TECHNICAL BULLETIN

# Production and Post-Harvest Management of Mushrooms in Hot and Arid Region


Sakharam Kale
Prerna Nath
Vijay Singh Meena
R K Singh

Cooperating Centre
AICRP on Plasticulture Engineering and Technology (PET)
ICAR-Central Institute of Post- Harvest Engineering and Technology
Malout-Hanumangarh Bypass Road, Abohar
Dist: Fazilka (Punjab)

TECHNICAL BULLETIN

# Production and Post-Harvest Management of Mushrooms in Hot and Arid Region

**Sakharam Kale**
**Prerna Nath**
**Vijay Singh Meena**
**R K Singh**

## Cooperating Centre

**AICRP on Plasticulture Engineering and Technology (PET)**
**ICAR-Central Institute of Post- Harvest Engineering and Technology**
**Malout-Hanumangarh Bypass Road, Abohar**
**Dist: Fazilka (Punjab)**

***Citation:***

Kale Sakharam, Nath Prerna, Meena Vijay Singh, Singh R K. 2017. Production and postharvest management of mushrooms in hot and arid region. Technical bulletin (01/2017), ICAR-CIPHET, Abohar, pp. 1-34.

***Published by:***

ICAR-Central Institute of Post- Harvest Engineering and Technology, Abohar- 152116.



***Abohar campus Address:***

ICAR-CIPHET, Malout-Hanumangarh By-pass road, Abohar- 152116, (Punjab), India
Phone: 01634-224024, Fax: 01634-225313

***Printed at:***
M/s Yugantar Prakashan Pvt. Ltd., WH-23, Mayapuri Industrial Area Phase-I, New Delhi- 110064
Phones: (O) 011-28115949, (M) 09811349619, 09953134595
E-mail: yugpress01@gmail.com, yugpress@rediffmail.com

# PREFACE

Mushroom farming in India is started since 1960s. Colossal amount of agricultural wastes and availability of suitable strains have contributed to the growth and diversification of mushrooms in the country. Mushroom producing areas in India are the temperate regions for button mushrooms and tropical and sub-tropical regions for oyster, milky, paddy straw and other tropical mushrooms. Two to three crops of button mushrooms are grown seasonally in temperate regions, while one crop of button mushroom is cultivated in North Western plains (hot and arid region) of India seasonally. Oyster, paddy straw and milky mushrooms are grown seasonally in the tropical/sub-tropical areas from April to October. Significant amount of information is available on production of mushrooms in temperate climates. However, unfortunately, very little information is available on mushroom structures and production methods of mushrooms in hot and arid regions.

Information about appropriate postharvest management of mushrooms is also essential to reduce the postharvest losses in mushrooms. Hence, efforts have been made to compile every aspect of mushroom production, growing structures as well postharvest management strategies to enhance the mushroom production and to reduce the postharvest losses in hot and arid region. The bulletin has been written in a simple and understandable language. Description of the mushroom polyhouse developed by ICAR-CIPHET Abohar under AICRP on PET has also been included in the bulletin.

We express our sincere thanks to Dr. R.K. Gupta, Director, ICAR-CIPHET Ludhiana for his keen interest and support during the execution of the project and giving constructive suggestions for improvement of the manuscript.

**Sakharam Kale**
**Prerna Nath**
**Vijay Singh Meena**
**R K Singh**

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# 1. Introduction

Mushroom is a fruiting body with no photosynthesis and vascular system like green plants. Hence, it cannot synthesize its own food and is dependent upon the organic matter for food. Mushrooms may be defined as a macro fungus with distinctive fruiting bodies, large enough to be seen with naked eyes and picked up by the hands. Mushroom mainly consists of a cap and a stalk. Some mushrooms have additional structures like veil and cup. Cap is the expanded portion of the fruit body which may be thick, fleshy, membranous or corky. On the underside of the cap, gills are situated. Many species of mushrooms such as straw mushroom (*Volvariella volvacea*), button mushroom (*Aaaricus bisporus*), oyster mushroom (*Pleurotus ostreatus*), milky mushroom (*Calocybe indica*) etc. are grown all over the world depending upon the climatic conditions. Mushrooms can be grown in hot and arid region of India taking the advantage of huge agricultural waste in the region in the form of wheat and paddy straw, cotton stalks etc.

## 1.1. Nutritional importance

Since last few years, mushroom has become one of the most important ingredients of Indian diet. Wide acceptance of mushroom is not only due to its culinary value but also due to its potential as a source of proteins (Table 1). Mushrooms contain more protein than many fruits and vegetables. They are considered as supplements to the diets lacking proteins and hence are rightly called as vegetable meat. Carbohydrate and fat contents of edible mushrooms are comparatively low. Besides proteins, mushrooms are also rich in certain vitamins such as vitamin B, C, D, riboflavin, thiamine and nicotinic acid (Table 2). Vitamin contents in mushrooms are comparable with most of the vegetables.

**Table 1. Protein contents (dry weight) of edible mushrooms**

| S. No. | Species | Protein (%) |
|---|---|---|
| 1. | *Volvariella volvacea* | 21.32 |
| 2. | *Agaricus bisporus* | 27.8 |
| 3. | *Pleurotus ostreatus* | 27.4 |
| 4. | *Pleurotus florida* | 37.19 |
| 5. | *Pleurotus sajor-caju* | 36.94 |
| 6. | *Lentinula edodes* | 17.5 |
| 7. | *Auricularia auricular-judae* | 8.1 |
| 8. | *Flammulina velutipes* | 21.9 |

(Source: Chang and Miles, 2004)

**Table 2. Vitamin content of edible mushrooms**

| S. No. | Species | Thiamine (mg/100g db) | Riboflavin (mg/100g db) | Niacin (mg/100g db) |
|---|---|---|---|---|
| 1. | *Agaricus bisporus* | 1.1 | 5.0 | 55.7 |
| 2. | *Lentinula edodes* | 7.8 | 4.9 | 84.9 |
| 3. | *Pleurotus florida* | 0.35 | 2.97 | 64.88 |
| 4. | *Volvariella volvacea* | 0.32 | 1.63 | 47.55 |
| 5. | *Pleurotus sajor-caju* | 1.16 – 4.8 | - | 46.11 |

(Source: Chang and Miles, 2004)

Mushrooms are considered of high nutritional value due to presence of minerals such as iron, phosphorus, sodium and potassium (Oei, 1996). Mineral contents in mushrooms are higher than many fruits and vegetables. They are also a good source of folic acid, an ingredient known for enriching the bloodstream and prevention deficiencies.

Therefore, it can be stated that increased mushroom cultivation and its consumption would help to raise the nutritional standard of Indian population by providing a superfluous source of protein (20 to 45 %), valuable minerals and vitamins.

### 1.2. Medicinal Importance

Many fungi have pharmacological properties. Invention of penicillin was the milestone in the field of medicinal uses of fungi. In recent times, many fungi have been identified for their antifungal, antibacterial, antiviral, antitumor, anticancer and many other pharmacological values. Mushrooms also have good medicinal value. Recently, medicinal formulations in the form of tablets, capsules and extracts from various mushrooms have been developed and marketed. It can be emphasized that mushrooms are the only fungi which are deliberately and knowingly consumed by human beings. Their chemical composition makes them suitable for specific group suffering with certain physiological disorders or ailments. Polysaccharides present in mushrooms have anti-tumor and immunological properties.

Mushrooms are regarded as an ultimate health food, low in calories due to presence of good amount of quality protein, iron, zinc, vitamins and dietary fibres which protects from digestive ailments. Mushrooms help in activating intestinal peristalsis thereby preventing constipation. Various mushrooms and their metabolic extracts have been reported to protect against cancer, tumor and pathogenic microorganisms. It is suggested that regular consumption of different mushroom varieties protects humans from heart related issues. The absence of starch in mushrooms makes them an ideal food for diabetic patients. Due to their cholesterol-reducing property, mushrooms are ideal for the persons worried about their fattiness.

Thus, mushrooms and their derivatives can be eaten as health foods to protect as well as prevent various diseases. Due to their enormous nutritional and medicinal importance, improved production techniques under protected conditions were develpoed and evaluated under All India Coordinated Research Project (AICRP) on Plasticulture Engineering and Technology (PET). Postharvest managemnet strategies were also suggested to reduce the postharvest losses in mushrooms. Hence, an attempt has been made here to discuss about the production techniques of mushrooms, structures for obtaining conducive microclimate for optimum production and appropriate postharvest management strategies for postharvest loss reduction.

## 2. Mushroom Production in Hot and Arid Region

Hot and arid region mainly falls in the north western India which comprises parts of Punjab, Haryana and Rajasthan. Three distinct seasons are discernible in this region. The hot and dry season begins in April or mid-April and lasts up to July or mid-July. This season is followed by hot and humid season which lasts from mid-July to October. Winter starts in November and ends in mid-February to early March. During hot days, maximum temperature reaches as high as 50°C whereas during winter, temperature dips up to 2°C. Like temperature, relative humidity also varies throughout the year. During hot and dry days, humidity is as low as 10% whereas during hot and humid days it is more than 70%. In general, relative humidity ranges between 10-90%. Such variation in ambient temperature and relative humidity does not allow the cultivation of edible mushrooms in the region for considerable period of time. Presently, farmers of the region grows button mushroom during November to February (3-4 months). On the contrary, growing period is from October to April (6-7 months) in temperate regions. Also, paddy straw mushroom, oyester mushroom and milky mushrooms can not be produced in hot and arid region during summer due to very high ambient temperature. Hence, appropriate strategies are required in this region to extend the cultivation season of button mushroom and to provide suitable climate for cultivation of other edible mushrooms.

Production practices followed by mushroom growers of hot and arid region to produce edible mushrooms have been breifed below.

### 2.1. Scales of production system

According to the size of mushroom structure, mushroom production systems are divided in to three categories (Singh and Chaube, 1995).

1) Marginal scale:
- Mushroom structure: Huts, made up of straw, bamboo, grasses etc.
- Structure size : 30 ft x17 ft x 9 ft
- Containers: Racks of bamboo and sarkanda
- Composting : Long method
- Yield : 14-18 kg / 100 kg of compost in 8-10 weeks of harvesting

2) Small scale:
- Mushroom structure: Conversion of old buildings into crop rooms
- Structure size : 40 ft x18 ft x12-14 ft or 50 ft x21 ft x 12 ft
- Containers : 3-5 tires of bamboo shelves or MS angle racks for 10-12 kg compost
- Composting : Long method / Short method
- Yield : 15-20 kg / 100 kg compost in 8-10 weeks of harvesting

3) Industrial scale:
- Mushroom structure: Insulated and controlled
- Structure size : 48-100 ft x 18-27 ft x12-18 ft
- Containers : MS angle / GI pipe racks for bags / shelves
- Composting : Short method

- Yield : 18-22 kg / 100 kg compost in 4-6 weeks of harvesting

## 2.2. Spawn production

Spawn is the planting material for mushrooms. Following steps are generally followed for production of spawn.

Wheat grains
↓
Boiled in water (1:1.5 w / v)
↓
Drain off excess water
↓
$CaCO_4$ (12 g / kg of grains) and $CaCO_3$ (3 g / kg of grains)
↓
Filled in bottle
↓
Sterilized at 22 psi for 90 minutes
↓
Incubation with pure culture
↓
Spawn

## 2.3. Production of edible mushrooms in hot and arid region

### 2.3.1 White Button Mushroom (*Agaricus bisporus*)

- Favourable season: October to March / April (for plains of India) and Novemner to February for hot and arid region
- Required temperature and relative humidity:14-22°C and 80-85%

Cultivation of white button mushroom involves following four steps.

i. Compost / substrate preparation
ii. Spawning
iii. Casing (covering the spawned compost)
iv. Cropping and crop management

**Table 3. Materials required for compost preparation**

| S. No. | Particular | Quantity |
|---|---|---|
| 1 | Wheat straw | 300 kg |
| 2 | Wheat bran | 15 kg |
| 3 | Ammonium sulphate or CAN | 9 kg |
| 4 | Super phosphate | 3 kg |
| 5 | Muriate of potash | 3 kg |
| 6 | Urea | 3 kg |
| 7 | Gypsum | 30 kg |
| 8 | Furadan | 150 g |
| 9 | B.H.C. | 150 g |

### Compost preparation

Compost is prepared from agricultural wastes like straw, stem, shoot etc. This compost is pasteurized by various micro-organisms and at appropriate temperature range. Essential supplement are also added to the compost. The whole process is termed as composting. There are two methods of composting, long method and short method. Long method is an outdoor process and takes around 28 days whereas short method lasts for 20-22 days. Long method is usually followed at marginal and small scale production. Compost provides nutrients, minerals, vitamins and ions required for proper growth of mushroom. The materials required for compost preparation by long method are given in Table 3.

Steps of compost preparation are given below.

i. Watering the straw

   Wheat straw is spread on cemented floor and is turned several times with water being spread at regular intervals. Moisture content of straw should be 75%.

ii. Day 0:

   Wheat bran, calcium ammonium nitrate (CAN), urea, murate of potash and super phosphate are mixed thoroughly and evenly in the straw. Mixed material is piled/heaped. Water is sprayed twice or thrice to keep the substrate moist. Temperature in the range of 70-75! would be beneficial.

iii. 1st turning Day 6: turning is given to the straw so that every portion of the pile should get equal amount of aeration and water.

iv. 2nd turning (Day 10)

v. 3rd turning (day 13): alnog with turning, gypsum and furadan are mixed at this stage.

vi. 4th turning (day 16)

vii. 5th turning (day 19): compost is turned and B.H.C. is added.

viii. 6th turning (day 22)

ix. 7th turning (day 25): if no ammonia persists in the compost, spawning is done.

## Spawning

The process of mixing spawn in the compost is known as spawning. Spawn is thoroughly mixed in the compost at the rate of 600-750 g per 100 kg of compost. The spawned compost is filled in tray or polythene bags covered with formalin treated newspapers. After spawning, temperature and humidity of crop room should be maintained at 22-25°C and 85-90%, respectively. After 12-14 days of spawning white mycelium growth is seen on the compost.

## Casing

After mycelium growth, compost is covered with casing soil. Casing is done to maintain the moisture content and exchange of gases within the surface of compost which helps in appropriate growth of mycelium. pH of casing material should be 7.5-7.8 and must be free from any infection or disease. Casing soil is prepared from different materials such as well decomposed Farm Yard Manure (2 years old), well decomposed Spent Mushroom Compost (2 years old), composted coir pith, decomposed powdered bark, paper industry waste, burnt rice husk, soil etc. The casing material should be pasteurized and disinfected prior to its use. 4% formalin solution is generally spread on the casing material, turned thouroughly and covered with polythene sheet for the next 2-3 days. Pasteurization of casing material at 65°C for 6-8 hours is found to be more effective. Generally 3-4 cm thick layer of casing material is spread on the compost when the surface is covered by mycelium. Formalin solution (0.5%) is then sprayed. Temperature and humidity of the room should be maintained at 24±1°C and 85-90%, respectively.

**Harvesting of crop**

After casing, environmental conditions are changed by lowering the temperature to 14-18°C and RH to 85%. Pin head initiation takes place after 10-12 days of casing and the fruiting bodies of the mushroom can be harvested for around 50-60 days. The crops should be harvested before the gills open as this may decrease its quality and market value.

**Productivity**

From 100 kg compost approximately 18-20 kg mushroom can be obtained.

### 2.3.2. Oyster mushroom (*Pleurotus sajor-caju*)

- Favourable season : April to June / July
- Required temperature and relative humidity: 25 ±2°C and 85-90%

The tropical wastes like rice straw, wheat straw, corncobs, dried water hyacinth, sugarcane bagasse, banana leaves, cotton waste or sawdust are used as substrates. These materials are soaked in water (sterilized with 7- 10 g bavistin and 120-150 ml formalin / 100 litre of water for 16-18 hours) to prepare substrate. The usual rate of spawning is 2.0-2.5% of the wet substrate. But sometimes, it may be equal to that of button mushroom. Before filling the substrate in polythene bags, holes of about 1 cm diameter are made at 10-15 cm distance all over the surface for free diffusion of gases and heat generated inside. An average biological efficiency (fresh weight of mushrooms produced divided by dry substrate weight x 100) generally ranges from 70 to 80% and sometimes even more. These mushrooms remain fresh for up to 3 to 6 days in a refrigerator / cool place.

### 2.3.3. Milky mushroom (*Calocybe indica*)

- Favourable season : April to September / October
- Required temperature and relative humidity: 25-35°C and 85-90%

Milky mushroom is an edible white summer mushroom. It has moderate protein content and has good biological efficiency (60-70%) under optimum conditions. It has long shelf life. The major advantage is that it can be best fitted in relay cropping when no other mushroom can be grown at higher temperature. It has a very good scope for cultivation in hot and arid regions and it can replace the other tropical mushrooms. The steps involved in the production of milky mushroom have been shown in following flow chart.

Wheat straw / paddy straw
↓
Soak in fresh water
↓
Treat with hot water
↓
Remove excess water
↓
Mix 5% wheat bran
↓
Spawning @ 4%
↓
Casing
↓
Primordial stage
↓
Harvesting
↓
Milky mushroom

### 2.3.4. Paddy-straw mushroom (*Volvariella volvacea*)

- Favourable season : March to September / October
- Required temperature and relative humidity: 28-38°C and 75-85%

Paddy straw mushroom is the most popular mushroom in Southeast Asia. It is also common in Southern parts of India. Bundled substrates (paddy straw, banana leaves or water hyacinth) are soaked in water, drained, and then packed (layered) in the wooden frames. Spawn is mixed with each layer. The spawned substrate may be placed in a specially built incubation room with a high temperature (35 to 38°C) and high relative humidity (≥75%), or it may be covered with plastic sheets and placed under shade outdoors. For spawning, the air temperature is cooled to 35°C and the bed temperature to about 28 to 32°C. The amount of spawn to be used is about 1.5% on wet weight basis.

## 2.4. Cost-benefit status and desired temperature of different mushrooms

Cost-benefit status as well as desired temperatures of different mushrooms is given in Table 4.

**Table 4. Cost-benefit status of different edible mushrooms**

| S. No. | Mushroom species | Temp. (°C) | Substrate | Production | Cost (Rs/kg) | Market rate (Rs/kg) | Net gain (Rs/kg) |
|---|---|---|---|---|---|---|---|
| 1. | Button mushroom | 14-22 | Compost (LMC / SMC) | 14-18 kg / qt. by LMC<br>18-22 kg / qt. by SMC | 40-50 | 80-100 | 40-50 |
| 2. | Oyster mushroom | 18-28 | Wheat / paddy straw | 60-70 kg / qt. dry basis | 30-40 | 60-80 | 30-40 |
| 3. | Milky mushroom | 25-35 | Wheat / paddy straw | 50-60 kg / qt. dry basis | 30-40 | 60-80 | 30-40 |
| 4. | Paddy-straw mushroom | 28-38 | Paddy straw | 10-15 kg / qt. | 30-40 | 60-80 | 30-40 |

## 3. Structures For Mushroom Production

In early days of mushroom cultivation, mushrooms used to be cultivated outdoors. But gradually indoor cultivation started by using different types of mushroom structures. Most of the mushroom growing structures used at marginal and small levels are either simple, temporary structures or retrofit of an existing structure or permanent buildings. Commerical units use well insulated structures with heating, ventillation and air conditioning provisions. Ideal mushroom structure is well insulated, well ventilated and provides desirable temperature and humidity. The major role of mushroom structure is to provide favorable conditions for mushrooms and protect them from adverse environmental factors such as harsh weather, pests, pathogens and pollutants. Better mushroom structures perform these tasks effectively.

### 3.1. Site of the structure

Selection of suitable site for mushroom structure is very important, especially when structure is a simple, makeshift structure where the crop yield is mostly dependent on the environmental conditions of the growing site. The major factors that should be considered when selecting a mushroom production site are as follows.

#### 1) Climate conditions

Prevailing climatic conditions decides the type of mushroom to be grown. By selecting a site with ideal climatic conditions, cost of mainitaing the desired room conditions can considerably be decreased.

#### 2) Water

Mushrooms contain about 90% of water and are best grown at high humidity conditions (80-90% RH). Hence, mushroom cultivation requires large quantity of water, especially during dry spell. It needs continuous water supply during compost preparation, maintaining constant high humidity, watering mushroom bags / beds, cleaning the rooms etc.

#### 3) Environmental safety

Air-borne pollutants, chemicals and effluents could be detrimental to the mushrooms as well as health of farmers. Locations near industrial complexes, waste incineration facilities, brick kilns or sewage treatment plants should be avoided.

#### 4) Market

Mushrooms are highly perishable. The price of mushrooms depends on their quality, especially their freshness. Once mushrooms lose freshness, their marketability and price drops drastically. Hence growing site should be near to the markets.

### 3.2. Different structures for mushroom production

Mushroom structures are classified as temporary structures and permanent structures. Temporary structures are not durable and are built using locally available materials whereas permanent structures last for considerable period of time. When and where environmental conditions are within acceptable temperature and humidity ranges, a simple, open-type structure made from any available material is found enough. However, if the environmental conditions are adverse farmers need to construct a closed-type structure in which room conditions are less affected by outdoor weather conditions. Different types of mushroom structures are discussed below.

#### 3.2.1. Outdoor cultivation

Mushroom is cultivated under open conditions (Fig.1a). Compost is kept open but sometimes it may be covered with plastics after fruiting. This type of cultivation requires no investment in constructing a structure and found suitable for resource poors. This cultivation practice can be followed in humid climates.

#### 3.2.2. Readily available buildings

Many farmers use readily available buildings like godowns, warehouses (Fig.1b), cattle houses etc. for mushroom cultivation. Such structures do not require any investment. These structures are used for mushroom cultivation during cropping season only. Sometimes appropriate cooling arrangements such as water sprays, foggers, misters, air-conditioners etc. need to be provided in such structures during cultivation.

#### 3.2.3. Structures from locally available agricultural materials (thatch houses)

Locally available agricultural materials like bamboo, woods, grass, banana leaves, sugarcane bagasse, wheat straw, paddy straw etc. are used to construct thatch houses. Thatch houses are the most widely found simple growing structures. They are air permeable, thermo-insulating, light weight and highly pliable. These structures are reasonably efficient in providing desirable microclimatic conditions. However, they are susceptible to entry of contaminants, insects, pests, diseases etc. from outside which can deteriorate mushroom quality. Snails and rats and their predators eat away mushrooms, substrate bags and even growing houses. Many farmers in Haryana and Punjab use these types of structures (Fig.2). These are temporary structures and need to be constructed and repaired again and again.

#### 3.3.4. Improved thatch houses

Shortcomings of thatch houses are addressed in improved thatch houses. These structures are provided with appropriate sheltering, insulation, screening, barriers and other materials that could be readily placed on the structures. Installing proper physical and chemical protective barriers is recommended for these thatch houses. Protective barriers include fencing, shade net (Fig.3a), insect net (Fig.3b), plastic sheeting, rodent repellent etc.

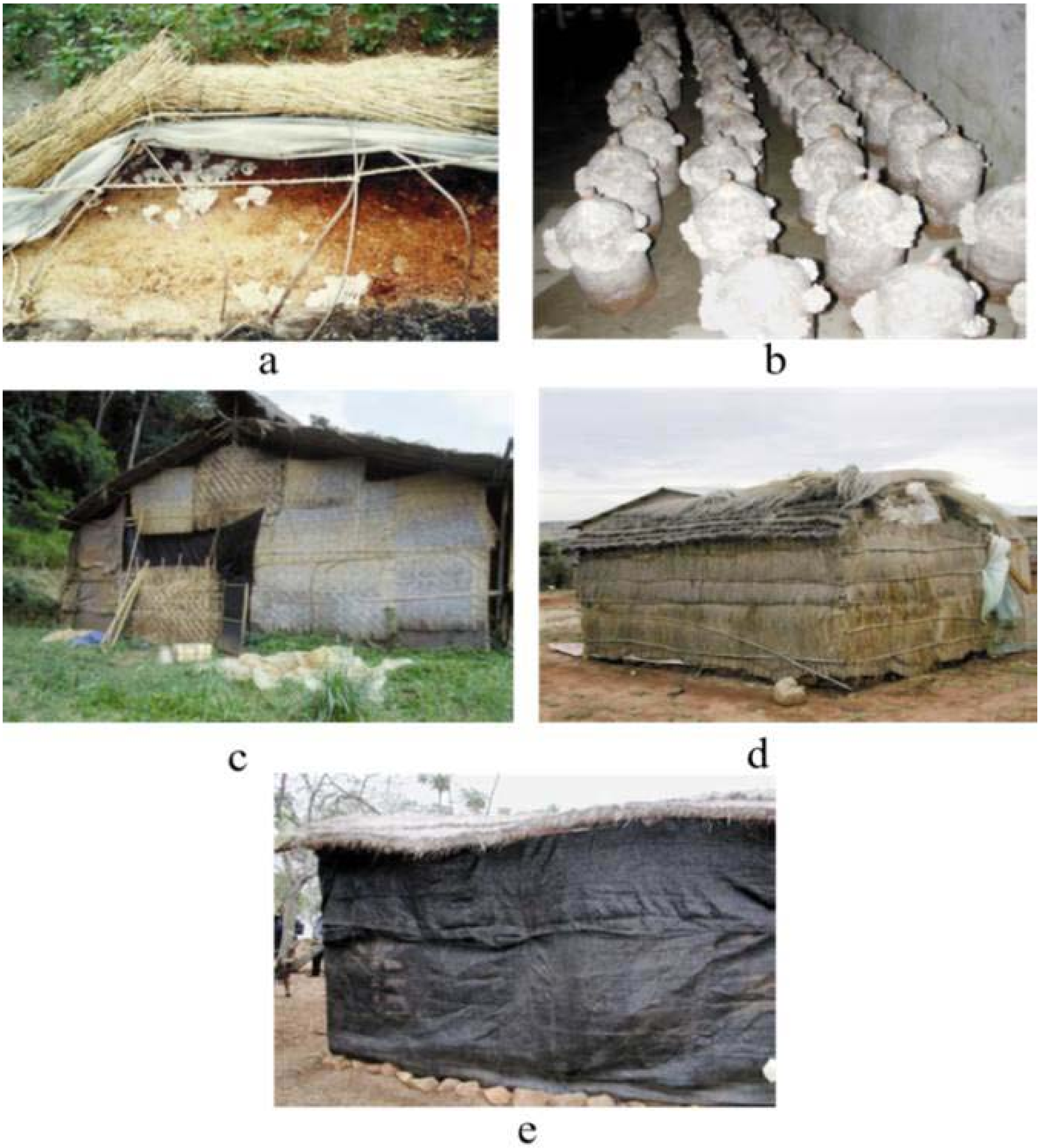

**Fig. 1. (a) Outdoor straw mushroom cultivation, (b) warehouse-turned mushroom structure, (c) bamboo mating house, (d) thatch mushroom structure, (e) thatch mushroom structure draped by shade cloth (Source: Kwon et al., 2004)**

**Fig. 2. Structures from locally available agricultural materials in Haryana and Punjab (Photo courtesy: S. J. Kale)**

### 3.3.5. Brick and clay houses

Thatch wears out within few years. Once it begins to leak, the thatch structure need to be renewed. Also, thatch structures are not found reliable in heavy rains and storms. Commercial scale units want more durable growing structures that are suitable for all seasons. Clay and bricks (Fig.3c) are found better options over agricultural wastes as they allow for good insulation, ventilation and prevention from pests and diseases. Walls of such structures are made of bricks and clay whereas any suitable material is used for the roof depending upon material availability and their preferences. Such structures are provided with ventilation openings in order to ensure frequent air-exchanges.

### 3.3.6. Ventilated structures with pitched roof

Open type structure with pitched-roof permits good ventilation (Fig.3d). Higher rate of air exchange helps in cooling of structure. However, the control of humidity in this structure is not easy when the weather is too dry or too wet. The system requires more water than other closed-type structures because of greater evaporation water loss. Such structures are suitable during hot and humid conditions.

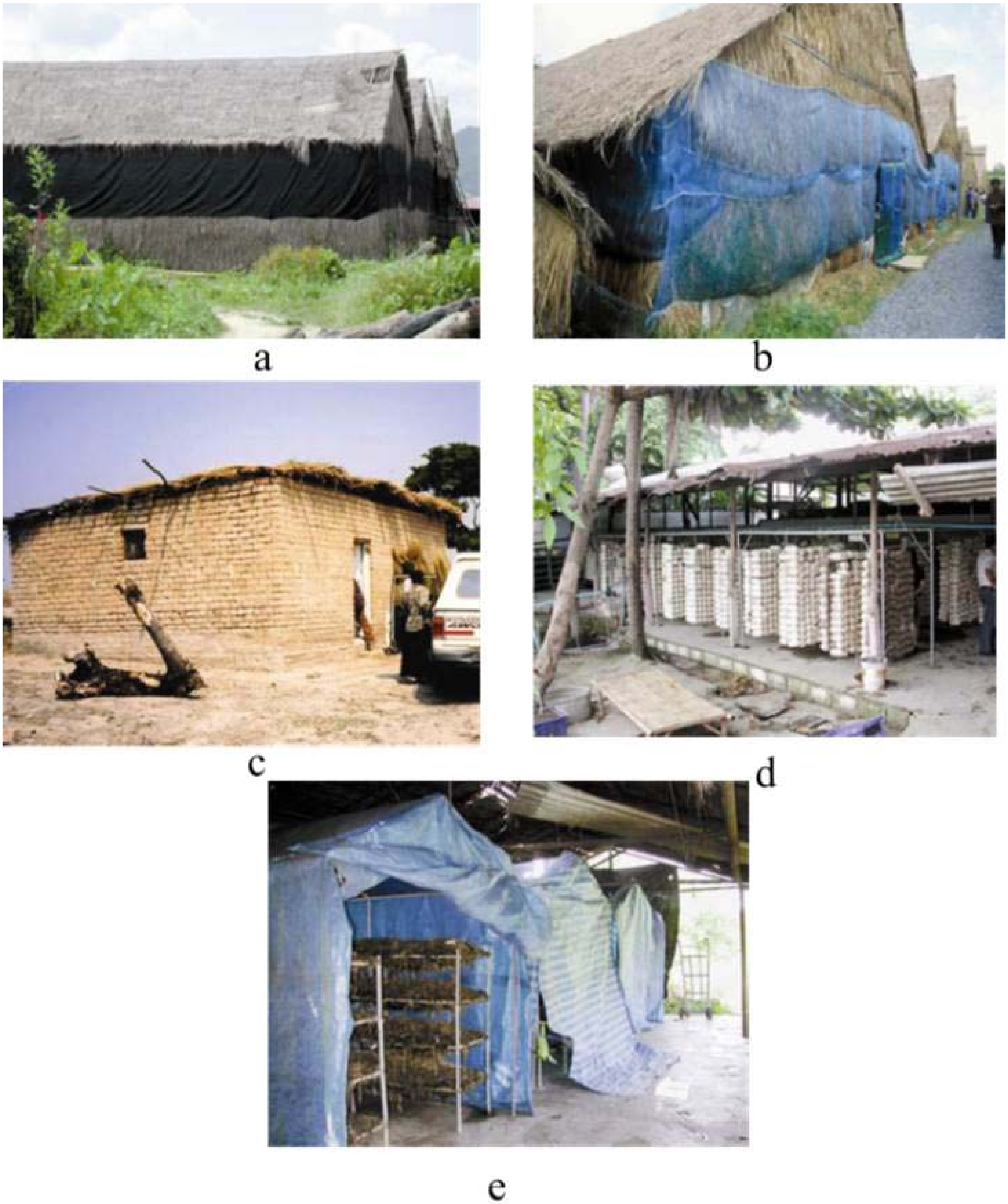

**Fig. 3. (a) Thatch house with shade net, (b) thatch house with insect net, (c) thatch house with brick walls, (d) steel frame structure with roof, (e) steel structure covered with tarpaulin/plastic (Source: Kwon et al., 2004)**

### 3.3.7. Steel structures draped by a plastic covering

These draped structures (Fig.3e) are more insulated from outside weather conditions, but are still simple structures. The proper covering provides a good insulation and a high humidity holding capacity for the structure but farmers need to pay close attention to temperature and ventilation (removal of excess carbon dioxide and supply of oxygen).

### 3.3.8. Permanent mushroom structures

Structures described above are temporary in nature and vulnerable to various biotic and abiotic factors that affect quality and growth of mushrooms. Therefore, these structures may not be suitable for round the year production as well as large scale mushroom production. In order to achieve sustainable production of mushrooms, with adverse climate conditions and varying seasons, well insulated growing structures are essential. Farmers invest considerable amount of money to set up such growing houses and provide an ideal microclimate for the growth of mushrooms to produce the highest yields possible. Such structures require more input cost and higher technology to set up but provide better drainage, ventilation and temperature control.

In these closed-type permanent structures (Fig.4), temperature, humidity and $CO_2$ concentration are monitored and controlled at all the times. Such structures are equipped with sensors and controllers to maintain desirable microclimate. These structures are durable, simple insulation houses and last for 15 years or even more.

**Fig. 4. Permanent mushroom structures**

### 3.3.9. Mushroom polyhouse

An ideal mushroom structure may not be a high-tech, high-cost structure with all automatic controls. The most desirable characteristic of mushroom structure is preventing possible pests and pathogens and maintaining desirable temperature, humidity and air exchanges. Hence, in recent years, mushroom is being cultivated in specially designed polyhouses (Fig.5) which provide all the desirable characteristics. Such mushroom polyhouses are quite popular in China as well as European countries whereas In India, farmers are still unaware of polyhouse cultivation of mushrooms.

**Fig. 5. Mushroom polyhouse structures in China**

Mushroom does not require sunlight for photosynthesis therefore; mushroom polyhouses are covered with insulation sheet to avoid heat gain from outside. Such structures are provided with an arrangement for ventilation, evaporative cooling, shade nets, insect net etc. Mushroom polyhouses require lesser capital investment as compared to permanent mushroom structures. They are durable, and with proper maintenance can be last for 10-15 years. Using mushroom polyhouses, farmers can cultivate different mushrooms round the year.

### 3.3.10. Mushroom polyhouse structure at ICAR-CIPHET Abohar, Punjab

As a fungus, mushroom needs moist environment and moderate temperatures to flourish. Hence, temperature and relative humidity inside mushroom structures need to be controlled precisely. Attainment of desirable environment is easier in temperate regions. On the contrary, it is quite difficult in hot and arid regions. Abohar is located in hot and arid region of Punjab. Some of the farmers of this region grow button mushroom from November to February. However, they are able to grow only one crop during season due to unfavorable climatic conditions. Also, cultivation of oyster mushroom in the region is difficult during April-August as temperature during this period is very high (up to 50°C) and relative humidity drops considerably (up to 10% from April-June). Hence, in order to increase the cultivation season of button mushroom and to provide favorable conditions for oyster mushroom, a specially designed mushroom polyhouse structure (Fig.7) was constructed at ICAR-Central Institute of Postharvest Engineering and Technology (CIPHET), Abohar, Punjab under All India Coordinated Research Project (AICRP) on Plasticulture Engineering and Technology (PET) scheme.

Description of experimental site is given below:

- Location: ICAR-CIPHET, Abohar, Punjab
- Latitude: 30.167°N
- Longitude: 74.18° E
- Altitude: about 390 m above the mean sea level
- Average annual rainfall: 328 mm (200-500 mm)
- Monthly Average Insolation (kWh / $m^2$ / day): 5.07

This mushroom polyhouse is insulated from external environment using jute, EPF thermocol and UV-stabilized polythene. It is also provided with two evaporative cooling arrangements namely, foggers and Fan-pad system to control inside temperature and relative humidity. A pasteurization unit, in the form of polytunnel, is also provided with the structure to prepare compost at elevated temperatures (≥40°C).

**Specifications of the structure are as follows (Fig. 6 and 7).**

- Orientation: east-west
- Dimensions: length - 15 m, width - 4 m, ridge height - 4.27 m
- Foundation walls: height - 1.22 m, width – 0.2 m
- Roof: ridge height from the floor - 4.27 m, eve height from the floor - 2.13 m.

It is a multi-layered roof composed of iron net (half inch mesh), polythene sheet (25 micron), jute sheet (2-3 mm thick), EPF thermocol sheet (8 mm thick) and UV stabilized polythene sheet (400 micron). Thermal conductivities of all these materials are listed in Table 5.

- Walls: Front wall - centre height is 4.27 m, front wall is furnished with two 18 inch exhaust fans. Rear wall - centre is height 4.27 m.

  Evaporative cooling pad is provided in the rear wall (Fig.7).

  Pad: material *khus*, length - 4 m, height - 1. 37 m, thickness - 4 cm.

- Floor: floor material: single layer vertical brick

  Floor of the structure is at **1 m deep** below ground level

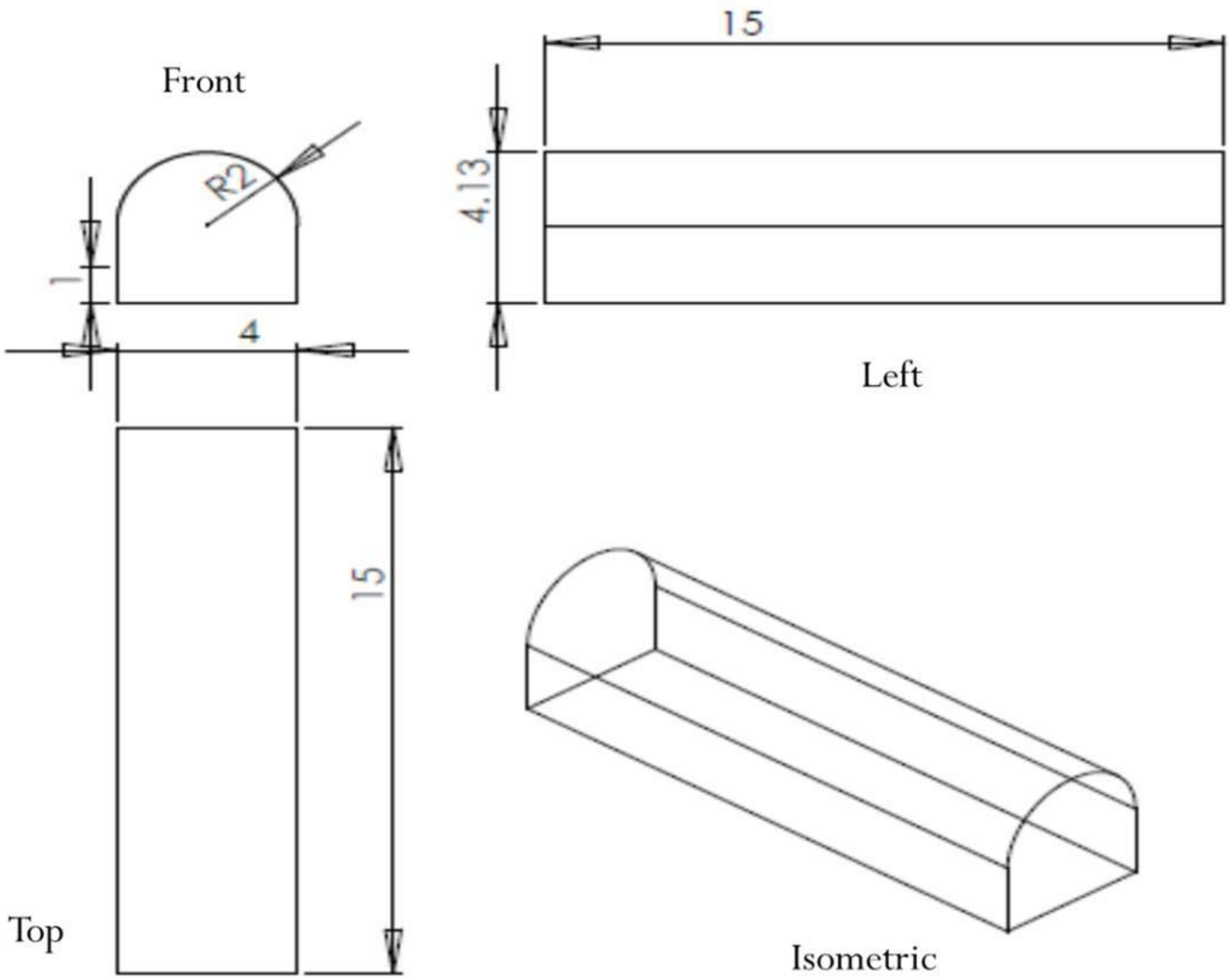


**Fig. 6. Conceptual diagram of mushroom polyhouse (Dimensions in 'm')**

**Table 5. Thermal conductivities of different materials used in roof**

| Roof material | Thickness (mm) | Thermal conductivity | Reference |
|---|---|---|---|
| EPF (expanded polyurethane foam) thermocol | 8 mm | 0.0245 w / m.K | Table A–6 adapted from ASHRAE, Handbook of Fundamentals |
| Jute sheet | 3 mm | 0.25 w / m.K | Kawabata and Rangaswamy (2001) |
| UV stabilized black polythene sheet (300 gsm) | 0.4 mm | 0.45 w / m.K | 23C. 55-120. Polyethylene - Low Density. LDPE. 100-200. 50. |
| LDPE Polythene sheet | 0.025 mm | 0.33 w / m.K | 23C. 55-120. Polyethylene - Low Density. LDPE. 100-200. 50. |

– to provide extra height to the structure with minimized **risk of overturning** due to strong winds
– to achieve more **cooling effect** through evaporative cooling system (overhead foggers).

**Fig. 7. Mushroom polyhouse at ICAR-CIPHET, Abohar**

o Door: double door frame

## Temperature profile inside mushroom polyhouse

After its construction, temperature profile inside mushroom polyhouse was determined. Temperatures at 9 different locations inside mushroom polyhouse were recorded under no crop load condition (Fig. 8). No any cooling arrangement was provided to the structure during this period. It was found that different locations in the structure attained different temperatures. Lower tier (T3, T6 and T9) showed considerably lower temperatures (by about 10°C) compared to other six locations (Fig. 9). It might be due to the height of the structure and depth of the floor. T9 showed the least value of temperature.

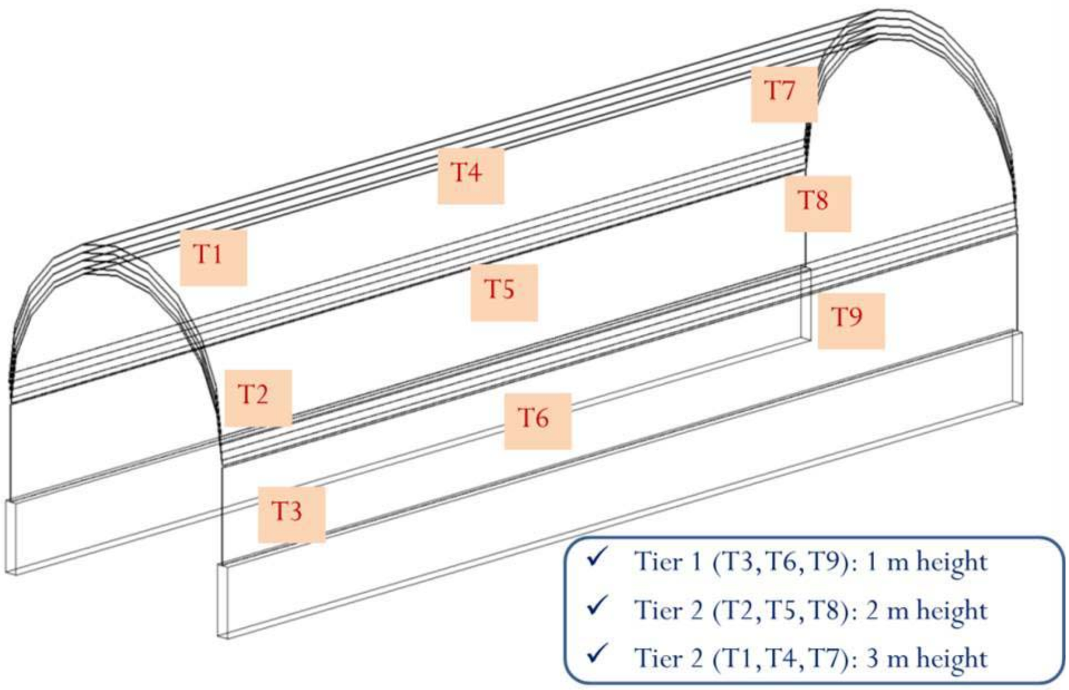


**Fig. 8. Temperature profile inside mushroom polyhouse**

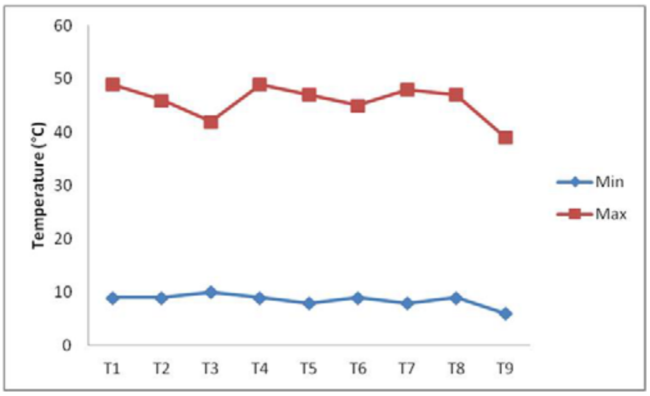


**Fig. 9. Maximum and minimum temperatures recorded during day hours**

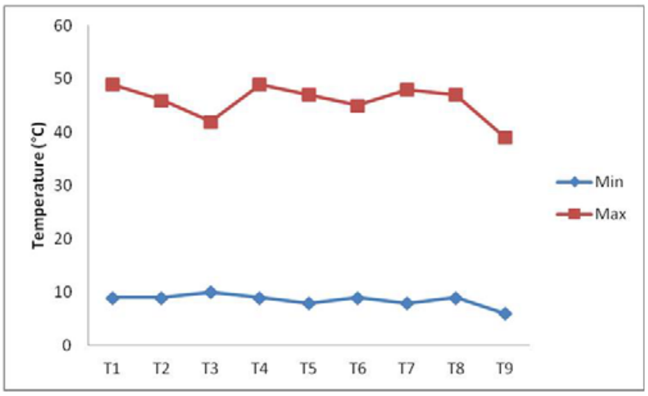


**Fig. 10. Temperature behavior inside and outside the structure in October month**

### Empty polyhouse analysis

- No cooling provided
- Data recorded continuously for 24 h

### Heat gain by Mushroom polyhouse

Heat gained by mushroom polyhouse was determined in the study. Heat load was the total heat accounted for increasing or decreasing the temperature inside mushroom polyhouse. Total heat gain ($Q_T$) inside polyhouse was due to,

- heat inflow from surroundings ($Q_S$)
- heat generated by compost ($Q_C$)
- heat generated by workers ($Q_W$)
- heat generated by data logger, battery etc. ($Q_D$)

$$Q_T = Q_S + Q_C + Q_W + Q_D$$

However, $Q_{C,}$ $Q_W$ and $Q_D$ were negligible in comparison to $Q_S$ ($Q_C$ >> $Q_{C,}$ $Q_W$ and $Q_D$ ). Hence $Q_S$ was given more consideration during study.

$Q_S$ had two components: heat gain through roof ($Q_R$) and heat gain through walls ($Q_W$) as shown in Fig.11.

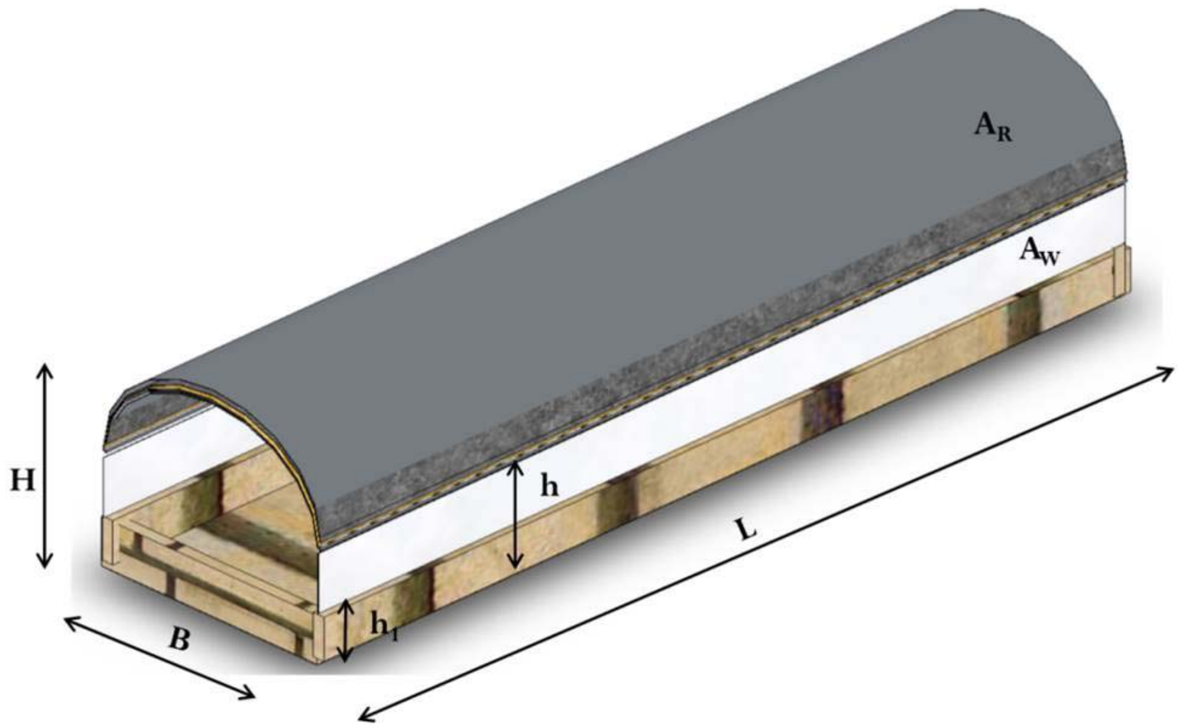


**Fig. 11. Surface area exposed to the surrounding**

Description of the dimensions mentioned in Fig.11 is as follows.

L = 15 m  B = 4 m   H = 4.27 m   h = 2.36 m   H – h = 1.91 m   $h - h_1$ = 1.3 m

Surface area exposed to the surrounding was determined as follow.

1. Roof area ($A_R$) = 89.38 $m^2$
2. Wall area ($A_W$) = 66.23 $m^2$

Heat gain through roof ($Q_R$) was determined using Eq.1.

$$Q_R = U_R A_R \Delta T \quad \text{...(1)}$$

$U_R$ was determined using Eq.2

$$\frac{1}{U_R} = \frac{1}{h_i} + \frac{x_P}{K_P} + \frac{x_J}{K_J} + \frac{x_F}{K_F} + \frac{x_U}{K_U} + \frac{1}{h_o} \quad \text{...(2)}$$

Where, $Q_R$ = heat infiltrated through roof (W)

$U_R$ = overall heat transfer coefficient of roof (W / $m^2$K) = 2.29

$A_R$ = roof area ($m^2$)

ΔT = temperature difference of inside and outside of roof (°C)

h = convective heat transfer coefficient of air at low speed (W / $m^2$.K)

X = layer thickness ($X_P$= polythene, $X_J$= jute, $X_F$= foam, $X_U$= UV stabilized polythene)

K = thermal conductivity of layers ($K_P$= polythene, $K_J$= jute, $K_{PF}$= foam, $K_U$= UV-stabilized polythene)

Heat gain through wall ($Q_W$) was determined using Eq.3.

$$Q_W = U_W A_W \Delta T \quad \text{...(3)}$$

$U_W$ was determined using Eq.4

$$\frac{1}{U_W} = \frac{1}{h_i} + \frac{x_U}{K} + \frac{1}{h_o} \quad \text{...(4)}$$

Where, $U_W$ = overall heat transfer coefficient of wall (W / $m^2$.K) = 9.12

$A_W$ = surface area of wall ($m^2$)

ΔT = temperature difference of inside and outside of wall (°C)

Total heat gained during October and November months was determined and presented in Table 6. It was observed that heat gained by the structure was dependent on outside temperature and varied with the months of year. Consequently, cooling requirements varied with the month.

**Table 6. Heat gained by structure during two different months**

| Month | Average Outside temp (°C) | Roof | | | Wall | | | Total heat gain ($Q_T$ in W) |
|---|---|---|---|---|---|---|---|---|
| | | Area ($M^2$) | $U_R$ ($W/M^2K$) | $Q_R$ (W) | Area ($M^2$) | $U_W$ ($W/M^2K$) | $Q_W$ (W) | |
| Oct | 30.91 | 89.38 | 2.29 | 371.79 | 66.23 | 9.12 | 2479.3 | 2545.51 |
| Nov | 25.95 | 89.38 | 2.29 | 638.04 | 66.23 | 9.12 | 1010.3 | 1648.3 |
| Dec | 16.0 | 89.38 | 2.29 | 321.2 | 66.23 | 9.12 | 612.3 | 933.5 |
| Jan | 14.6 | 89.38 | 2.29 | 293.5 | 66.23 | 9.12 | 692.1 | 985.4 |
| Feb | 19.7 | 89.38 | 2.29 | 381.6 | 66.23 | 9.12 | 863.2 | 1244.8 |
| March | 22.9 | 89.38 | 2.29 | 492.5 | 66.23 | 9.12 | 2132.1 | 2624.8 |

## Cooling of mushroom polyhouse

### Two evaporative cooling arrangements were provided:

1. Foggers

   During *spawn run*, structure needs to be closed without air exchange to achieve desirable $CO_2$ concentration. During this period, cooling is possible with foggers only. Fan-pad system would reduce $CO_2$ concentration and hence may not be advisable.

2. Fan-pad system

   This system is useful during case run and cropping period as air exchange is desirable during *fruiting stage*.

### Water requirement for cooling the structure using evaporative cooling system

Amount of water required to cool the structure using evaporative cooling system was calculated using following equation (Eq. 5).

$$V \times \rho \times C \times \Delta T = \frac{d_m}{d_t} \times \lambda \qquad \dots (5)$$

Where, V = volume of polyhouse ($m^3$)

$\rho$ = density of air ($kg/m^3$)

C = specific heat of air (kJ/kg)

$\Delta T$ = temperature difference (°C)

m = mass of water required (kg)

$\lambda$ = latent heat of water (2257 kJ/kg)

Water required to reduce the inside temperature using evaporative cooling system was determined as 0.13 litre/°C. Therefore, water required to reduce inside temperature by approximately 10°C was about 1.3 litre. However, structure was receiving heat continuously from the sun. Hence, in actual sense, more water required to be sprayed / misted to achieve desired temperature.

### Efficacy of mushroom polyhouse in providing desirable environment

Fan-pad system and foggers were operated individually and temperatures and relative humidity inside structure were determined at different locations. Based on data recorded, following observations were made.

- ✓ During summer months (May to early-July), average ambient air temperature during day time varied from 32 to 49°C. Such high temperature was not desirable for cultivation of oyster mushroom. However, CIPHET mushroom polyhouse could provide desired temperature (28-35°C) and RH (80%) using evaporative cooling arrangements. Favourable temperature and RH were achieved by operating Fan-pad system for 50 minute and foggers for 40 min.
- ✓ During October, average ambient air temperature was 31°C whereas structure maintained inside temperature between 23-31°C. With evaporative cooling, inside temperature and RH were altered to 22-27°C and e”80%, respectively. These conditions were suitable for *spawn run* of button mushroom. Similarly, during November, structure could provide 20-23°C temperature and RH e”80%. These conditions were found suitable for *spawn run* and *case run* of button mushroom. Similar results were observed in February and early-March also.
- ✓ Thus, study revealed that oyster mushroom can be efficiently cultivated in hot and arid region from May to early-July in CIPHET Mushroom polyhouse. Similarly, cultivation of button mushroom can be started in October month (one month earlier) and it can be carried till early-March in hot and arid region using developed mushroom polyhouse.

Crop production and return (in Rs.) per annum from CIPHET mushroom polyhouse is given in Table 7.

**Table 7. Crop production and return (in Rs.) per annum from CIPHET mushroom polyhouse**

| Crop | Number of crops | Average production | Total production (kg) | Market price (Rs.) | Return (Rs.) |
|---|---|---|---|---|---|
| Button | 2 | 16 kg / qt of compost | 1280 | 100 | 128000 |
| Oyster | 1 | 14 kg / qt of compost | 560 | 80 | 44800 |
| Total | | | | | 172800 |

### Economic evaluation of CIPHET mushroom polyhouse

Input costs, net return and benefit-cost ratio (B / C ratio) are presented in Table 8.

**Table 8. Economic evaluation of CIPHET mushroom polyhouse**

| | Particular | Amount (Rs) | Particular | Amount (Rs) |
|---|---|---|---|---|
| | **Cost** | | | |
| 1. | **Non-recurring cost (fixed cost)** | | | |
| | UV stabilized polythene | 20000 | Cement | 4000 |
| | EPF thermocol | 12000 | Bricks | 20000 |
| | Jute | 5600 | GI and MS pipes | 72000 |
| | Plastic | 900 | Labor | 16000 |
| | Iron net | 10000 | Misc. | 12500 |
| | Insect net | 6000 | | |
| | **Total** | | | 180000 |
| 2. | **Interest (on fixed cost)** | | | |
| | @ 15% per annum and depreciation @ 10% per annum on initial investment | | | Rs. 45000 |
| 3. | **Recurring cost** | | | |
| | Cost of straw, spawn, chemical treatments, electricity, labour, water, polythene, packaging etc.(2 crops of button mushroom and 1 crop of oyster produces about 1840 kg mushroom) | | | Rs. 35 / kg of mushroom |
| | Total recurring cost for three crops | | | Rs. 55200 |
| | **Total cost per annum (2 + 3)** | | | Rs. 100200 |
| | **Benefit** | | | |
| 1. | **Total mushroom production** | | | |
| | Button mushroom (2 crops) | | 1280 kg (@16kg / qt of compost | |
| | Oyster mushroom (1 crop) | | 560 kg (@ 14 kg / qt of compost | |
| 2. | **Total income** | | | |
| | Button mushroom (2 crops) | | Rs.128000 (@ Rs.100 / kg | |
| | Oyster mushroom (1 crop) | | Rs. 44800 (@ Rs.80 / kg | |
| | **Total income** | | | Rs. 172800 |
| 3. | **Net benefit per annum** | | | Rs. 72600 |
| 4. | **Benefit : cost ratio** | | | 1.38 |

## 4. Postharvest Management of Mushrooms

Mushrooms are highly perishable due to high moisture content (about 90%). Even after harvesting mushrooms continue to grow and respire resulting in weight loss, veil-opening, browning, wilting and spoilage. Almost all the mushrooms have very short shelf-life. Paddy straw mushroom has the shortest (few hours) whereas milky mushroom has better shelf-life (3-5 days). Postharvest losses in mushrooms include blackening of button mushrooms, cap opening in paddy straw mushroom and mucilage in the oyster mushroom. Weight loss is very serious problem in all the mushrooms as they are not protected by conventional cuticle. All the lethal changes in mushrooms demand utmost postharvest care. Withholding of fresh mushrooms at any point of supply chain is neither feasible nor advisable as it may result in deterioration in quality. Appropriate information about postharvest management and processing of mushrooms is therefore essential. With the adoption of suitable packaging, storage and processing techniques, postharvest losses in mushrooms occurring due to improper handling, seasonal gluts, distress sales etc. can be limited.

India is primarily a market for a fresh mushroom with very little quantity of mushroom is canned, mainly for export purpose. However, coming days are going to witness better contribution from processing sector also. Demand for processed mushroom products is now increasing day by day. Hence, information about packaging, storage as well as value addition of mushrooms is very important. Thus, postharvest management of mushrooms has two components: 1) appropriate packaging and storage of fresh mushrooms; 2) processing for production of value added products.

### 4.1. Packaging

Packaging of mushrooms is an important aspect of postharvest management. Packaging is required to deliver the produce safely from production site to the consumers. Generally, transparent packaging is used to increase consumer confidence in the product. If the packaging and storage is not done properly, mushrooms deteriorate in their saleable quality as well as nutritional quality due to enzymatic changes. Mushrooms are packed in many ways as per retail, whole sale and transport requirements.

The most common method of packaging in developing countries like India is small polyethylene or polypropylene packets containing 200 or 400 g of mushrooms. Quantities more than this have a tendency to lose their acceptability. Mushrooms packed in tray with transparent covering are shown in Fig.12.

**Fig. 12. Tray packed mushrooms (Source: Rai and Arumuganathan, 2008)**

Many other alternatives like CFB boxes, corrugated polypropylene bond boxes, plastic trays, crates, woven sacks, thermoformed plastic trays and stretch film and shrink wrapping are also available for packaging of mushrooms. Other improved packaging systems suitable especially in developed countries are modified atmospheric packaging (MAP), controlled atmospheric packaging (CAP) and modified humidity packaging (MHP).

**Table 9. Consumer preferences for different quality factors (Source: Gormley and Mac Canna, 1967)**

| S. No. | Quality factor | Consumer emphasis |
|---|---|---|
| 1. | Whiteness | 3 |
| 2. | Degree of maturity | 3 |
| 3. | Free from disease | 3 |
| 4. | Flavor | 2 |
| 5. | Aroma | 2 |
| 6. | Toughness | 2 |
| 7. | Cleanliness | 2 |
| 8. | Size and shape | 2 |
| 9. | Nutritional value | 1 |

(3= very important; 2= less important; 1= not very important)

Various quality parameters are used to identify the quality of fresh button mushroom (Table 9). Out of these parameters, consumers mostly prefer color (whiteness) and stage of maturity to differentiate among mushroom samples.

### Washing

Button mushrooms need to be washed before packaging, sale or processing. Although, many consumers have developed a preference for washed mushrooms, some still prefer unwashed. Washing is essential to remove adhering soil and dust but washed mushrooms deteriorate faster than unwashed. Surface water due to washing results in shogging and spoilage by bacteria. Mostly, plain water is used for washing that makes mushrooms free from adhering casing soil, but it does not impart whiteness to mushroom. Hence, some of the pretreatments have been suggested to improve and maintain whiteness. Dipping mushrooms in dilute solutions of hydrogen peroxide (1:3) for half an hour and then steeping in 0.25 per cent citric acid solution containing 550 ppm sulphur dioxide maintains the whiteness (Pruthi *et al.*, 1984).

### 4.2. Transportation

Mushrooms need complete cool-chain for storage and transport. Polypacks of mushrooms are stacked in small wooden cases or boxes with sufficient crushed ice in polypacks (over wrapped in paper). For transport of the large quantities to the long distances, refrigerated trucks are essential.

### 4.3. Storage

Freshly harvested mushrooms need to be stored properly to retard/delay postharvest deterioration. The refrigeration or cold-storage is the most essential part of the storage of mushrooms. Most of the times, pretreatments, packing and precooling precede the refrigerated storage. The requisite temperature and humidity for storage of mushrooms and their derivatives are given in Table 10.

**Table 10. Requisite temperature and RH for storage of mushrooms**

| Mushroom | Temperature (°C) | Storage period | RH (%) |
|---|---|---|---|
| Fresh | 0 – 1.1 | 3 – days | 87 – 92% |
| CA storage | 0 – 1.1 | 5 – 8 days | 87 – 92% |
| Refrigerated | 0 – 3.3 | 6 – 8 weeks | Plastic vessels with water tight lids |
| Frozen | -18 to -23<br>-23 to -29 | 3 months<br>6 months | Vapor proof packaging |
| Canned | 21 -24<br>04-Jul | 1 year<br>2 years | 30 – 50% |
| Dehydrated | 21<br>2.2 | 6 months<br>1 year | Gas tight vacuum packaging |

## 4.4. Steeping

Steeping preservation of mushrooms is simple and economical way for extension of shelf-life of mushrooms. Mushrooms can be preserved for periods ranging from 3-6 months by steeping them in concentrated solutions of salts or acids. Steeping extends shelf life and also retains whiteness of mushrooms. Cost of the canned and freeze-dried mushrooms is very high and not many can afford such products. Under such circumstances, steeping is found very appropriate processing technique. In steeping process, mushrooms are washed in water and filled in plastic containers. It is followed by blanching in a brine solution for 5 minutes. Sometimes blanching is done before filling them in containers. Brine solution is then added into the cans or containers. Brine solution consisting of 2 % sodium chloride, 2% citric acid, 2 % sodium bicarbonate and 0.15 % KMS was found appropriate for steeping the mushrooms (Kapoor, 1989).

## 4.5. Drying

Mushrooms contain approximately 90% moisture at the time of harvesting and are dried up to moisture content of 7-8%. The temperature of drying air, moisture content of mushroom and humidity of air affect the color of the dried product. Dried mushrooms are used in several foods such as instant soups, pasta, snack seasonings, casseroles, and meat and rice dishes. Almost all the mushrooms, except button mushroom, are traditionally dried for long-term storage. Button mushroom becomes brown or black, changes its texture, which often discourage its drying. Following drying methods are used to dry the mushrooms.

i. Sun-drying
ii. Cabinet air drying
iii. Dehumidified air cabinet drying
iv. Osmo air drying
v. Freeze drying

vi. Fluidized bed drying

vii. Microwave drying

### 4.6. Value added products

Various value added products can be prepared from mushrooms. Preparation methods of these products are given below (Rai and Arumuganathan, 2008).

#### 4.6.1. Pickle

Mushrooms
↓
Washing (0.05 % KMS)
↓
Slicing (4 parts)
↓
Blanching (5-8 min with 2 % salt + 0.1 % citric acid)
↓
Mixing of salt with blanched mushrooms
↓
Treating for over night
↓
Removal of oozed-out water from mushrooms
↓
Mixing of acetic acid, sodium benzoate and spices with treated mushrooms
↓
Mushroom pickles

Ingredients: black mustard seed powder 35 g / kg, turmeric powder 20 g / kg, red chili powder 10 g / kg, cumin seed powder 1.5 g / kg, fennel seed powder (*saunf*) 1.5 g / kg, carom seed (*ajwain*) 10 g / kg, nigella seed (*kalonji*) 10 g / kg, oil 200 ml / kg Salt 90 g / kg.

#### 4.6.2. Mushroom soup powder

Dried mushroom slices / whole oyster
↓
Grinding
↓
Mushroom powder
↓
Addition of milk powder
↓
Addition of corn flour gelatinized in refined oil @ 4 %
↓
Addition of ingredients
↓
Mushroom soup powder

Ingredients: mushroom powder 16%, corn flour 5%, milk powder 50%, refined oil 4%, salt 10%, cumin powder 2%, black pepper 2%, sugar 10%, ajinomoto 2%.

### 4.6.3. Mushroom Cookies

Ingredients + water
↓
Mixing (5 min)
↓
Keeping at 30°C for 60-90 min covered with cloth
↓
Dough
↓
Discs
↓
Oven drying at 212°C for 15 min
↓
Cookies

Ingredients: maida 100 g, sugar 30 g, fat 45 g, baking powder 0.6 g, ammonium bicarbonate 0.3 g, salt 0.6 g, vanilla essence 0.02 g, milk powder 1.5 g, glucose / fructose 1.5 g, water 12 to 22 %.

### 4.6.4. Mushroom nuggets

Mushroom powder
↓
Mixing with dhal powder
↓
Making paste by adding water
↓
Mixing of ingredients and spices
↓
Making round balls of 2-4 cm diameter
↓
Spreading on steel tray
↓
Sun drying
↓
Mushroom nuggets

Ingredients: mushroom powder 10%, urad dhal powder 80%, salt 2%, red chili powder 1%, sodium bicarbonate 0.01%, water 7%.

### 4.6.5. Mushroom ketch-up

Ingredients: 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 chili powder 1%, ajinomoto 0.2%, arrarote 0.2%.

Fresh button mushrooms
↓
Washing
↓
Slicing
↓
Cooking in 50 % of water for 20 min
↓
Making of paste
↓
Addition of ingredients
↓
Cooking (35°Brix)
↓
Filling in sterilized cans
↓
Mushroom ketch-up

### 4.6.6. Mushroom candy

Button mushrooms
↓
Washing
↓
Halving
↓
Blanching in 0.05 % KMS for 5 min
↓
Sugar treatment @ 1.5 kg / kg of blanched mushrooms for 3 days
↓
1$^{st}$ day – covering blanched mushrooms with 1$^{st}$ part of sugar for overnight
↓
2$^{nd}$ day – covering with 2$^{nd}$ part of sugar
↓
3$^{rd}$ day - removal of mushrooms from syrup
↓
Addition of remaining sugar + 0.1 % citric acid to the syrup
↓
Boiling up to 70°Brix
↓
Cooling
↓
Addition of mushroom pieces
↓
Boiling for 5 min to bring syrup concentration 72°Brix
↓
Cooling and removing of mushroom pieces from syrup
↓
Sorting
↓
Drying at 60°C for 10 h
↓
Packing and storage at cool and dry place

### 4.6.7. Mushroom preserve (*Murraba*)

Fresh button mushrooms
↓
Grading
↓
Washing in 0.05 % KMS
↓
Pricking
↓
Blanching
↓
Adding 1 kg of blanched mushrooms with 400 g sugar and curing for 24 h
↓
Adding another 400 g sugar and curing for 24 h
↓
Removal of mushrooms from syrup
↓
Add remaining 400 g of sugar and 0.1 % citric acid
↓
Boiling up to 65°Brix
↓
Addition of mushrooms
↓
Boiling for 5 min
↓
Rapid cooling
↓
Packing in jars
↓
Mushroom *murabba*

### 4.6.8. Mushroom chips

Fresh button mushrooms
↓
Slicing
↓
Blanching in 2 % brine solution
↓
Dipping in solution of 0.1 % citric acid + 1.5 % NaCl + 0.3 % red chili powder overnight
↓
Drying in cabinet dryer at 60°C for 6 h
↓
Deep frying
↓
Spices spreading / mixing
↓
Ready to eat mushroom chips

### 4.7. Canning

Canning is technique by which the mushrooms can be stored for longer periods up to a year. Canning process is divided into various unit operations which include cleaning, blanching, filling, sterilization, cooling, labeling and packaging.

**Cleaning:** Whole mushrooms are washed 3-4 times in cold running water to remove adhering substances. Use of iron free water with 0.1 per cent citric acid prevents discoloration.

**Blanching:** It is done to inhibit polyphenol oxidase enzyme activity and to inactivate microorganisms. It also removes gases from mushroom tissue and reduces bacterial counts. Mushrooms are blanched in stainless steel kettles filled with a boiling solution of 0.1% citric acid and 1% common salt. Blanching time usually ranges from 5-6 min at 95-100°C.

**Filling:** Mushrooms, after blanching, are filled in tin cans. The size of the can depends on the requirements of customer. In India, generally A-2½ and A-1 tall can sizes contain approximately 440 and 220 g drained 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.

**Lidding or Clinching:** After filling, cans are covered loosely with the lid so that dissolved gases as well as free air can escape from the contents easily. It also gives pass to vapor formed during the exhaust process.

**Exhausting:** Before sealing, it is necessary to remove all the air from contents. Hence filled cans are exhausted for 10-15 min. During exhausting, filled cans are passed through a hot steam at about 100°C on a moving chain conveyor through a covered double jacketed steam box. The time of exhaust varies from 10 to 15 min. At the end of the exhaust box, the temperature at the centre of the can should be about 80°C.

**Sterilization:** Sterilization is the process of heating the cans at high temperatures to prevent the spoilage by microorganisms during storage. Cans are kept in an autoclave and sterilized for 25-30 min, under pressure. Pressure and time varies with can and mushroom size, mushroom variety etc.

**Cooling:** Cans are cooled immediately after sterilization process to stop over-cooking and to prevent stack burning. Cooling is generally achieved by keeping cans in a cold-water tank. It also gives an abrupt shock to the microorganisms to get rid of their adverse activities.

**Labeling and Packing:** Clean and dry cans are labeled manually or mechanically and packed in strong wooden crates or corrugated cardboard cartons.

## 5. Conclusion

Production of adequate amount of edible mushrooms is obligatory to improve the nutritional status of India population. Presently the production of button mushroom, the most preferred mushroom in Indian diet, is concentrated in temperate region only. However, some amount of button mushroom is also produced in hot and arid region of north-western India comprising of parts of Punjab, Haryana and Rajasthan. However, cultivation season of button mushrooms is considerably lower in the region due to adverse climatic conditions. Hence, a study was conducted at ICAR-CIPHET, Abohar under AICRP on PET to develop a specially designed mushroom polyhouse suitable for production of mushrooms in hot and arid region. Study indicated that CIPHET mushroom polyhouse was able to increase the cultivation season of button mushroom by about 2 months during which 2-3 crops can be produced. Study also revealed that oyster mushroom can be produced in the region during April to June or early-July using CIPHET polyhouse.

Like production, postharvest management of edible mushrooms is also crucial as it reduces the postharvest losses of mushrooms. Freshly harvested button mushrooms have moisture content of about 90 % that invites numerous undesirable effects. Hence, information about safe handling, storage as well as processing for production of value added products of mushrooms is found indispensible.

## 6. References

Chang S., Hayes W. 1978. The biology and cultivation of edible mushrooms. New York: Academic Press.

Chang S.T. and Miles P.G. 2004. Mushroom cultivation: nutritional value, medicinal effect and environmental impact. CRC Press, Boca Raton.

Gormely T.R. and Mac Canna C. 1967. Prepackaging and shelf-life of mushrooms. Irish Journal of Agricultural Research, 6 (2): 255-265.

Kapoor J.N. 1989. Mushroom Cultivation. ICAR, New Delhi.

Kwon H., Kang S.W. and Cho S.B. 2004. Mushroom growing houses *In*: Oyster mushroom cultivation, Mushroom Grower's Handbook, Mush World.

Oei P. 1996. Mushroom Cultivation: with special emphasis on appropriate techniques for developing countries. Tool Publications, P.O. Box 321, 2300 AH Leiden, The Netherlands, 274.

Pruthi J.S., Manan J.K., Raina B.L. and Teotia M.S. 1984. Improvement in whiteness and extension of shelf-life of fresh and processed mushrooms (Agaricus bisporus and Volvariella volvacea). Indian Food Packer, 38(2): 55-63.

Rai R.D. and Arumuganathan T. 2008. Postharvest Technology of Mushrooms. Technical bulletin, National Research Centre for Mushrooms.

Senyah, J., Robinson, R., Smith J. 1989. The cultivation of the oyster mushroom, Pleurotus ostreatus on cocoa shell waste. Mushroom Science, 12 (2):207-218.

# NOTES

# NOTES

## CONTACT

**Head, Horticultural Crop Processing Division,
ICAR-Central Institute of Post Harvest Engineering
and Technology, Abohar-152 116
Phone: 01634-224024; Fax: 01634-225313
www.ciphet.in**


भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch