Technical Bulletin

CULTIVATION TECHNOLOGY OF PADDY STRAW MUSHROOM (*Volvariella volvacea*)

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Printed: 2007, 1000 Copies

Published by:
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Designed & Printed at:
Yugantar Prakashan Pvt. Ltd.
WH-23, Mayapuri Indl. Area, New Delhi-64
Ph.: 011-28115949, 28116018

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FOREWARD

Mushrooms are known for their delicacy and nutritional values and paddy straw mushroom is not an exception. This mushroom prefers tropical and sub-tropical climates, so it has great potential in a country like India, where diverse climatic conditions prevail. The fast growing nature, easy cultivation technology and great acceptability at consumers' level further make this mushroom an important species among the cultivated edible mushrooms. Paddy straw mushroom is commonly grown on paddy straw and cotton waste, which are available in abundance and at a very low cost in the country. The adoption of this mushroom will bring the well needed diversification and will provide the nutritional food at a cheaper rate than many other foods of similar nature. I appreciate the efforts and labour put in by the authors in compiling and editing the bulletin for its use at farmers' level. I would also like to encourage the farmers to adopt this mushroom for getting the better revenue out of the agrowaste available at their door-step.

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Dated: August, 2007

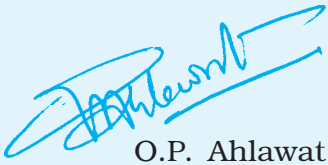
PREFACE

Paddy straw mushroom *(Volvariella volvacea)* also known as Chinese mushroom, ranks sixth among the cultivated mushrooms of the world. Being started cultivating in 1940 at Coimbatore, this mushroom could not make much head way with the time except in some coastal states like Orissa, Andhra Pradesh, West Bengal, Tamil Nadu and Kerala. This mushroom has several advantages like requirement of the tropical or sub-tropical climate, fast growth rate, easy cultivation technology and good acceptability at consumers' level. The raw materials required for its cultivation are also available in abundance in country at very nominal rates. The high temperature requirement for its cultivation also makes it a good choice for adoption in round the year cultivation of mushrooms. Paddy straw mushroom contains good amount of protein, crude fibres and ash, all make it a health diet along with superior composition of various elements and essential amino acids.

This bulletin contains the biology and life cycle of paddy straw mushroom, spawn preparation technology, cultivation methods, key points for better crop management, harvesting/processing, diseases and insect–pests management and the list of books for further consultation. All in all, the necessary points needed for starting the cultivation of this mushroom have been covered along with good diagrammatic and pictorial presentations which make the task understandable and easier for the mushroom growers and R & D personnel.

During the process of writing of this bulletin, starting from the conceptualization of the idea, I got constant support from various colleagues which is praise worthy. But amongst these, the typing/ composing support rendered by Mrs. Shashi Poonam and Mr. Pardeep Gupta is very special. I got significant contribution from Dr. M.P.Sagar and Dr S.R. Sharma, both of them helped us without any hesitation in guiding for further improvement and editing of the document.

Last but not the least, the constant encouragement from Dr. R.P. Tewari, Director, National Research Centre for Mushroom, though he is one of the authors, really motivated me to take up such a time consuming task. Once again I wish to thank all those who helped me directly or indirectly in bringing out this bulletin.



O.P. Ahlawat

CHAPTER - I

Introduction

Paddy straw mushroom (*Volvariella volvacea*), commonly known as the straw mushroom, or the Chinese mushroom, belongs to the family Pluteaceae (Kotl. & Pouz) of the Basidiomycetes (Singer, 1961). It is an edible mushroom of tropics and subtropics, and first cultivated in China in 1822 (Chang, 1969). Initially this mushroom was known as "Nanhua mushroom" after the name of Nanhua Temple in Northern Guangdong Province in China. In the beginning, paddy straw mushroom was cultivated by Buddhist monks for their own table, however, by 1875 it was sent as a tribute to the royal family. It is presumed that cultivation of this mushroom begun before the 18th century, almost 300 years ago (Chang, 1977). Around 1932 to 1935, this mushroom was introduced into the Philippines, Malaysia and other South Asian countries by Chinese (Baker, 1934; Chang, 1974).

Paddy straw mushroom is also known as "warm mushroom" as it grows at relatively high temperature. It is a fast growing mushroom and under favourable growing conditions total crop cycle is completed with in 4-5 weeks time. This mushroom can use wide range of cellulosic materials and the C: N ratio needed is 40 to 60, quite high in comparison to other cultivated mushrooms. It can be grown quite quickly and easily on uncomposted substrates such as paddy straw and cotton waste or other cellulosic organic waste materials (Ahlawat & Kumar, 2005). It has been considered as one of the easiest mushrooms to cultivate. Paddy straw mushroom was first cultivated in India in 1940, however, its systematic cultivation was first attempted in 1943. Presently this mushroom is more popular in coastal states like Orissa, Andhra Pradesh, Tamil Nadu, Kerala and West Bengal, however, it can also be

cultivated in most of the states, where agroclimatic conditions suit and agrowaste is available in plenty.

LIFE CYCLE AND GENETICS OF BREEDING SYSTEM

In contrast to green plants, most mushroom species are haploid, and diploid phase is normally transient and restricted to the basidium. Paddy straw mushroom has distinction from other mushrooms. Being homothallic species, the individual uninucleate haploid self fertile spores germinate to produce mycelia and completes the life cycle without the need of a mating type factor. Clamp connections are entirely absent in *Volvariella* spp. In *V. volvacea*, the hyphal cells are multinucleate, clamp connections are absent and basidiospore receives only one nucleus each following meiosis. Wide variation exists in growth rate and other characteristics of single spore mycelia. It is still difficult to call this mushroom as primary homothallic as the research carried out by different workers have given different explanations behind existence of self fertility among majority of the basidiospores and non-existence in minority of the basidiospores.

BIOLOGICAL CHARACTERISTICS

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

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

2. **Tiny button**: Both the tiny button and pinhead stages are formed from interwoven hyphae. In a young tiny button, only the top of the veil is brown, while the rest is white (Fig. 1). It is round in shape and if a vertical cut is made through the button, the lamellae are seen as a narrow band on the lower surface of pileus.

3. **Button stage**: This stage of paddy straw mushroom is sold

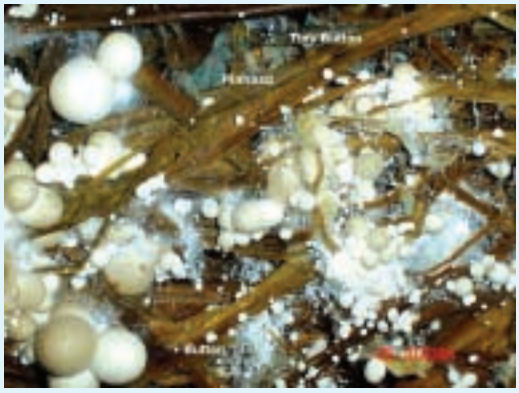


Fig. 1.

in the market at a premium price. In this stage, the whole structure is wrapped by a coat, which is called as the universal veil (Fig. 1). Inside the veil, closed pileus exists. As such the stipe is not visible but in longitudinal section of mushroom it is visible.

4. **Egg stage**: This stage also fetches premium price in the market, at this stage, the pileus is pushed out of the veil and the veil remains as volva (Fig. 2). The stipe is again not visible at this stage. The lamellae of this stage do not bear basidiospores. The size of the pileus remains very small upto this stage.

5. **Elongation stage**: The pileus remains close and the size is smaller than mature stage, while the stipe attains the maximum length (Fig. 2). The stipe is marked with water proof drawing ink.

Fig. 2.

6. **Mature stage**: At mature stage, the structure is divided into three regions: (i) the pileus or cap, (ii) stipe or stalk and (iii) the volva or cup (Fig. 3). The pileus is connected in the

Fig. 3.

centre with stipe and is of usually 6 to 12 cm in diameter.

The fully grown pileus is circular in shape with an entire margin and smooth surface. The surface is dark grey at centre and light grey near the margin. The lower surface of the pileus bears lamellae and their number varies from 280 to 380. The lamellae vary in size from full size to one quarter size of pileus. Under the microscope, each lamella is seen to be composed of three layers of interwoven hyphae. The outermost layer is called the hymenium and it forms the club-shaped basidia and the cystedia. The basidia bear basidiospores. Usually one basidium bears four basidiospores. The basidiospores vary in shape; egg shaped, spherical or ellipsoidal. The colour of basidiospores again vary and it may be of light yellow, pink or dark brown.

Another important part of mature fruiting body is the stipe, which connects the volva and the pileus. The length of the stipe depends upon the size of the pileus and it is usually about 3 to 8 cm in length and 0.5 to 1.5 cm in diameter. It is white, fleshy and without any annulus. At the base of stipe remains the volva, which is basically a thin sheet of interwoven hyphae around the bulbous base of the stipe. The volva is fleshy, white and cup shaped with irregular margins. The base of volva bears rhizomorphs, which absorb the nutrition from the substrate.

CHAPTER - II

Nutritive Value

The excellent unique flavour and textural characteristics distinguish this mushroom from other edible mushrooms. The nutritive value of straw mushroom is affected by the method of crop raising and the stages of maturation. The 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 a fully mature fruiting body contains as high as 5% fat. The N-free carbohydrates increase from button stage to the egg stage levels, off at the elongation and drops at the mature stage. The crude fibre remains almost at 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.

Table 1. Proximate composition of paddy straw mushroom

Content	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)

(Verma, 2002)

The straw mushroom is known to be rich in minerals such as potassium, sodium and phosphorus. Potassium constitutes the major fraction of 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 & P which

drop at the elongation and the mature stages. The contents of minor elements, namely Cu, Zn and Fe do 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 (FAO, 1972; Chang, 1979). At all stages, lysine is the most abundant essential amino acid and glutamic acid and aspartic acid are the most abundant non-essential amino acids. 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 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 mushrooms and the abundance of lysine is very important. The other three amino acids namely leucine, isoleucine and methionine are low in paddy straw mushroom as compared to other mushrooms.

Table 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
Phenylalanine	4.9
Threonine	4.2
Arginine	4.1
Methionine	0.9

(Zakia Bano *et al.*,1972; Verma, 2002)

CHAPTER - III

Spawn Production

Spawn is the mycelium of mushrooms growing in its substratum and prepared for the purpose of propagating mushroom production. In a more simple language, it is defined as a medium impregnated with mushroom mycelium that serves as the "seed" for mushroom cultivation. The different stages of spawn production are as follows:

i. STARTING CULTURE

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

A) SINGLE SPORE CULTURE TECHNIQUE

- Selection of unopened mushroom fruiting body, removing dirt with clean cotton followed by wiping of mushroom with 70% alcohol & removing lower portion of stipe with sharp edged knife.
- Placing the fruiting body on pointed end of spiral wire stand placed in a sterilized petridish and covering the whole unit with round mouth beaker.
- Leaving the whole assembly for 30 minutes at room temperature and removing the beaker as well as the fruiting body along with spiral wire stand under a laminar flow chamber followed by covering of petridish aseptically.
- Serial dilution of spore collection upto 10^{-7} or 10^{-8} till 10-20 spore/ml count reached and pouring with molten plain agar medium in sterilized petridishes.
- Incubation of dishes at 32 ± 2^0C in BOD incubator for 3-4 days and visualization of germlings under inverted microscope for single spore isolates selection.
- Selection of single spore isolates and multiplying on

Malt Extract Agar (MEA) medium by incubating at 32 ± 2°C for next 7-10 days in BOD incubator (Fig. 4).

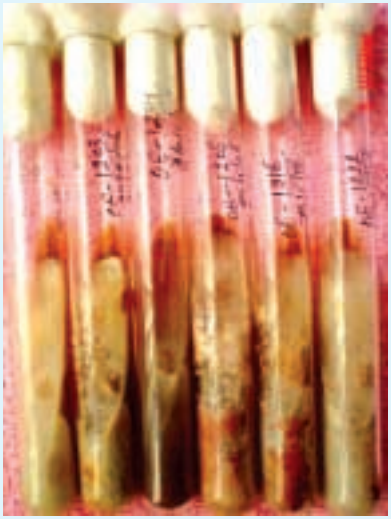


Fig. 4.

B) MULTISPORE CULTURE TECHNIQUE

- The sterilized loop of inoculation needle is used for lifting of the spores from the spore print.
- The loop bearing thousands of spores is touched on top surface of the petridishes containing the Malt Extract Agar or any other fungal media, followed by incubation of plates at 32 ± 2°C for 4-5 days in BOD incubator.

C) TISSUE CULTURE TECHNIQUE

- Disinfection of working area and hands with disinfectant and wiping of mushroom fruiting body with 70% alcohol.
- Making two equal halves of mushroom with the help of sterilized but cooled knife without touching the inner surface of mushroom fruiting body.
- Removing small pieces of tissue from the stipe pileus connecting point and placing several pieces on the Malt Extract Agar plate on different locations.
- Incubation of plates at 32 ± 2°C for 4 to 5 days in BOD incubator or room temperature (Fig. 5).

Fig. 5.

- Transferring of small mycelium bearing portion of medium on the fresh MEA slants followed by incubation at 32 ± 2^{0}C for further 4-5 days.
- Use of cultures directly in spawn substrate.

ii. CULTURE MEDIA

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

a) PDA (Potato Dextrose Agar) medium

- Washing, peeling & slicing of 200g potatoes.
- Boiling in 1000ml distilled water until potatoes become soft enough to be eaten but not over cooked.
- Straining through cheese cloth & collecting of liquid in graduated cylinder followed by restoring of volume to 1000 ml by adding fresh distilled water.
- Addition of 20g dextrose and 15g agar followed by boiling while stirring occasionally until agar is dissolved completely.
- Transferring of the medium into 10ml tubes or 250ml Erlenmeyer flasks followed by plugging with non-absorbent cotton.
- Sterilization at 121^{0}C or 15p.s.i for 15-20 minutes.
- Preparation of slants by putting still hot tubes in slanting position or pouring of medium in sterilized petridishes and leaving as such for next 24 hours for cooling.

b) Malt Extract Agar

- Water 1000ml, Malt extract 25g, peptone 5g, Agar 20g, pH 7.0 – 7.5.
- Mixing of weighed quantity of each ingredient in 1000ml of distilled water.
- Constant heating with intermittent stirring till complete mixing of agar.
- Pouring of medium in tubes or Erlenmeyer flasks followed by plugging with non-absorbent cotton.
- Sterilization at 121^{0}C or 15p.s.i for 15-20 minutes.

- Putting of still hot medium containing tubes in slanting position for slant preparation or pouring of medium in sterilized petridishes followed by cooling at room temperature.

iii. SPAWN MEDIA

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

a) Grain spawn (Rye/sorghum/ wheat)

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

- Mixing of 2kg calcium carbonate and 2kg calcium sulphate with the surface dried cereal grains followed by their thorough mixing and filling in glucose bottles up to 2/3 portion of the available space or in polypropylene (PP) bags of 100 gauge thickness upto their 2/3 available space depending upon the size of the PP bags. Putting of plugs of non-absorbent cotton neither very tight nor very loose.

- Sterilization of glucose bottles or PP bags containing spawn substrate at 126^{0}C or 22 p.s.i for 2 hours followed by cooling under laminar flow bench under aseptic air.

- Inoculation of sterilized spawn substrate with mycelium culture followed by incubation at 32 $\pm$ 2^{0}C for about 2 weeks.

- By the time spawn is ready for use (Fig. 6).

Fig. 6.

b) Straw spawn (paddy straw)

Rice straw is first soaked in water for 2 to 4 hours, then cleaned and cut into pieces of 2.5 to 5cm long. Calcium carbonate and rice bran are mixed @ 1% and 1 to 2%, respectively followed by filling in wide mouth glucose bottles or polypropylene bags of 100 gauge thickness. The bottles/PP bags are closed by plugs of non-absorbent cotton.

- Sterilization of bottles/PP bags containing the spawn substrate at 126^{0}C or 22p.s.i for 2 hours.
- Cooling of spawn substrate and inoculation with mycelial culture under laminar flow chamber.
- Incubation of bottles/PP bags at 32 ± 2^{0}C for 2 weeks (Fig. 7).

Fig. 7.

c) Used tea leaves spawn

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

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

d) Cotton waste spawn

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

e) Manure-husk spawn

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

- The compost is filled in glucose bottles or in air tight aluminium canes and sterilized.

- After cooling of the compost, mushroom mycelium is inoculated and the compost is incubated at 32 ± 2°C for 2 weeks or till the spawn is ready.

iv. KEY POINTS OF SPAWN MAKING PROTOCOL

1. Substrates such as rice straw and cotton waste etc. should not be over wet as if water stands on the bottom, mycelium will not grow.

2. Container should not be tightly sealed as air can not escape and steam can not enter properly. Autoclaving will be imperfect.

3. One can prevent entry of moulds from outside after sterilization by:

   a) Using only very clean cotton stoppers.

   b) Leaving at least 3-4 cm free space between lower surface of cotton stopper and substrate.

   c) Avoiding the spoilage of container walls around the stopper and between stopper and the substrate surface.

   d) Preventing cotton plug from getting wet during autoclaving by covering loosely with aluminium foil.

   e) Keeping the outside of the containers clean as far as the aluminium foil reaches.

4. Inoculate under clean conditions in a room without any air movement (close door and windows) or under laminar flow bench.

   a) Clean the table with disinfectant

   b) Disinfect the hands with soap and disinfectant

   c) Safe transfer of autoclaved substrate in the inoculation room

   d) Use only pure culture spawn

   e) Cover opening after inoculation with aluminium foil and press around the neck of the container.

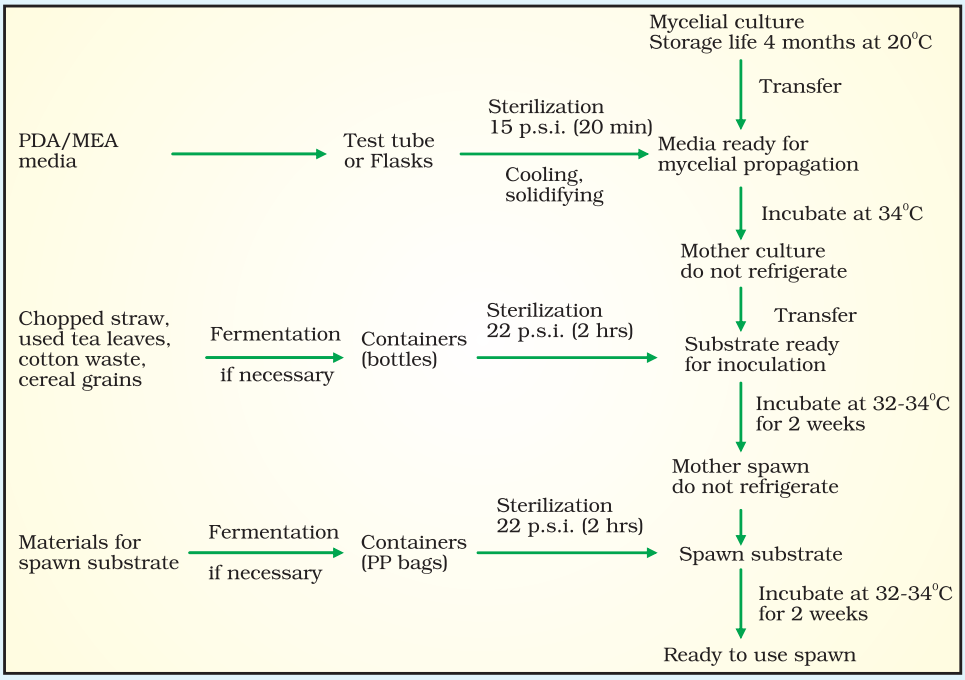


Fig. 8. Spawn production flow chart for *V. volvacea* (Chang and Miles, 2004)

5. Place spawn under optimal growth conditions. Spawn which is not needed for inoculation can be used for mushroom production.

v. STORAGE OF PURE CULTURES AND SPAWN

The optimal temperature for growth of *V. volvacea* ranges from 30-35°C and the most suitable temperature is 32°C. Mycelium does not grow at all when the temperature is raised to 45°C or dropped to 15°C. At a temperature of 15±1°C most strains of *V. volvacea* survive for the longest period (Ahlawat, 2003).

After complete colonization of spawn substrate with mushroom mycelia, it is ready to be used. However, if it is not to be used immediately, then it should be removed from incubator and stored at a lower temperature to prevent further growth, aging and death. The storage temperature should range from 15-20°C as at this temperature the growth of mycelium is arrested and mycelia are unharmed and remain viable for longer period (Ahlawat, 2003).

CHAPTER - IV

Mushroom Cultivation Technology

A variety of waste materials have been used for cultivation of the paddy straw mushroom, which include: paddy straw (Chang, 1965), water hyacinth (Chang & Mok, 1971), oil palm bunch (Naidu, 1971), oil palm pericarp waste (Graham & Yong, 1974; Yong & Graham, 1973), banana leaves & saw dust (Chua & Ho, 1973), cotton waste (Chang, 1974, Hu *et al*; 1973 & Yau and Chang, 1972), sugarcane bagasse (Hu *et al.*, 1973, 1976 & 1976) etc. Paddy straw mushroom prefers high cellulose, low lignin containing substrate and produces a family of cellulolytic enzymes (Ahlawat *et al.*, 2005). The cultivation of *Volvariella* is less sophisticated, less extensive and can be rewarding in tropical & subtropical climates (Sukara *et al.*, 1985).

Before 1970, it was only paddy straw, which was in use for paddy straw mushroom cultivation. However, in 1971, cotton waste (Ginning mill waste) was first introduced as the heating material for growing of straw mushroom followed by complete replacement of paddy straw with cotton waste by 1973 in Hong Kong. This was practically the turning point in the history of paddy straw mushroom because cotton waste gives a higher and more stable yield (30 to 40%) along with early fructification and harvesting. After adoption of cotton waste, the cultivation of paddy straw mushroom has become semi-industrialized in Hong Kong, Taiwan, Indonesia, China & Thailand.

The common methods employed for paddy straw mushroom cultivation are given below:

A) CONVENTIONAL METHOD

The different steps involved in this method are as follows:

- Preparation of paddy straw bundles of 0.75 – 1.0 kg (80-

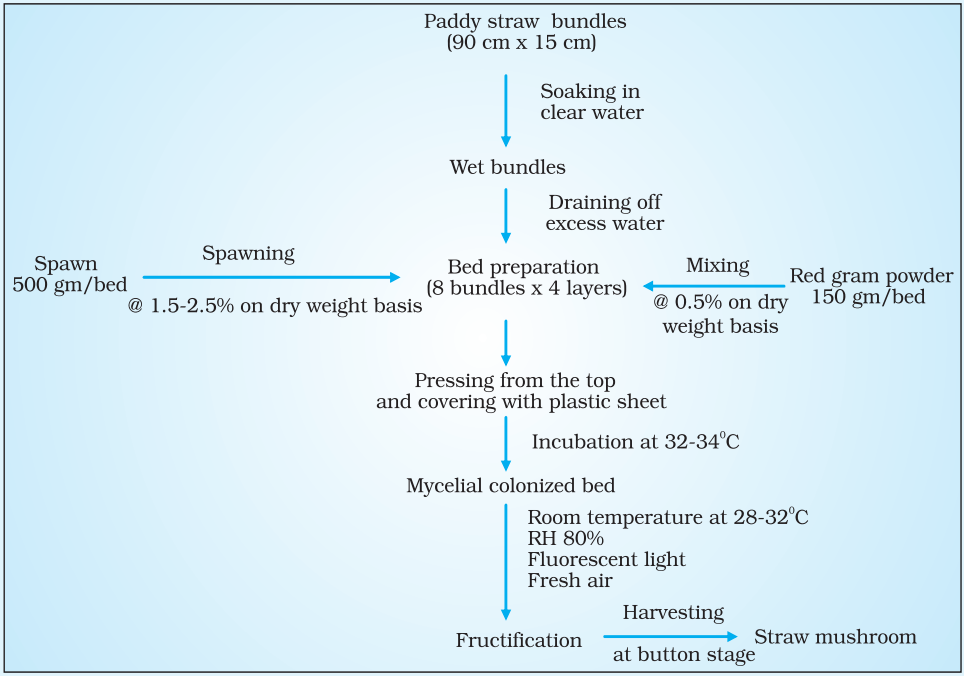


Fig. 9. Conventional method of paddy straw mushroom cultivation

95cm long & 12.16cm wide) preferably from hand threshed paddy.

- Immersing of bundles in clean water for 12-18 hours in a cemented water tank.
- Draining out of excess water by placing bundles on raised bamboo 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. The open ends of bundles from opposite sides should overlap in the middle.
- Forming of second, third & fourth layer by intermittent spawning between first and second, second and third and third and fourth layers.
- Spawning on entire surface of the layers of the beds at a space of 5cm apart leaving margin of 12-15cm from edges.
- Sprinkling of red gram powder over the spawned surface.
- Using 500 gm spawn and 150 gm of red gram powder for a

bed of 30-40 kg of dried paddy straw.

- Pressing of bed from the top and covering with clean plastic sheet for maintaining required humidity (80-85%) and temperature (30-35^{0}C).
- Removing of plastic sheet after 7-8 days of spawning and maintaining temperature of 28-32^{0}C and relative humidity about 80%.
- Mushroom will start appearing after 4-5 days of sheet removal and will continue for next 20 days.
- After crop harvest the substrate can be used for manure in the field.

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 in 3rd, 4th & 5th layers. The 5th layer can be of bundles or of loosened paddy straw.
- The size of beds may vary from 100cm x 100cm x 100cm; 60cm x 60cm x 30cm and 60cm x 60cm x 120cm.
- Alternatively the beds can be prepared with the help of boxes of 80cm x 80cm x 10cm and of 60cm x 40cm x 30cm size. In this method the material is to be chopped to a uniform length of 20cm and followed by filling in box parallel with the length of the box. It is followed by soaking of the material along with box in 2% $CaCO_3$ solution for 2 hrs or until the straw becomes dark brown. It is followed by draining of excess water and spawning of substrate at a depth of 5 cm from the sides of the box followed by plugging the openings with previously water soaked newsprint. The boxes are to be incubated at a temperature of 35 to 38^{0}C with RH of 75% for next 4-5 days. It is followed by lowering of temperature to 28 to 30^{0}C with RH of 75 to 85% along with introduction of fresh air. Use only superfine mist for maintaining proper level of humidity in the room. The bedding material can also be sprayed with fine mist if it is getting dried. Controlling of ventilators is must for maintaining optimum aeration and temperature inside the room.

B) IMPROVED CAGE-CULTIVATION

i) Material required

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

ii) Methodology

- Select dry, fresh and hand threshed paddy straw free from moulds and leafy portion. Make 25 cm long and 10 cm thick bundles @ 60 bundles for each cage (Bed).
- Soak the bundles in boiling water for 20-30 minutes and allow cooling and draining of excess water.
- Disinfect the cage and polythene sheet with 2% Formaline or Dettol solution.
- Arrange ten bundles uniformly in the cage as the bottom layer and put some spawn grains over and inside the bundles (Fig. 10). Put a second layer of ten bundles over the first and spawn as before. Repeat this till six layers of bundles are achieved or till filling of the cage.

Fig. 10.

- Spray solutions of 0.1% Malathion and 0.2% Dithane Z-78 all over the bed. Cover the whole bed with polythene sheet and bind securely with a binding thread.
- Keep the spawned cage in a room or a shed for mycelial run (Fig. 11). A warm place with temperature around 30°C is

Fig. 11.

helpful for better mycelial growth.

- Remove the polythene sheet after the mycelial run is completed (Fig. 12). Maintain high humidity in and around the bed till pinheads appear (Fig. 13).

Fig. 12.

- Pinheads appear within 10-15 days after spawning. Harvest at the egg stage (Fig. 14).

Fig. 13.

Fig. 14.

- Continue spraying water for the next flush of mushroom to appear within a week or so.

C) OUTDOOR METHOD

The best place to cultivate paddy straw mushroom outdoor is in shade created by trees or creepers. The steps involved are as follows (Chang, 1982 & Ho, 1985).

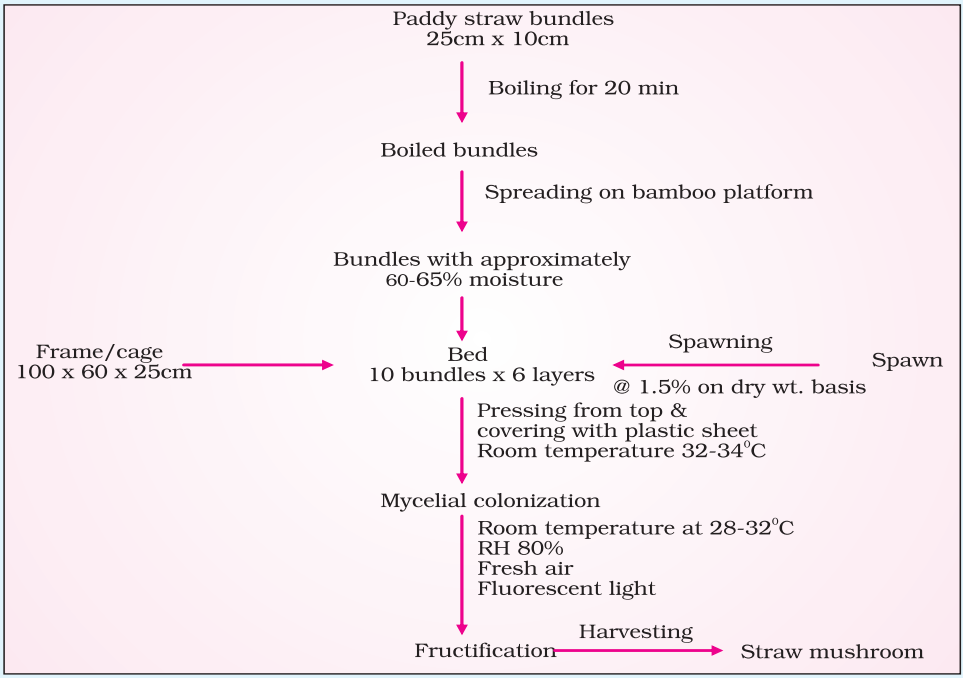


Fig. 15. Cage method of paddy straw mushroom cultivation

- Preparation of raised platform either with sand or bamboo poles or wooden planks or bricks.
- Preparation of bundles of 40cm length and 10 cm width.
- Soaking of bundles in running water or in 2% $CaCO_3$ solution.
- Driving of bamboo pole into the center of each end of the bed.
- Preparation of layer of bundles followed by spawning.
- Laying down of 4 layers of bundles during summer months and 7 layers during rainy season.
- Topping of bed with 20cm deep layer of rice straw followed by covering with polythene sheet.
- Removing of polythene sheet after 4 days and sprinkling of water carefully on 6th day. Spraying of water can be avoided during rainy season.
- Prohibit spraying of water after appearance of the mushroom pinheads.

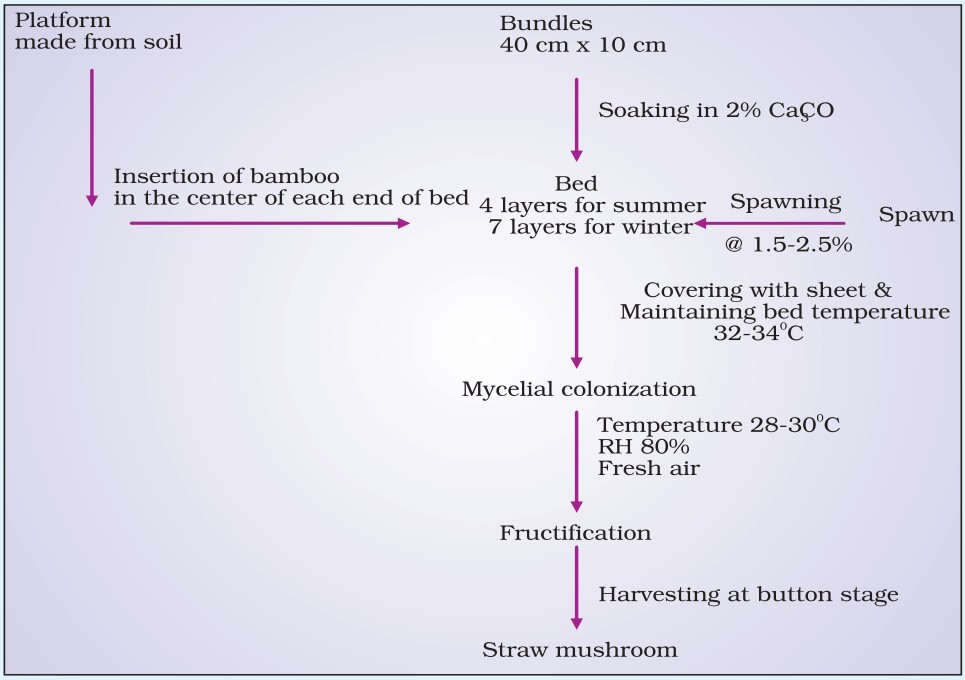


Fig. 16. Outdoor method of straw mushroom cultivation

D) INDOOR METHOD

The indoor method can be divided into following 5 steps (Quimio, 1993):

i) 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 (Table 3). The fine texture of cotton waste helps in retention of moisture, which minimizes the water requirement at later stages of cropping, and thus helps in avoiding damage to mushroom primordia.

ii) Compost preparation: Substrate is wetted with 1% lime (on dry weight basis) and for cotton waste, a square wooden rack (92x92x28cm) is used for holding a layer of cotton waste about 30cm deep. The workers are used to tread the cotton waste so that it absorbs sufficient quantity of water. After first layer is

Table 3. Carbohydrate composition in popular substrates of paddy straw mushroom

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

Chang & Miles, 2004

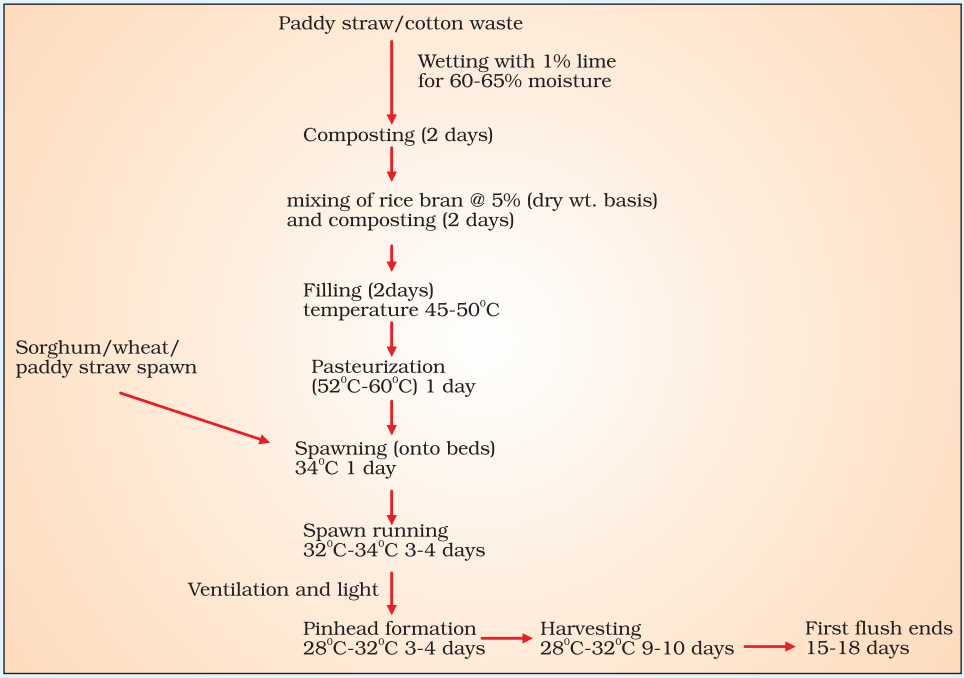


Fig. 17. Indoor method of paddy straw mushroom cultivation

trodden another layer is applied. This process is repeated until the required quantity is trodden. However, in case of paddy straw, pile is made (1.5 m high x 1.5 m wide) by adding sufficient quantity of water mixed with 1% lime (Fig. 18). The pile is also made with wet cotton waste and left to ferment in the open but under cover during rainy

Fig. 18.

season or extreme cold. First turning is given after 2 days and 5% rice bran is mixed in case of paddy straw substrate and water is added if needed. However, nothing is added in case of cotton waste substrate. Again pile is formed and left for fermentation for the next 2 days.

iii) Bedding and Pasteurization: The compost is spread on shelves in rooms or in pasteurization tunnel in suitable thickness (Fig. 19). The thickness of the substrate on shelves varies in different seasons from 5 cm to 10 cm thick. During summer months, lesser thickness is needed, while higher in winter to preserve moisture and heat. The surface is made even by

Fig. 19.

pressing lightly. After 8-12 hours of compost spreading live stream is introduced with the help of rubber hose of 6cm in diameter. A temperature of 62^{0}C is maintained for 2 hours for cotton waste compost and of 65^{0}C for 6 hrs for paddy straw compost. After steaming, the shed or room is closed to keep a temperature of 50^{0}C for next 24-36 hrs and followed by natural cooling of the substrate. The compost is spawned on reaching the temperature near 35^{0}C.

iv) Spawning: The compost is spawned with fresh spawn @ 1.4% of dry weight or 0.4% of wet weight basis of the compost

(Fig. 20). The pieces of broken spawn are inserted in compost at a depth of 2 to 2.5 cm at a distance of 12 to 15 cm. The spawn is covered with

Fig. 20.

displaced compost and the bed is covered with thin plastic sheet. The room temperature is maintained at 32 to 34^{0}C during spawn running and the compost will be colonized

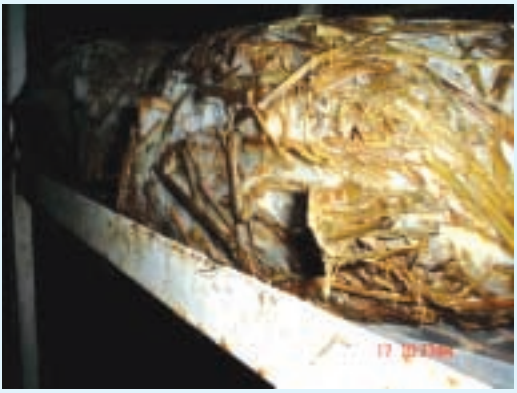


Fig. 21.

within next 4-5 days in cotton waste and 5-6 days in paddy straw compost (Fig. 21).

v) Fructification and Crop Management: During spawn running period, water and light are not needed but a little ventilation is needed. By the end of 3-4 days, fluorescent light along with little more ventilation is provided in the rooms. The plastic sheets are removed on 4-5th day followed by little sprinkling of beds with water. The pinheads start appearing on 5th – 6th day of spawning (Fig. 22). After another 4 to 5 days, the first flush of mushroom will be ready for harvesting (Fig. 23). The room conditions needed for better fructification are temperature 30^{0}C, relative humidity 80%, fluorescent light and intermittent fresh air. The quick growth rate of this mushroom demands ample supply of water and oxygen, which are antagonistic to each other in practice. Watering of the compost is not oftenly recommended as it lowers the temperature, suffocates the tiny primordia and reduces yield. Crop management to

Fig. 22.

Fig. 23.

achieve the best possible combination of light, temperature, ventilation, relative humidity and compost moisture is in fact an art of judgment, experience and effort.

E) CIRCULAR METHOD

The steps involved in this method are (Thakur *et al.*, 2003):

- Preparation of bundles of one kg each from paddy straw.
- Soaking bundles in 2% $CaCO_3$ for 12 hours.
- Winding of water soaked bundles around wooden or cemented poles and mixing of mushroom spawn @ 1.5% on dry weight basis.
- Covering of spawned substrate with thin polythene sheet.
- Maintaining room temperature at 32-34^{0}C, RH 85%, with no light but little air circulation for 5-6 days.
- Removing of polythene sheet followed by spray of water on beds and lowering of room temperature to 28-32^{0}C, RH 80% and fluorescent light with enhancement in fresh air injection.
- Maintaining RH of 80% by fine misting on floor or walls without any direct spray on beds.
- Development of mushroom and harvesting by little lifting and twisting at egg stage.
- Packaging and sealing.

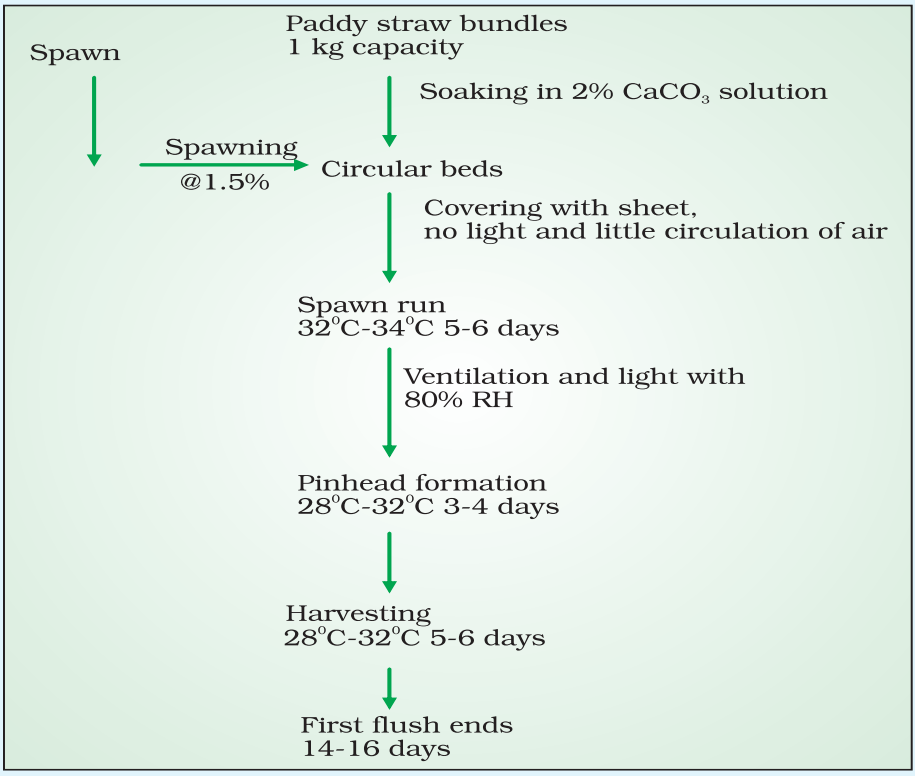


Fig. 24. Circular method of paddy straw mushroom cultivation

F) INDIGENOUS CHINESE CULTIVATION PRACTICE

The method adopted at Green Poplar Village, Ping-Shan County, Hebei Province, China is mentioned below (Chang & Miles, 2004).

a) Compost preparation

- Overnight soaking of wheat straw (10-15cm long pieces) in 1% $CaCO_3$ solution.
- Draining off of excess water by placing straw on ground.
- Piling of compost and covering with plastic sheet.
- Compost turning after 1 to 2 days interval, preferably on reaching the pile temperature at 50°C.
- Filling of compost in 70cm x 35cm x 22cm size frame, first by putting a layer of compost followed by placing of spawn on four sides of this layer along with some wheat bran. The second layer is placed on top of the first one and then

spawn and wheat bran are added around the edges. The third and fourth layers are added like the first and second layers.

b) Arrangement of bed blocks

- Soil base is raised several centimeters surrounding the base of the frame.
- The blocks are arranged in two rows with a gap of 20-25 cm in between.
- Poplar branches are used to provide roofing on the blocks and are bowed in a shape to form the frame.
- Plastic sheet is spread over the frame, which in turn covered by straw.
- Temperature of around 33 to 35^0 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 mushroom 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 mushroom yield.
- Four to 5 crops are harvested each year.

d) Spent compost

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

IMPORTANT STEPS FOR OBTAINING HEALTHY MUSHROOM CROP

- Compost moisture in the range of 60 to 65%.
- Immediate spawning on obtaining compost temperature at 35^0C followed by covering with plastic sheets, which should be maintained for next 4 days.
- No ventilation during first 3 days following spawning.
- Removal of plastic sheets after 4 to 6 days of spawning and sprinkling of water on bed surface followed by ventilating the cropping room.

CHAPTER - V

Harvesting and Processing

HARVESTING

The straw mushroom is harvested before the volva breaks or just after repture. These stages are called as the button and egg stages. This mushroom grows at high temperature and moisture, therefore, its growth is very fast. So, for harvesting of straw mushroom at good condition it has to be harvested twice or thrice in a day (morning, noon & afternoon). This mushroom usually takes 9-10 days from spawning to first harvest of crop and the first flush normally lasts for 3 days, which constitutes about 70 to 90% of the expected mushroom yield. The intervening period of 3 to 5 days requires thorough watering and maintenance of optimum conditions inside the cropping rooms. The next flush will again lasts for 2-3 days and yields less mushroom than the first flush. The second flush adds only 10 to 30% of the total crop.

The mature fruiting bodies should be carefully separated from the beds/substrate by lifting and shaking slightly left or right and then twisting them off. The mushrooms should not be cut off by knives or scissors from the base of the stalk, because the stalk left behind on the bed/substrate will rot and be attacked by pests and contaminated by moulds, which in turn will destroy the mushroom bed.

PROCESSING

Straw mushroom is more perishable than other edible mushrooms and can not be stored at 4^0C as it undergoes autolysis at this temperature (Ahlawat *et al.* 2006). This mushroom can be stored at a temperature of 10 to 15^0C for 3 days and little more at 20^0C or under controlled atmosphere storage. The loss of moisture in 4 days stored mushroom could be as high as 40-50% in unpacked mushroom, while it can be reduced to 10% on packaging in perforated polythene begs. Straw

mushroom can be processed by canning, pickling and drying. However, practically the straw mushroom from China to Hong Kong is transported in wooden cases, in which the two compartments of the case are filled with ice, while the central compartment with mushroom. On the other hand, this mushroom is transported by air from Taiwan to Thailand in bamboo baskets with central aeration tunnel and packed with dry ice wrapped in paper. However, like button mushroom, more research work is needed in this mushroom also for studying the effect of blanching, post harvest storage, soaking and other chemical treatment before canning in order to increase the drained weight and improve the quality of the canned product.

Air Drying: Sun drying is very common in straw mushroom. The mushrooms are cut longitudinally before drying. Drying by hot air is better than sun drying because mushroom retains better flavour and colour. Drying takes place in 24 hours at 30^{0}C. However, mushroom can also be dried with temperature beginning at 40^{0}C than increasing gradually until it reaches at 45^{0}C for eight hours. Blanching of mushrooms for 3-4 minutes in hot water or 4-5 minutes in steam helps in retaining better colour of the dried product during storage. Pretreatment of mushrooms with 0.1% KMS or combination of 0.05% KMS and 0.05% citric acid significantly improves the quality of the dehydrated product (Dev Raj *et. al.*, 2004). The optimum drying temperature, time and critical moisture content for drying of the paddy straw mushroom has been recorded to be 60^{0}C, 7 hrs & 5%, respectively (Singh *et. al.*, 1996). Fresh mushrooms are reduced to about one-tenth of their original weight after dehydration. Dried mushrooms should be placed in air tight containers, to prevent moisture absorption. Dried mushrooms can be powdered and then used for making soup, ketchup or curry after reconstitution in water.

Freeze Drying: Freshly picked mushrooms are to be frozen at –20^{0}C and then freeze dried. The finished produce on rehydration used to be better than air-dried product. On reconstitution it becomes almost indistinguishable in appearance from the fresh ones.

CHAPTER - VI

Diseases/Insect-Pests and Their Management

Cultivation of paddy straw mushroom at industrial scale is a recent development and not much attention has been paid to the diseases and insect-pests aspects of this mushroom. The limited information available has been given in the under mentioned paragraphs.

A) PESTS

The common pests of straw mushroom are the mites, millipedes, grubs, nematodes and earthworms. Mites contribute to the maximum damage of the mycelium and the buttons. Among other pests, the damage caused by the nematodes is also very significant which has been discussed in detail.

Nematodes: Infestation of nematodes occurs if the compost has not been properly pasteurized. High water content of compost does not allow proper fermentation to occur and the temperature does not rise sufficiently high and consequently the compost remains immature. The high moisture does not allow to raise the temperature of the center of the bed sufficiently high (+50^{0}C) to kill the nematodes and thus nematodes survive even after pasteurization. On spawning, the temperature further comes down and suits to the nematodes for their rapid multiplication. Nematodes eat mushroom mycelium and thus stop the supply of nutrients to the growing pinheads which consequently die. The mushroom house, tools, materials and place of composting, all are capable of harbouring nematodes for their subsequent spread to the compost in the beds. The active stage of nematodes can not tolerate a temperature of 50^{0}C. Considering the above facts, the following suitable strategy can be adopted for obtaining a quality compost.

- Maintaining of compost moisture between 60-65%.

- Injection of steam after 10-12 hours after filling as it will allow the nematodes to come on the surface of the compost. The nematodes on compost surface will be killed faster during pasteurization than those which are in the center of the compost.

B) DISEASES

As such not much research work has been carried out on the diseases aspect of this mushroom. However, *Coprinus* sp. damages the crop to the greatest extent being having the same growth requirements as of the *Volvariella* spp. The other competitor moulds which have been recorded are the *Trichoderma* sp., *Penicillium* sp. and *Mucor* sp., which mainly come because of the improper pasteurization of the substrate or because of the use of contaminated spawn.

***Coprinus* - Fungal competitor of Paddy straw mushroom**: The straw mushroom has several competitors, but *Coprinus* is the most frequently encountered. *Coprinus* completes its life cycle in a much shorter duration (1 week) than the straw mushroom, which takes around 9 to 10 days. Hence, *Coprinus* becomes a very strong competitor of straw mushroom.

The pileus of *Coprinus* fruiting body opens quickly and then overnight the mushroom undergoes auto-digestion, leaving spores as a black ink of fluid. It leads to a strong odour in the residue and followed by the growth of green mould. That is usually *Trichoderma*. *Coprinus* has the same growth requirements as of the *V. volvacea* and hence, damages the mushroom beds. The one major difference between two fungi is the requirement of nitrogen level, as *Coprinus* requires almost 4 times more nitrogen than *Volvariella*. The optimal pH requirement for two fungi also differs and *Volvariella* grows best at 9.0 pH, while *Coprinus* at 5.0 pH. Considering the differences in these two requirements, growers can manipulate the growing conditions favouring *Volvariella* than *Coprinus*. The important steps can be:

- Keeping C: N ratio of the compost in the range of 40:1 to 50:1 and if any nitrogen source is to be added, it should be added in the beginning of the composting, as it will be

utilized properly during fermentation.

- The moisture content should be maintained in the range of 60 to 65% to obtain high temperature fermentation. The wet compost will decay fast and will promote the growth of *Coprinus*.

COMMON PROBLEMS ENCOUNTERED DURING CROPPING AND THEIR ORIGIN

- **Poor growth of the fungi**: Insufficient food, inadequately beaten or too compact compost bed or poor quality spawn.
- **Presence of contaminants**: Temperature might not have been enough high 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 fruitbody**: 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 CO_2, sharp temperature fluctuations or diseases caused by fungi or virus.
- **Growth of *Coprinus***: Excessive nitrogen, poor quality straw or excess heat of the compost bed.

CHAPTER - VII

Conclusion

As we know cultivation of mushrooms and in particular the tropical mushrooms is the easiest way of agro-waste utilization in the shortest possible duration with an additional advantage of producing a quality food, possessing good proportion of essential amino acids, elements, fibre, ash and fatty acids. The additional advantage with paddy straw mushroom is, its shorter life cycle, fast growth, simple cultivation technique and high acceptability at consumers' level because of its unique texture and aroma. The bottle-neck of lower biological efficiency has almost been sorted out after bringing in of the cotton waste as the substrate; however, much more research work is needed to be done for developing suitable processing technology like of the button and other commercially grown mushrooms.

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