, 95% RH) are provided.

Once the pins have grown up enough to form the cap, indicated by the flattening of the whitish top of the pinhead, relative humidity is reduced to 80% and more fresh air is introduced to achieve around 1000 ppm CO₂ (Fig. 25.1). Once the cap is fully formed, indicated by yellowing of the cap margin (that is otherwise white), temperature is lowered to 25°C and RH is further reduced to 60% for cap thickening, reddening and maturation of the fruit-bodies.

Full maturity is indicated, when the cap is fully reddish brown and spores are shed on the top of the cap. Harvesting is done by the tight plucking, holding the root with one hand and pulling up with another; scissors and knives can also be used but no residual bud is left after harvesting. One cycle of the growing takes 10-15 days (Fig. 25.2). After harvesting the first flush, conditions for pinning are again switched on (i.e. 28°C, 95% RH, 1500 ppm CO₂, 800 lux light) for staring and completing the second flush. Depending upon the conditions, 2-3 flushes appear and a total 25% B.E. can be achieved. One crop cycle takes about four months.



Fig. 25.2. View of *Ganoderma* cropping room

Some workers consider *Ganoderma* a mild pathogen of broad leaved trees and many countries like Australia, New Zealand do not allow its direct entry. Hence it is important that due care is taken during cultivation to check that the spores do not get distributed freely and the substrate after cultivation is properly cooked out to prevent accumulation of inoculum in the fields or forest areas. The used substrate may be dried and burnt as fuel.

Harvested mushrooms, after washing with water, are dried at low temperature (<50°C) in the cabinet driers, preferably at 35°C in the dehumidifying cabinet drier. Freeze drying is, however, the best. *Reishi* mushroom has very high dry matter (45% i.e. 450 g dry from 1 kg fresh). Fig. 25.3 shows the flow chart of *Ganoderma* cultivation.

Marketing

Reishi is used as medicine and not as food because it is bitter, corky and hard. Its market value is basically as herbal medicine and food supplement (nutraceuticals). Manufacturers of herbal medicines and food supplements can process, pack and trade it in various forms like capsules, tablets, liquid extracts, etc.

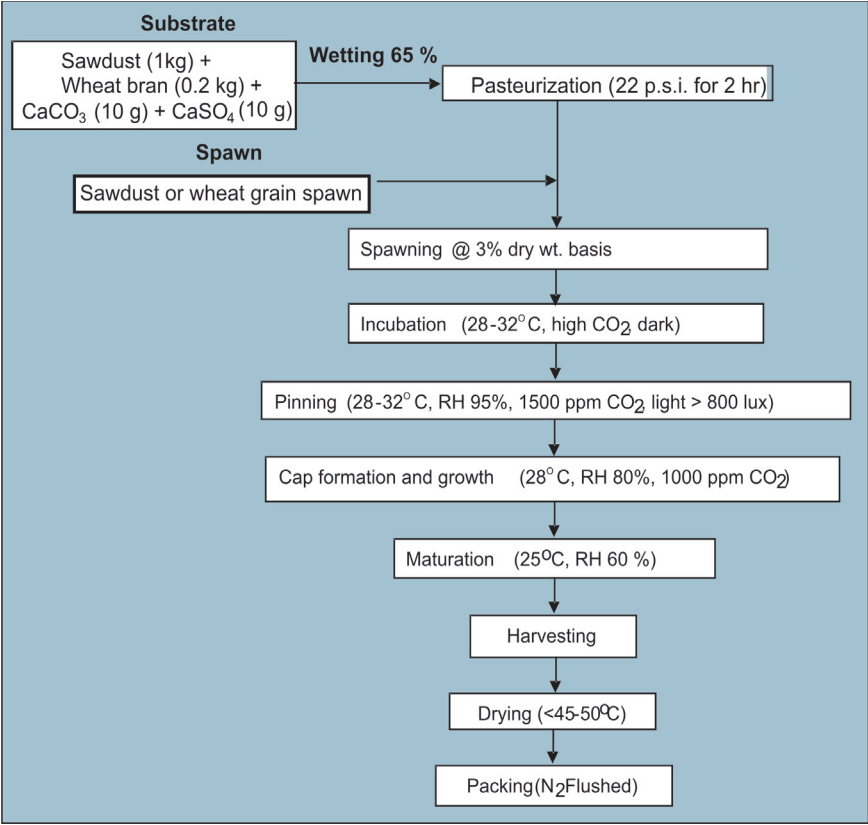


Fig. 25.3. Flow diagram of *Ganoderma* cultivation

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Round the Year Cultivation of Mushrooms

Mahantesh Shirur

Over the years farmers are following crop rotation and multiple cropping with astute understanding of their suitability to different climatic conditions. The practice of crop rotation and multiple cropping followed by farmers aims to make better use of the resource available with them. Several underlying principles in crop rotation are effective utilization of water and nutrients in the soil, sunlight, farm physical resources, etc.

The practice of taking crops alternatively to utilize the principles of crop rotation can also be implemented in mushroom cultivation. However, the cultivation of different mushrooms in rotation is not yet popular because of mushroom being a non-traditional crop. Majority of the farmers are cultivating mushrooms only during particular seasons. Farmers in the plains of North India cultivate white button mushrooms during winter only and stop the mushroom cultivation during summer and dismantle their temporary growing houses. It is also paradoxical to note that India is largely a tropical country and we mainly cultivate temperate mushroom. The tropical and sub tropical mushrooms like oyster (*Pleurotus* spp.), paddy straw (*Volvariella* sp.), milky (*Calocybe* sp.), reishi (*Ganoderma* sp.), wood ear (*Auricularia* spp.), etc. are not cultivated on a larger scale. To cultivate different types of mushrooms based on different seasons and prevailing climate one should know the requirement of specific temperature and humidity of different edible mushrooms. Since mushrooms contain about 90% water it is desirable to grow them

Table 26.1. Temperature requirements of some important mushrooms

S.N.	Scientific name of Mushroom	Common name	Temperature requirement	
			Spawn run	Cropping
1	<i>Agaricus bisporus</i>	White button mushroom	23-25	14-16
2	<i>Agaricus bitorquis</i>	Summer white button mushroom	28-30	25
3	<i>Auricularia</i> sp.	Black ear/ Wood ear mushroom	20-30	20-30
4	<i>Lentinula edodes</i>	Shiitake mushroom	22-27	15-20
5	<i>Pleurotus eryngii</i>	Kabul Dhingri	18-22	14-18
6	<i>P. flabellatus</i>	Dhingri (<i>flabellatus</i>)	25-30	22-26
7	<i>P. florida</i>	Dhingri (Florida)	25-30	18-22
8	<i>P. sajor caju</i>	Dhingri	25-32	22-26
9	<i>Volvariella volvacea</i>	Paddy straw/ Parali mushroom	32-34	28-32
10	<i>Calocybe indica</i>	Milky/ Dudhiya mushroom	25-30	30-35

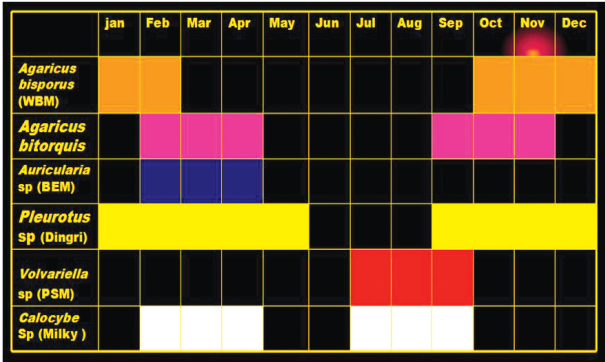


Fig. 26.1. Possibility of mushroom cultivation in plains

summer, the sub tropical or tropical mushroom species like high temperature tolerant white button mushroom, milky, oyster or paddy straw mushroom can be cultivated. It is also worth mentioning the fact that even the various *Pleurotus* spp. (Oyster mushroom) alone offers scope to cultivate it through out the year in many parts of India. A model for round the year cultivation of different mushrooms in north India is depicted below (Fig. 26.1).

From the above figure it is clear that white button mushroom can be cultivated during winter months of October to February. High temperature tolerant button mushroom can be cultivated from September to April except during peak winter. Black ear mushroom during February to April, dhingri from September to May, paddy straw mushroom from July to September and milky mushroom from February to April and July to September.

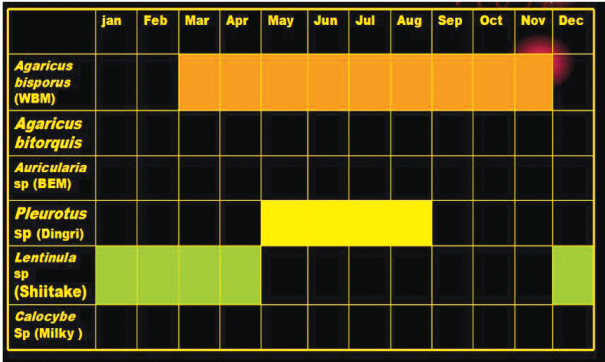


Fig. 26.3. Possibility of mushroom cultivation in high elevation/hilly areas

cultivated almost through out the year in medium elevated lands. Model for mushroom cultivation in these lands is depicted in Fig. 26.2.

under a relative humidity of above 85-90%. The temperature requirements of some important mushrooms are given in Table 26.1.

From Table 26.1, it is clear that mushrooms can also be cultivated round the year based on season like other field crops. In the plains of North India white button mushroom can be cultivated during winter. In

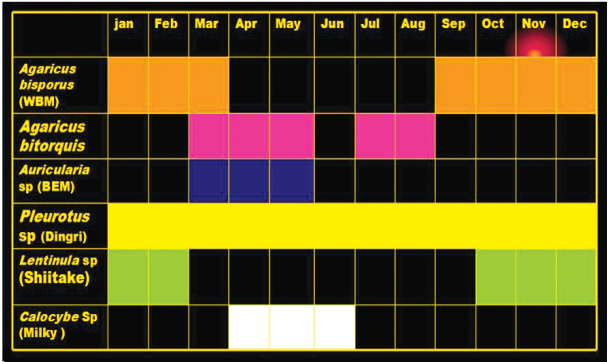


Fig. 26.2. Possibility of mushroom cultivation at medium elevated lands

mushroom from February to April and July to September.

In medium elevated lands, white button mushroom can be cultivated from September to March while the summer white button mushroom can be cultivated during July to August and also during March to May. Shiitake can be cultivated from October to February, while milky mushroom from April to June. The oyster mushroom can be

The high-elevated lands are suitable for white button and shiitake mushroom for most part of the year while the dhingri can be taken up during the summer season in these areas. Fig. 26.3 indicates the scope of mushrooms in the high-elevated lands.

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

A. Round The Year Economic Returns

It is quite understandable that the farmers would chose the enterprises that are rewarding throughout the year. Growing of any particular mushroom in a particular season and stopping the mushroom activity in rest of the season may not lure farmers. Hence, the continuous cultivation of different mushrooms depending on the season is certain to increase the economic returns of the mushrooms growers. Round the year cultivation assumes much significance especially for rural livelihood security.



Fig. 26.4. Different mushrooms for cultivation in rotation

B. Round The Year Employment Opportunities

It goes without saying that, continuous mushroom activity will definitely keep the hands busy throughout the year. It is germane to mention that the problem of unemployment and disguised unemployment can effectively addressed with the promotion of the round the year mushroom cultivation.

C. Round The Year Resource Utilization in The Farm

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

D. Continuous Nutrition to Family Members

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

E. Break in The Chain of Epidemic of Pests and Diseases

Growing single mushroom through out the year may cause repeated incidence of some pest and diseases in mushrooms. However, growing of different mushrooms in rotation would help in breaking the chain of epidemics of pests and diseases. This ensures the farmers against the loss they may incur with monocropping.

Hence, looking at the opportunities various mushrooms offers to cultivate them through out the year, farmers should practice round the year cultivation to reap maximum benefits.

Mushrooms- Value Added Products

G.C. Wakchaure

The focus of Indian mushroom industry is predominantly on trade of the fresh produce rather than the real value-addition. Almost entire domestic trade is in the fresh form while most of the export is in the preserved form (canned or steeped). Current era is characterized by greater awareness about quality and, above all, with the demand for the readymade or ready-to-make food products. As mushrooms contain high moisture and are delicate in texture, these cannot be stored for more than 24 hours at the ambient conditions of the tropics. This leads to weight loss, veil opening, browning, liquefaction and microbial spoilage of the product making it unsaleable. Effective processing techniques will not only prevent the post harvest losses but also result in greater remuneration to the growers as well as to the processors. Value can be added to the mushrooms at various levels, right from grading to the readymade snacks or the main-course items. Improved and attractive packaging is another important but totally neglected area in mushroom it is still unprinted plain polypouches in India whereas attractive and labelled over-wrapped trays are in vogue in the developed countries. Real value-added product in the Indian market is the mushroom soup powder. Technologies for production of some other products like mushroom based biscuits, nuggets, preserves, noodles, papad, candies and readymade mushroom curry in retort pouches have been developed but are yet to be popularized. Attractive packaging of the value-added products is yet another area, which may be called the secondary value-addition. While small growers may add value by grading and packaging, industry may go for the processed products for better returns as well as improvement in the demand, which shall have cascading positive effect on the production.

A. Mushroom Soup Powder

Soups are commonly used as appetizers but also as main course by the diet-conscious. Experiments were conducted at DMR, to prepare good quality ready-to-make mushroom soup powder using quality mushroom powder produced from the button and oyster mushroom, dried in the dehumidifying air cabinet-drier (Fig.23.1 and Fig.23.2).

Dried button mushroom slices or whole oyster mushrooms were finely ground in a pulveriser and passed through 0.5 mm sieve. Mushroom soup powder is prepared by mixing this powder with milk power, corn flour and other ingredients (Table 23.1). This has to be mixed with equal quantity of water for the preparation of good quality mushroom soup with characteristic aroma and taste. The mushroom soup powder can also be made by using the vacuum concentrated whey, a byproduct of dairy industry.



Fig. 23.1. Button mushroom soup powder

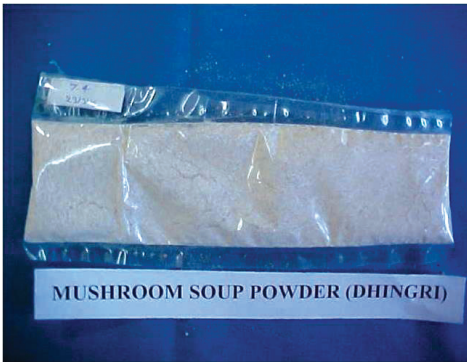


Fig. 23.2. Oyster mushroom soup powder

Table 23.1. Ingredients for mushroom soup powder

Ingredients	Parts (%)
Mushroom powder	16
Corn flour	5
Milk powder	50
Refined oil	4
Salt	10
Cumin powder	2
Black pepper	2
Sugar	10
Ajinomoto	2

B. Mushroom Biscuit

Delicious and crunchy mushroom biscuits were prepared by using the button/oyster mushroom powder and various ingredients viz., maida, sugar, ghee (bakery fats), mushroom powder, coconut powder, backing soda, ammonium bichromate and milk powder (Table 23.2). For making biscuits entire ingredients were finely ground using electric mixture and cleaned with the help of fine sieve separately. The ingredients viz., ghee and sugar were well mixed for 5-7 minutes using Dough kneeder to make the

mixture homogenous. These ingredients were first added to dough kneeder for dry mixing of 20-25 minutes. Thereafter, 500 ml water was added to kneeder to make dough cohesive and homogenous and mixing continued for next 10-15 minutes. After that dough was kept for 10 minutes under the wet cloths to make it cool. Thereafter, thin sheets of dough (1.25 cm thick) were made and cut into different shapes of biscuits using different steel dies. These raw cut biscuits were kept in the steel trays in systematic manner and then these

Table 23.2. Ingredients for mushroom biscuits

Ingredients	Parts (g)
Maida	50
Sugar powder	20
Bakery ghee	5
Oyster mushroom powder	5
Coconut powder	8.3
Baking powder	5
Ammonium bichromate	0.035
Milk powder	3.4
Water	8.3



Fig. 23.3. Mushroom Biscuits

trays were shifted to hot oven (180°C) for baking purpose. After 20 minutes, baking trays were removed from the hot oven and cooled, the biscuits were ready for packaging and or for serving (Fig.23.3). The ingredient like sugar gives desired sweetness, ghee gives smoothness and ammonium bichromate gives the crunchiness to the biscuits. The various ingredients required for preparation of delicious and crunchy mushroom biscuits are listed in Table 23.2.

C. Mushroom Nuggets

'Nuggets' are generally prepared out of 'pulse' powder namely, black gram powder, soybean powder, urad dhal powder, etc., and used in the preparation of vegetable curry in North India. For preparation of mushroom nuggets, mushroom powder (dried and coarsely ground mushrooms) is mixed with the 'Urad' dhal powder and a paste is prepared by adding required quantity of water. Ingredients and spices are added to the prepared paste and round balls of 2-4



Fig. 23.4. Mushroom Nuggets

Table 23.3. Ingredients for mushroom nuggets

Ingredients	Parts (%)
Mushroom powder	10
Urad dhal powder	80
Salt	2
Red chilly powder	1
Sodium bicarbonate	0.01
Water	7

cm diameters are made out of the paste. The prepared balls are spread over a steel tray and dried by sun-drying method and thus the mushroom nuggets are prepared (Fig. 23.4).

The ingredients used for the preparation of nuggets at DMR, Solon are listed in Table 23.3. These nuggets can be relished in two ways: straightaway this can be deep-fried and used as snacks or can be used in

vegetable curry preparation along with suitable vegetables or alone.

D. Mushroom Ketch-Up

Ketch-up is made by concentrating the juice/ pulp of the fruits/ vegetables without seeds and pieces of skin. It does not flow freely and is highly viscous in nature. They also contain more of sugar and less of acid.

Freshly harvested button mushrooms are washed, sliced and cooked in 50% of water for 20 minutes. Mushroom paste is prepared using a mixer grinder. Arrarote (0.2%), acetic acid (1.5%) and other ingredients (Table 23.4) are mixed in the paste and cooked to bring its TSS to 35°Brix. Then the ketch-up is filled in the sterilized bottles or jars (Fig. 23.5).

E. Mushroom Candy

A fruit or vegetable impregnated and coated with sugar, subsequently taken out and dried is called a candied fruit or vegetable. The total sugar content of the impregnated produce is kept at about 75% to prevent fermentation.

Table 23.4. Ingredients for mushroom ketch-up

Ingredients	Parts (%)
Salt	10
Sugar	25
Acetic acid	1.5
Sodium benzoate	0.065
Onion	10
Garlic	0.5
Ginger	3
Cumin	1
Black pepper	0.1
Red chilly powder	1
Ajinomoto	0.2
Arrarote	0.2



Fig. 23.5. Mushroom ketch-up

Fresh mushrooms after harvesting are washed and halved longitudinally into two pieces. Halves are blanched for 5 min in 0.05% of KMS solution. After draining for half an hour these are treated with sugar. Sugar treatment is given at the rate of 1.5 kg sugar per kg of blanched mushrooms. Initially sugar has to be divided into three equal parts. On the first day, blanched mushrooms are covered with one part of sugar and kept for 24 h. Next day, the same mushrooms are covered with second part of sugar and are kept over night and on the third day mushrooms are removed from the sugar syrup. The sugar syrup is boiled with 3rd part of sugar and 0.1% of citric acid to bring its concentration up to 70°Brix. Mushrooms are mixed with this syrup and again the contents are boiled for 5 min to bring its concentration upto 72°Brix. After cooling, the mushrooms are removed from the syrup and drained for half an hour. The drained mushrooms are placed on the sorting tables to separate, to reject defective and unwanted pieces. Finally mushroom pieces are subjected to drying in a cabinet dryer at 60°C for about 10 h. As soon as these become crispy, all mushroom candies are taken out, packed in polypropylene bags and sealed. The mushroom candy can be stored up to 8 months with excellent acceptability and good chewable taste.

F. Mushroom Preserve (Murabba)

Murabba (preserve) is made from matured fruits or vegetables, by cooking it whole or in the form of pieces in heavy sugar syrup, till it becomes tender and transparent. In murabba preparation, around 45 kg of fruit or vegetable is used for every 55 kg of sugar and cooking is continued till a concentration of at least 68% of soluble solid is reached.

Fresh button mushrooms are graded, washed, pricked and blanched in 0.05% KMS solution for 10 min. It is treated with 40% of its weight of sugar daily for 3 days. Then,



Fig. 23.6. Mushroom Murabba

mushrooms are taken out from the syrup and 0.1% citric acid and remaining 40% of sugar is mixed in the syrup. After bringing its concentration to 65°Brix, mushrooms are added in the syrup and good quality murabba is prepared (Fig.23.6).

G. Pickle

According to a formulation developed and standardized at the DMR and its coordinating centers, mushrooms are washed, sliced and blanched for 5 min in 0.05% KMS solution. The blanched mushrooms are washed in cold water for 2-3 times and the excess water is drained off. Then the mushrooms are subjected to salt curing process, in which 10% sodium chloride is added and kept over night. The excess water oozed-out of mushrooms is removed on the next day and spices & preservatives are mixed to the desired taste and quality of mushroom pickle. The various spices namely turmeric powder, black mustard seed powder (*rai*), red chilly powder, cumin seed powder, fenugreek seed powder, aniseed powder (*suwa/ shopa*), black pepper, carom seed (*ajwain*), nigella seed (*kalonji*), fennel seed powder (*saunf*) and mustard oil are added to prepare tasty pickle (Fig. 23.7). Acetic acid and sodium benzoate within the permitted limits are used as preservatives.



Fig. 23.7. Mushroom pickle

Table 23.5. Ingredients for mushroom pickle

Ingredients	g/kg
Black mustard seed powder (<i>rai</i>)	35
Turmeric powder	20
Red chilly powder	10
Cumin seed powder	1.5
Fennel seed powder (<i>saunf</i>)	1.5
Carom seed (<i>ajwain</i>)	10
Nigella seed (<i>kalonji</i>)	10
Oil	200 ml
Salt	90

This pickle can be stored upto one year in the lug bottles. The various ingredients required for preparing mushroom pickle using 1 kg blanched mushroom are listed in Table 23.5.

Good quality pickle can also be prepared from oyster mushroom. Cleaned mushrooms are blanched in hot water (80°C for 5 min), rapidly cooled and added to 60% brine to obtain mushroom to brine ratio of 7:3 by volume. The mixture is maintained at 15-20°C for 15 days for fermentation and

further kept at 0-4°C to obtain a pH of 3.9. Sugar is added to the preparation @ 3.3% by weight to the brine and final salt concentration reached to 6.6% by weight. Studied on the suitability of *Pleurotus* spp. for pickle preservation reported that the product could be stored for a minimum period of 6 months at the ambient temperature (22-34°C) without any off flavour. The pickle prepared from paddy straw mushroom also has good keeping quality.

H. Mushroom Chips

The freshly harvested button mushrooms are washed, sliced (2 mm) and blanched in 2% brine solution. The mushrooms are dipped overnight in a solution of 0.1% of citric acid + 1.5% of NaCl + 0.3% of red chilly powder. After draining off the solution, the mushrooms are subjected to drying in a cabinet dryer at 60°C for 8 h. Then it is fried in the refined oil and good quality chips are prepared. Garam masala and other spices can be spread over the chips to enhance the taste. After mixing the spices, the chips are packed in polypropylene packets and sealed after labelling.

I. Ready-to-Serve Mushroom Curry

In view of the growing market for the readymade / ready-to-eat food items and keeping in mind the popularity of the Indian 'Curry' world over, a technology was developed at DMR, Solan for production of "Mushroom curry in flexible-retortable pouches". The retort pouch of 105 µ thick with polypropylene outer layer (80 µ), aluminium middle layer (12.5 µ) and polyester inner layer (12.5 µ) available in the market was used for packing mushroom curry.

The ingredients used to prepare the curry are presented in the Table 23.6. In a frying pan, oil was added and heated. Sliced onions and green chillies were added to the oil and fried till golden brown. Garlic and ginger were ground into a paste, added and lightly fried till oil reappeared. Curry powder, salt and red chilly powder were added and lightly fried. About one litre of water was added to the spices mixture and boiled till thick consistency was obtained. Hundred grams of cut mushrooms were filled in the retort pouch and 50 g of curry was added into the pouch. Then it was heat processed for FO value of 10 (final 13.2) at 121°C for 43 min and cooled rapidly.

The ready-to-serve mushroom curry (Fig. 23.8) prepared was delicious with good taste, attractive colour and a storage life of one year. Mushroom curry was also successfully prepared from dried oyster mushroom and button mushroom after its rehydration

Table 23.6. Ingredients for mushroom curry

Ingredients	Quantity
Onion	510 g
Garlic	250 g
Ginger	200 g
Red Chilly powder	150 g
Curry powder	100 g
Green chilly	250 g
Oil	400 ml
Salt	160 g
Water	1000 ml



Fig. 23.8. Ready-to-serve mushroom curry in retort pouch pack (DMR-Process)

Despite of above described value added products mushrooms are used for making papad, chutney powder, jam, cake, mater, dokhla, sev, idli, macroni and nodles, etc.

Further Reading

1. R.D. Rai and T. Arumuganathan (2008). Post Harvest Technology of Mushrooms, Technical Bulletin-2008, NRCM, ICAR, Chambaghat, Solan-1731213, (H.P.).

Art of Mushroom Cooking

Shailja Verma

From ancient times our ancestors had been collecting and consuming wild mushrooms. Even today in few regions of our country people collect wild mushrooms. During rainy season different types of mushrooms appear in fields and forests and people use indigenous knowledge to identify the edible mushrooms. Many mushrooms appearing in the forests are poisonous and many people fall sick due to consumption of such mushrooms. Fortunately many of the edible mushrooms have now been cultivated world over and mushrooms like button, oyster, shiitake, paddy straw are common household name.

Today mushroom recipes have become a delicacy in the vegetarian menu in restaurants or meals served during marriages and other celebrations. Mushroom has become a very good substitute for cheese on the table these days. It is an inexpensive and easy way to meet our protein needs. From taste point of view, mushroom add to variety, flavour and texture to our daily food items. Every mushroom has a typical aroma and texture. Mushroom stands well on its own for taste and flavour and works wonderfully with other dishes. They blend well with other vegetables and products. Any seasoning go well with mushrooms.

Mushrooms are more common in menu of parties and restaurants then in Indian household kitchens. A common man or a housewife is still hesitant to cook mushrooms due to less exposure about its cooking methods. Creative cooking with mushroom has a lot of potential in our kitchens. We need to spread this among the masses that mushrooms are not only tasty but have lot of nutritive and medicinal values. In few regions of the country, it is still associated with non-vegetarian food. To overcome with this myth we really need to popularize mushroom recipes and its cooking methods.

Mushrooms can be used in different forms in cooking. Whole of mushroom is used and there is no need to peel the mushroom - hence there is no wastage like other vegetables. Only the stem end needs to be cut to remove debris if any. Mushroom needs to be washed thoroughly before cooking. They can be used as whole in few of the recipes like mushroom munchurian, cut into halves or quarters, can be sliced into thick or thin slices and can be used in soups and salads. Mushrooms can be coarsely or finally chopped for sandwiches, pakodas and koftas. In few of the recipes caps of the big sized mushrooms can be used such as stuffed mushrooms in which we can use different kinds of fillings to stuff mushrooms and bake them. Oyster and shiitake mushrooms can be minced in food processor for use in koftas or pakodas. Do not wash the mushrooms if you need to store them for one or two days, preferably keep them in a paper bag and store in a refrigerator.

A. How to Use Mushrooms in Cooking

Pressure cooking : Pressure cooking is the most common Indian method of cooking. For cooking mushroom in pressure cooker only one pressure is enough as mushroom has the quality not to dissolve with liquids or gravy but retain same shape. Over cooking can make mushroom more chewy to eat.

Raw : Few mushrooms like button and oyster are delicious on their own when taken raw with green salads or sandwiches. Wash mushrooms under running water for 2-3 minutes so that the soil or any other chemical residue is thoroughly washed away. Wipe mushrooms with dry cloth or paper towel after washing so that the water is not retained on the surface of mushroom as they turn brown early if the water content is more on surface. Raw mushrooms can be sliced, diced, cut into halves or the whole pieces of small mushrooms can be used as raw.

Toss or soute : Mushrooms taste excellent after soute'ing or tossing. First wash and dry mushrooms and cut into halves or quarters. Small button mushrooms can be used as whole for this type of cooking. Melt one table spoon of butter in a pan and add mushrooms to it. Cook for four to five minutes on high flame for tossing and keep stirring. Cook for five to six minutes on medium flame for soute'ing until golden brown or released water is thoroughly evaporated. This method is mostly used for preparing different mushroom salads or fillings.

Microwave : Microwaving is a good idea for oil free cooking. For microwaving, the mushrooms can be cut into slices, halves or quarters or whole, depends how we are going to eat them or with what we are going to season them. Two-three minutes are enough to cook mushrooms in microwave. Mushroom releases a lot of water during microwaving.

Grill : Before grilling, wash and dry the mushrooms. Whole mushrooms of smaller size are good for grilling or mushrooms of bigger size can be cut into halves. Brush the mushrooms with oil to avoid drying of outer surface and sprinkle little salt and pepper for seasoning. Cooking by this method also leaves a lot of water. Four-five minutes of grilling is enough to cook medium sized mushrooms. Capsicum and squash can be grilled with mushrooms.

Boiling / Blanching : In a deep pan boil water and add little salt. Add mushrooms and boil for five minutes. Sieve mushrooms and spread on a dry cloth or paper towel. Boiled mushrooms are mainly used in pickles or sandwich fillings. Few mushrooms like *Calocybe* and *Shiitake* have strong flavour, which is often disliked. To reduce the pungency we can use the boiled mushrooms for cooking main dishes.

B. Types of Mushrooms Available in India for Cooking

Button mushroom: This is the most common and popular mushroom used in Indian cooking as it has excellent culinary qualities. In India, mostly the fresh mushrooms are being used for cooking but canned mushrooms are also available in the market. Button mushroom is excellent for use as raw as well as in cooked form. Shelf life of this mushroom is not very good. However, we can store them for one or two days by keeping them in damp cloth or paper towel in the refrigerator. This mushroom can be used as whole or cut into pieces for cooking.

Oyster mushroom: Oyster mushroom is also gaining popularity in Indian cooking these days. Flavour and velvety texture of this mushroom is liked by most of the people. Though this mushroom can also be eaten raw as salad but it tastes better after cooking by any method. Wash oyster mushroom in hot water and drain extra water properly by squeezing. After washing it can be striped into small pieces with knife or hand tearing in the direction of gills. Oyster can also be minced in the food processor for making few recipes like koftas or munchurian.

Paddy straw mushroom: This is one of the tastiest mushroom and goes very well with Indian cooking. Wash this mushroom under running water for 2 minutes as this is a very delicate mushroom. Cut into small pieces and use it in the dishes of main course. This mushroom may not be consumed raw.

Milky Mushroom: This mushroom has a very strong aroma and meaty texture. To remove the pungency of this mushroom boil it for 10 minutes in salty water. After boiling, thoroughly drain the water by squeezing. This mushroom takes more cooking time as it is little harder to cook. This mushroom may not be consumed raw.

Shiitake mushroom: This mushroom is the second most popular mushroom in the world having medicinal properties. Due to its strong flavour and leathery texture this mushroom is not very popular in India for eating. This mushroom can also be cooked by any method. Boil this mushroom for 2-3 minutes and drain water. After this it can be striped into small pieces. Shiitake mushroom tastes very good in soups. This can also be blended with other vegetable such as capsicum, peas and carrots. This mushroom may not be consumed raw.

C. Recieps

Some of the recipes of cultivated mushrooms are given below :

1. MUSHROOM TOMATO SOUP

Serves - 4

Ingredients:

Fresh mushrooms (button or oyster)	-	200 g (chopped)
Tomatoes	-	4 (chopped)
Onion	-	1 medium(chopped)
Garlic	-	3 cloves
Corn flour	-	3 table spoon
Cream	-	2 table spoon
Butter	-	50 g
Salt and pepper	-	to taste



Fig. 28.1. Mushroom tomato soup

Method:

Boil tomatoes, onion and garlic in water for 10 minutes. Grind the above material and sieve it. Melt butter in a pan and saute chopped mushrooms for 10 minutes until they become golden brown. Add sieved material to it and sprinkle one table spoon of corn flour on to mushroom soup to thicken adding salt and pepper to it. Boil for 7-8 minutes and serve hot with cream (Fig. 28.1).

2. MUSHROOM ONION SOUP

Serves - 4

Ingredients:

Fresh mushrooms	- 200 g chopped/crushed (button or oyster)
Onion	- 4 medium sized (thinly sliced)
Garlic	- 1 clove, crushed
Corn Flour	- 1 table spoon
Water	- 4 cups
Sugar	- ½ table spoon
Bread	- 3 slices
Cheese	- 50 g grated
Butter	- 50 g

Method

Melt the butter in a heavy based sauce pan. When hot add onion and crushed garlic to it. Fry gently for about 10 minutes until onion turns soft and golden brown. Add mushrooms to it and fry for 10 minutes until mushrooms release its water. Remove the pan from the heat. Add Corn flour in a cup of water and stir well. Return pan to the heat, pour the mixture stirring all the time for 2-3 minutes until the mixture is smooth. Add sugar, salt and pepper to taste. When it starts boiling, cover with the lid and simmer gently for 20 minutes, stirring occasionally.

Cut bread into 1 cm thick pieces and deep fry until golden brown. Pour soup into bowls, sprinkle bread crumbs and grated cheese on the top of the soup and serve hot.

3. MUSHROOM CABBAGE SALAD

Serves - 4

Ingredients:

Fresh mushrooms	- 150 g (button cut into two pieces; (button or oyster) oyster cut into small pieces)
Capsicum	- 50 g (cut into square pieces)
Cabbage	- 50 g (separated into petals)
Onion	- 1 medium (quartered and separated into petals)
Spring onion	- 50 g (chopped)
Cooking oil	- 50 g
Soya sauce	- 1 table spoon
Corn flour mixed with a little water	- 2 table spoon
Green chilly sauce	- 1 table spoon
Tomato sauce	- 2 table spoon
Salt/pepper	- to the taste



Fig. 28.2. Mushroom cabbage salad

Method

Heat oil in a frying pan. Fry mushrooms until water evaporates. Add petalled onion and cook quickly tossing all the time for two to three minutes until softened slightly but are still crisp. Add cabbage, capsicum, spring onion and toss together on high flame. When cabbage starts wilting, mix all the sauces and ingredients together and cook stirring until smooth and sauce has heated thorough. Serve hot with any type of meal (Fig. 28.2).

4. MUSHROOM TOMATO SAUCE**Ingredients:**

Fresh mushrooms	-	250 g finely chopped (button or oyster)
Tomatoes	-	250 g fresh
Onion	-	1
Garlic	-	1 clove
Ginger	-	50 g
Cooking oil	-	25 g
Salt and pepper	-	to taste

Method:

Chop the tomatoes and boil it in 50 g of water to make thick paste. Add garlic and ginger to it. Give two whistles in cooker and then sieve the material. Now tomato paste is ready.

Heat oil in a heavy pan then gently fry chopped onions until light brown. Add chopped mushrooms and cook for 5 minutes. Add tomato paste, little water, salt and pepper to taste and 1/2 table spoon of sugar and boil for 10 minutes until it becomes in the form of creamy consistency. Serve hot with vegetables or on toast as breakfast.

5. MUSHROOM KOFTA

Serves - 4

Ingredients:

Fresh mushrooms	-	250 g blanched and squeezed - (all types of mushrooms)
Gram flour (besan)	-	100 g
Onion	-	2 (grated to prepare gravy)
Garlic	-	2 cloves (crushed)
Ginger	-	30 g (grated)
Cinnamon	-	½ table spoon
Turmeric powder	-	1 table spoon
Coriander powder	-	1 table spoon
Cumin seeds	-	1 table spoon
Tomato puree	-	1 cup
Cooking oil	-	100 g
Kasoori methi,	-	to taste
garam masala,		
red chillies		
powder and salt		

Method

Grind mushrooms in a mixer, add gram flour, salt, chilly powder, garam masala and little water to make a thick paste. Make round koftas and deep fry the same on the medium heat. When golden brown, take out of the pan and drain extra oil.

Heat oil in a pan, fry cumin seeds in it. Add onion, garlic and ginger paste and fry on low heat till golden brown. Add tomato puree and cook till the paste thickens and starts leaving oil. Add other ingredients, pour two glasses of water, stir well and let it boil for 6-7 minutes on high flame. Add koftas and boil 4-5 minutes on low heat. Garnish with coriander leaves. Serve hot with rice or chapati.

6. KADAI MUSHROOM

Serves - 4

Ingredients:

Fresh mushrooms	- 500 g (cut into small pieces)
(button or oyster or milky)	
Onion	- 2 (paste)
Ginger	- 2 tsp
Garlic	- 2 tsp
Capsicum	- 2 (sliced and seed removed)
Peas	- ½ cup boiled
Whole red chillies	- 4
Chilly powder (degi)	- 2 tbl
Green chillies	- 2 chopped
Tomato puree	- 1 cup
Cumin seeds,	- as per taste
kasoori methi,	
Garam masala, salt	



Fig. 28.3. Kadai mushroom

Method

Heat cooking oil in a kadai, put cumin seeds, when they get browned put mushrooms in it and saute in high flame for 2 minutes. Add peas, capsicum, salt and garam masala. Cook for 2 minutes and remove from heat.

Now heat oil in a deep pan, put whole red chillies and fry until deep brown. Add onion, ginger and garlic paste and fry till golden brown. Add green chillies and puree to it and keep stirring over low heat till the oil separates out. Add salt and other spices to it. Pour the gravy over the cooked mushrooms in kadai and cook for 5 minutes stirring thoroughly. Sprinkle kasoori methi and coriander leaves. Serve hot with tandoori roti (Fig. 28.3).

7. MUSHROOM PAKODA

Serves - 4

Ingredients:

- Fresh mushrooms - 500 g (Button or oyster or milky)
- Onion - 1 big (chopped)
- Ginger - 2 tbl (chopped)
- Garam masala - 10 g
- Anar dana powder - 1 tbl.
- Gram flour (besan) - 150 g
- Cooking oil - 100 g
- Salt, green chillies - to taste (chopped)

Method

Place washed mushrooms in 1 litre of water and add salt (half spoon). Boil for 5 minutes and drain the mushrooms and let it dry for 10 minutes by spreading on a dry cloth. Cut mushrooms into pieces and squeeze properly so that no water remains in mushrooms. Add all ingredients and salt as per your taste in gram flour. Pour little water to make thick paste. Add mushrooms to it and mix well. Deep fry in hot oil on medium heat. Serve hot with pudina chutney.

8. MUSHROOM CURRY

Serves - 4

Ingredients:

- Fresh mushrooms - 300 g (blanched and cut into pieces) (button or oyster or paddy)
- Onion - 2 (medium and chopped)
- Garlic - 3 cloves (crushed)
- Tomato puree - 1 cup
- Corn flour - 15 g (mixed in half cup water)
- Curry powder - 2 tbs
- Red chillies - 3 (whole)
- Salt and spices - To taste
- Mustard oil - 3 tbs
- Coriander leaves - 50 g (chopped)
- Cumin seed - ½ tbs
- Coriander powder - 1 tbs
- Garam Masala - 2 tbs
- Turmeric powder - ½ tbs



Fig. 28.4. Mushroom curry

Method

Heat oil in a deep heavy based pan, put red chillies and fry until deep brown then add chopped onion, garlic and ginger. Cook for 3-4 minutes. Pour puree and fry until contents start leaving oil. Pour in curry powder and corn flour and cook for a minute adding salt, spices and desired water, bring to boil for 5 minutes. Add mushrooms and cook for another 5-6 minutes. Garnish with coriander leaves. Serve with steamed rice (Fig. 28.4).

9. MUSHROOMS DAM BIRYANI

Serves - 4

Ingredients:

Fresh mushrooms	-	500 g (medium size) (button or oyster or milky)
Basmati rice	-	2 cup
Onion	-	2 medium (chopped into lengths)
Ginger	-	2" pod (washed, scrapped and cut into small pieces)
Garlic	-	5-6 cloves (crushed)
Red chillies	-	2 tbs
Coriander leaves	-	50 g (chopped)
Mint leaves	-	20 g (chopped)
Tomato puree	-	1 cup
Milk	-	½ cup (double toned)
Curd	-	½ cup
Cassia (Tej patta)	-	2
Cloves	-	4
Garam Masala	-	2 tbs
Green cardamom	-	2
Black cardamom	-	2
Mace (Javitri)	-	1 piece
Cumin seeds	-	1 tbs
Turmeric powder	-	½ spoon
Saffron	-	1 pinch
Salt	-	to taste



Fig. 28.5. Mushroom dam biryani

Method

Wash mushrooms and cut into four pieces. Soak rice for ½ hour. Grind ginger and garlic in a mixer. Beat curd thoroughly, soak saffron in milk.

Take a heavy based pan and boil 4 cups of water, add cassia, clove, cardamom, cinnamon, mace and one table spoon of salt and boil till the spices start leaving their colour and flavour. Add soaked rice, keep stirring and cook till the ¾ part of rice is cooked. Drain extra water and keep aside.

Heat oil in a non stick pan and add onion, fry till golden brown. Pour ginger, garlic and other spices and cook till it thickens to hard consistency. Add beaten curd, garam masala, coriander leaves, mint leaves and salt, cook for 2 minutes then add mushrooms and cook on high flame for 2-3 minutes till the mushrooms stop leaving water.

Take an oven-proof dish, put boiled rice and mushroom masala into layers one by one adding coriander leaves and sprinkle saffron milk after every layer. Top layer should be of rice and sprinkle coriander leaves and saffron milk. Seal the dish with foil and put it in the pre-heated oven for 10 minutes at 70°C temperature. Serve hot with pudina chutney and curd (Fig. 28.5).

Further readings

1. Verma, Shailja and Rai, R.D. 2004. Mushroom recipes. Technical Bulletin, DMR, Solan.

Unit Coverisons

Unit of Length

From \ To	inch	ft	m	cm	m m
m m	0.0394	0.0033	0.001	0.1	1
cm	0.394	0.0328	0.01	1	10
m	39.37	3.281	1	100	1000
ft	12	1	0.3048	30.48	304.8
inch	1	0.0833	0.0254	2.54	25.4

Unit of Volume

From \ To	cm³	inch³	l(liter)	ft³	gal
gal	3785	231	3.785	0.1337	1
ft³	28320	1728	28.32	1	7.48
l(liter)	1000	61.03	1	0.0353	0.264
inch³	16.387	1	0.0164	0.00057	0.0043
cm³	1	0.061	0.001	3.53×10 ⁻⁵	0.00026

Unit of Pressure

From \ To	mmHg	ft H ₂ O	psi	in H ₂ O	bar	kPa	in Hg
in Hg	25.4001	1.132	0.491	13.6	0.03390	3.38	1
kPa	7.5006	0.3345	0.145	4.01	0.01	1	0.295
bar	750.064	33.45	14.5	401	1	100	29.5
in H ₂ O	1.8683	0.0833	0.0361	1	0.00249	0.249	0.073
psi	51.7151	2.306	1	27.7	0.0689	6.89	2.03
ft H ₂ O	22.4199	1	0.43	12	0.029	2.98	0.882
mmHg	1	0.0446	0.0193	0.5352	0.0013	0.1333	0.0393

Unit of Flow rate

From \ To	CMH(m³/hr)	CFM(ft³/min)	CFH(ft³/hr)	GPM(gal/min)
CMH(m³/hr)	1	0.589	35.32	4.403
CFM(ft³/min)	1.7	1	60	7.48
CFH(ft³/hr)	0.02832	0.01667	1	0.1247
GPM(gal/min)	0.2271	0.1337	8.021	1

Fahrenheit to Centigrade

°F	°C	°F	°C	°F	°C	°F	°C
1.0	-17.2	41.0	5.0	81.0	27.2	121.0	49.4
2.0	-16.7	42.0	5.6	82.0	27.8	122.0	50.0
3.0	-16.1	43.0	6.1	83.0	28.3	123.0	50.6
4.0	-15.6	44.0	6.7	84.0	28.9	124.0	51.1
5.0	-15.0	45.0	7.2	85.0	29.4	125.0	51.7
6.0	-14.4	46.0	7.8	86.0	30.0	126.0	52.2
7.0	-13.9	47.0	8.3	87.0	30.6	127.0	52.8
8.0	-13.3	48.0	8.9	88.0	31.1	128.0	53.3
9.0	-12.8	49.0	9.4	89.0	31.7	129.0	53.9
10.0	-12.2	50.0	10.0	90.0	32.2	130.0	54.4
11.0	-11.7	51.0	10.6	91.0	32.8	131.0	55.0
12.0	-11.1	52.0	11.1	92.0	33.3	132.0	55.6
13.0	-10.6	53.0	11.7	93.0	33.9	133.0	56.1
14.0	-10.0	54.0	12.2	94.0	34.4	134.0	56.7
15.0	-9.4	55.0	12.8	95.0	35.0	135.0	57.2
16.0	-8.9	56.0	13.3	96.0	35.6	136.0	57.8
17.0	-8.3	57.0	13.9	97.0	36.1	137.0	58.3
18.0	-7.8	58.0	14.4	98.0	36.7	138.0	58.9
19.0	-7.2	59.0	15.0	99.0	37.2	139.0	59.4
20.0	-6.7	60.0	15.6	100.0	37.8	140.0	60.0
21.0	-6.1	61.0	16.1	101.0	38.3	141.0	60.6
22.0	-5.6	62.0	16.7	102.0	38.9	142.0	61.1
23.0	-5.0	63.0	17.2	103.0	39.4	143.0	61.7
24.0	-4.4	64.0	17.8	104.0	40.0	144.0	62.2
25.0	-3.9	65.0	18.3	105.0	40.6	145.0	62.8
26.0	-3.3	66.0	18.9	106.0	41.1	146.0	63.3
27.0	-2.8	67.0	19.4	107.0	41.7	147.0	63.9
28.0	-2.2	68.0	20.0	108.0	42.2	148.0	64.4
29.0	-1.7	69.0	20.6	109.0	42.8	149.0	65.0
30.0	-1.1	70.0	21.1	110.0	43.3	150.0	65.6
31.0	-0.6	71.0	21.7	111.0	43.9	151.0	66.1
32.0	0.0	72.0	22.2	112.0	44.4	152.0	66.7
33.0	0.6	73.0	22.8	113.0	45.0	153.0	67.2
34.0	1.1	74.0	23.3	114.0	45.6	154.0	67.8
35.0	1.7	75.0	23.9	115.0	46.1	155.0	68.3
36.0	2.2	76.0	24.4	116.0	46.7	156.0	68.9
37.0	2.8	77.0	25.0	117.0	47.2	157.0	69.4
38.0	3.3	78.0	25.6	118.0	47.8	158.0	70.0
39.0	3.9	79.0	26.1	119.0	48.3	159.0	70.6
40.0	4.4	80.0	26.7	120.0	48.9	160.0	71.1

Centigrade to Fahrenheit

°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.
0	32.0	20	68.0	40	104.0	60	140.0
1	33.8	21	69.8	41	105.8	61	141.8
2	35.6	22	71.6	42	107.6	62	143.6
3	37.4	23	73.4	43	109.4	63	145.4
4	39.2	24	75.2	44	111.2	64	147.2
5	41.0	25	77.0	45	113.0	65	149.0
6	42.8	26	78.8	46	114.8	66	150.8
7	44.6	27	80.6	47	116.6	67	152.6
8	46.4	28	82.4	48	118.4	68	154.4
9	48.2	29	84.2	49	120.2	69	156.2
10	50.0	30	86.0	50	122.0	70	158.0
11	51.8	31	87.8	51	123.8	71	159.8
12	53.6	32	89.6	52	125.6	72	161.6
13	55.4	33	91.4	53	127.4	73	163.4
14	57.2	34	93.2	54	129.2	74	165.2
15	59.0	35	95.0	55	131.0	75	167.0
16	60.8	36	96.8	56	132.8	76	168.8
17	62.6	37	98.6	57	134.6	77	170.6
18	64.4	38	100.4	58	136.4	78	172.4
19	66.2	39	102.2	59	138.2	79	174.2

Conversion Formulae

°C = (5/9)* (°F-32)

°F = (9/5)* (°C+32)

Relative Humidity Calculations Using Dry and Wet Bulb Thermometer

Temperature in Celsius

Difference Between Dry Bulb and Wet Bulb Temperatures (°C)	Relative Humidity - RH (%)							
	Dry Bulb Temperature - (°C)							
	15	18	20	22	25	27	30	33
1	90	91	91	92	92	92	93	93
2	80	82	83	84	85	85	86	87
3	71	73	75	76	77	78	79	80
4	62	65	67	68	70	71	73	74
5	53	57	59	61	64	65	67	69
6	44	49	52	54	57	59	61	63
7	36	42	45	47	51	53	55	58
8	28	34	38	41	45	47	50	53
9	21	27	31	34	39	41	45	48
10	13	20	25	28	33	36	40	43

Temperature in Fahrenheit

Difference Between Dry Bulb and Wet Bulb Temperatures (°F)	Relative Humidity - RH (%)							
	Dry Bulb Temperature - (°F)							
	60	64	68	72	76	80	84	88
1	94	95	95	95	96	96	96	96
2	90	90	90	91	91	92	92	92
3	84	85	85	86	87	88	88	89
4	78	80	81	82	83	84	84	85
5	73	75	76	78	79	80	80	81
6	68	70	72	73	75	76	77	78
7	63	66	67	69	71	72	73	74
8	58	61	63	65	67	68	70	71
9	54	57	59	61	63	65	66	68
10	49	52	55	57	59	61	63	64

Standard Composition of Dry Air

Gas	% by Volume	% by Weight	Parts per Million (by Volume)	Chemical Symbol	Molecular Weight
Nitrogen	78.08	75.47	780805	N ₂	28.01
Oxygen	20.95	23.20	209450	O ₂	32.00
Argon	0.93	1.28	9340	Ar	39.95
Carbon Dioxide	0.038	0.0590	380	CO ₂	44.01
Neon	0.0018	0.0012	18.21	Ne	20.18
Helium	0.0005	0.00007	5.24	He	4.00
Krypton	0.0001	0.0003	1.14	Kr	83.80
Hydrogen	0.00005	Negligible	0.50	H ₂	2.02
Xenon	8.7 x 10 ⁻⁶	0.00004	0.087	Xe	131.30

Common Mushrooms and Their Scientific Names

Common name	Scientific name
White button mushroom	<i>Agaricus bisporus</i>
Summer white button mushroom	<i>Agaricus bitorquis</i>
Oyster mushroom (Dhingri)	<i>Pleurotus</i> spp.
Paddy straw mushroom	<i>Volvariella volvacea</i>
Shiitake mushroom	<i>Lentinula edodes</i>
Black/Jew/Wood ear mushroom	<i>Auricularia</i> spp.
Giant mushroom	<i>Stropharia rugoso-annulata</i>
Winter mushroom	<i>Flammulina velutipes</i>
Milky mushroom	<i>Calocybe indica</i>
Reishi mushroom	<i>Ganoderma lucidum</i>
Maitake mushroom	<i>Grifola frondosa</i>
Morel (Gucchi) mushroom	<i>Morchella</i> spp.
Lion's Maine/Monkey head mushroom	<i>Hericium</i> spp.
Keera Ghas mushroom	<i>Cordyceps sinensis</i>
Black poplar mushroom	<i>Agrocybe aegerita</i>
Nameko mushroom	<i>Pholiota nameko</i>
Silver ear mushroom	<i>Tremella fuciformis</i>

R Values of Commonly Used Insulation Materials

R-value is a measure of thermal resistance. It is the ratio of temperature difference across an insulator (ΔT) and the heat flux (heat flow per unit area, Q_A) through it or $R = \Delta T / Q_A$.

SI units for R values are $M^2.K/W$ and US Units are $Ft^2.^{\circ}F.h/Btu$. These two units can be interconverted as $1h.Ft^2.^{\circ}F/Btu = 0.17611K.m^2/W$ and $1K.m^2/W = 5.678263 h.Ft^2.^{\circ}F/Btu$.

Doubling the thickness of a layer means doubling the R value. To find heat loss per square metre simply divide temperature difference by R value. Say inside temperature is $20^{\circ}C$ and outside is $10^{\circ}C$ and assuming insulation R-2 (i.e. $R = 2.0 m^2K/W$), energy will be lost @ $10K/2K.m^2/W = 5W$ per square meter.

Common R value per inch in SI and imperial units

Material $m^2.k (W.in)$	$ft^2.^{\circ}F.h$	(BTU in)
Vacuum insulated panel	5.3-8.8	R-30 – R-50
Polyurethane panels	1.0-1.2	R-5.5 – R-6.8
Polystyrene board	0.88	R-5.0
Fibre glass loose fill	0.44-0.65	R-2.5 – R-3.7
Card board	0.52-0.7	R-3 – R-4
Cellulose loose fill	0.52-0.67	R-3 – R-3.8
Straw bale	0.26	R-1.45
Brick	0.03	R-0.2
Poured concrete	0.014	R-0.08

Source : Wikipedia

Brick has nearly R-0.2 i.e. is a bad insulator, but has very good thermal mass. Even though straw bale has R-1.45 per inch but straws bale houses have thick walls and therefore, well insulated. R value of different layers can be added.

However, in India K value is also used which is inverse of R value but K value of different materials cannot be added as such. Hence it may be more useful to use R values.

Elementary Calculations of Spawn and Compost

How much spawn is required for button mushroom cultivation ?

One of the common question is that how much spawn will be required to produce a particular amount of mushroom. This can be calculated by using the simple formula:

$$\text{Spawn (kg) required} = \{ \text{SR (\%)/BE (\%)} \} \times \text{TP (kg)}$$

Where SR is Spawning rate in per cent; BE is Biological efficiency in per cent and TP is targeted production. SR and BE should both be taken either on wet wt or dry wt basis. The formula is applicable to all mushrooms.

For example to produce 100 kg mushroom when compost is spawned @ 0.5% and B.E. is 15%, the spawn required will be = $(0.5/15) \times 100 = 3.3$ kg. Spawn to produce 100 kg button mushroom and straw required for the same and spawn required per 100 kg dry straw are tabulated below

Spawn rate (%)	Spawn required in kg to produce 100 kg mushroom (%)			Spawn (kg) for 100 kg dry straw for SMC	Spawn (kg) for 100 kg dry straw for LMC
	15	20	25		
0.5	3.33	2.50	2.00	1.25	1.00
0.7	4.67	3.50	2.80	1.75	1.40
1.0	6.66	5.00	4.00	2.50	2.00
Dry straw required to produce 100 kg mushroom in:					
SMC	267	200	160		
LMC	333	250	200		

SMC – Short method compost, conversion from dry straw to compost 1:2.5

LMC – Long method compost, conversion from dry straw to compost 1:2.0

How much compost can be filled in tunnel and what will be the output ?

One square metre of the surface area of tunnel accommodates 0.9 to 1.0 ton of compost at the time of filling when filled upto 2 metres. In our country measurements at times are still expressed in feet. The surface area may be converted into square metres and for simplicity, the compost that can be filled (in tons) can be taken equal to this area. The output will be normally $3/4^{\text{th}}$ of this. For example if tunnel is 36' x 9' then the area in metres will be $9 \times 36 / 10.76 = 30.11$ which means that about 30 ton compost can be filled. The compost output at the end of Phase-II will be $30 \times 0.75 = 22.5$ implying that the tunnel will yield 20-22 ton compost.

How much compost can be filled in a room ?

In general air bed ratio of 6:1 to 5:1 is maintained in the cropping room. For simplicity one may calculate the volume (in cft) and divide by 600 to get the approximate amount of compost (in tons) that can be accommodated.

$$\text{Compost that may be filled in room} = \text{volume of room (in cft)} / 600 \pm 10 \text{ per cent}$$

For example a room of 60'x20'x12' can accommodate $14400/600 = 24$ ton compost ± 10 per cent i.e. 22-27 ton approximately.

Requirement of manpower, electricity and chilling plant

- Manpower required per day for 200 TPA = 30 - 35 persons
- Power load (kw) required for 200 TPA project = 120 - 150 KVA
- Chilling plant required for 200 TPA project = 80 - 100 tons

Approx. Nitrogen content (dry weight basis) of common compost ingredients

Wheat straw	0.4	Rice bran	2.0
Paddy straw	0.6	Urea	46.0
Soyabean straw	1.0	CAN	27.0
Chicken manure	2.5-3.5	Ammonium sulphate	22.0
Wheat bran	2.2	NPK	12.0
Horse manure	1.3	Cotton waste	5.0
Neem cake	1.5	Hay	1.5
Sunflower cake	4.0	Lucerne hay	2.5
Cotton seed meal	6.0	Soybean meal	6.5
Brewer's grain	2.0	Cotton seed cake	7.0

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