Part II. Oyster Mushrooms

Chapter 7

Cultivation Modes

BAG CULTIVATION

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Bag cultivation is the most commonly used method for mushroom cultivation in many locations around the world. Its advantages are as follows:
1) Much smaller risk of crop failure compared with other cultivation methods
2) Possible inside houses or unused structures
3) Possible with a small initial investment
5) Easy to control pests and diseases
6) Quick return of capital
7) Production is possible all year round

Substrate Preparation

Substrate materials and additives

The substrate is to mushrooms like soil is to plants. Mushroom mycelia grow on the nutritious media, taking from it the nutrients necessary for their growth. Commonly used substrate materials are sawdust, cottonseed hull, cereal straw, corncob, sugar cane bagasse, and other plant fibers with high cellulose contents. One of the merits of mushroom growing is that the agro-wastes used as substrates are very inexpensive and sometimes free. Moreover, oyster mushrooms can be grown on a wider variety of agricultural wastes than any other cultivated mushrooms thanks to their multilateral enzyme system.

At the beginning, growers must decide what kind of materials to use for the substrate. One of the best choices is using the substrate materials that a grower can secure around their neighborhood. A secure supply of readily available materials allows for sustainable mushroom production. The substrate materials are supplemented if necessary with additional nitrogen sources such as wheat bran, rice bran, sorghum, or millet. Other additives include gypsum, limestone, and sugar. Gypsum, limestone, and chalk function as buffers to control the pH value in the substrate. The proper use of additives that supply nutrients is recommended in order to achieve the best quality mushrooms.

Sawdust

Figure 1. The sawdust ready to mix on the cement floor

There are various trees available in each region that can be used as sources for sawdust. The frequently used tree species for mushroom cultivation include oak, poplar, alder, maple, birch, wild cherry, mango, and elm. It is important to select tree species that are both favorable for the growth of mushrooms and easily available. Tree species that should be avoided or that requiring significant additional treatments before their use include pine, cedar and redwood. Pine tree sawdust has resins that inhibit mycelial growth, and cedar and redwood sawdusts are also resistant to mycelial colonization.

Sawdust is mixed with water and other supplements either outdoors or indoors, either manually or mechanically. Close attention should be paid during mixing to the even distribution of water throughout the entire substrate. The substrate moisture content is usually adjusted to 65%. A palm test method is a simple way to check whether the mixture has the proper water content or not.

=Palm Test Method=

Figure 2. Optimum (left) and high substrate moisture contents

First, take a fistful of sawdust mixture and squeeze tightly. If just a few drops of water are released with pressure, the substrate mixture has the proper water content. If the sawdust is too wet, it could impede the free flow of air in the substrate. Too low a water content prohibits mycelial growth.

[Example 1. The use of sawdust as a substrate material in different countries]

Thailand - Sawdust made from rubber trees is used as a substrate material.
Bangladesh - Mango sawdust mixed with wheat bran in a ratio of 4:1 is used.
America - Oak, poplar, alder, maple, birch, and wild cherry are used as sawdust sources. Wood chips, cereal grain straw, corncob, hay, and sugar cane bagasse are used as well as sawdust. They are supplemented with such nitrogen sources as rice, wheat bran, pelt, and other grains, corn meal, and cottonseed meal at a ratio of 4 to 1. Other additives include sugar, molasses, gypsum, and limestone. All the ingredients of choice are mixed dry, and then water is added to obtain a 60-65% moisture content.
Korea - Sawdust from oak, poplar, and other broad-leaf trees are most commonly used. Some growers opt for

sawdust-only substrates and others use sawdust substrates supplemented with rice bran or other nitrogen sources. Supplements in powder form are mixed together but some supplements with tough textures need to be soaked for about 12 hours before mixing. Mixing is usually done in the ribbon mixer (Fig. 1).

Straw

Figure 3. Rice straw pile

Straw has long been favored because it is easy to get in most regions and rich in lignin and cellulose. Dirt, pest and mold-free straw should be chosen. Growers might want to secure a sustainable supply of high quality straw from one region, for this will allow for easy preparation with minimum efforts.

To make a substrate, straw is cut into one-two inch-long pieces. Different tools are used to chop the straw in different countries. Straw choppers, shredders, garden chippers and hand straw choppers are used. Extra precaution should be made not to get one's fingers into the blades. Chopped straw is soaked in water for 1-2 hours, then rinsed 2 or 3 times in clean water and left for 3 or 4 hours to drain excess water off.
The "Palm method" is also used to check whether this substrate mixture has the proper moisture content. If the moisture content is too high, the substrate is more vulnerable to infection. If the moisture content is too low, the spawn could grow poorly and the harvest quantity would decline.

[Example 2. The use of straws as a substrate material in different countries]

India - Paddy straw is used as a substrate. It is chopped manually or mechanically into bits of 3-5cm in length.
Nepal - Rice straw is cut into one or two inch pieces and soaked into water for about 1-2 hours. Then the soaked straw is washed 2 or 3 times in clean water and put aside for 3-4 hours to allow excess water to drain. Growers here prefer to supplement the substrate with protein-rich substances such as wheat or rice bran.
Vietnam - Straw is soaked in a container of limewater. The limewater contains 2kg of slacked lime per 100kg of dry straw, with as much water added as is needed to just cover the straw. The straw is left in the limewater for half an hour, so that it is thoroughly soaked. The straw is then piled up on a cement floor and covered with plastic or sacking. The top of the pile is left uncovered. The straw is left to ferment for 7-10 days. During this time, it will begin to ferment and become hot. The straw is turned once every three days, first from the top downwards, then from the bottom upwards, then from the inside outwards and finally from the outside inwards.
S. Africa - The main raw materials used as substrates here are chopped wheat straw and other available agricultural by-products such as sugarcane bagasse. These basic substrate materials are mixed with lime, gypsum and water. Wheat straw is available in large round bales (250kg), large square bales (350kg) and smaller 12kg square bales.
Some growers add organic nitrogen supplements to the substrate in the form of alfalfa meal, soybean meal, canola meal, and commercial delayed-release supplements. However, supplements are used only if sufficient cooling is available to control substrate temperatures.
Zimbabwe - The most common substrate is wheat straw and grass. Banana leaves, although higher yielding and producing higher quality mushrooms, are not usually preferred because they give a delayed break and this substrate is not as abundant as the other two.

Cotton waste or Cottonseed hulls

Cotton wastes are also a good substrate material for mushroom growing. Many growers choose cotton waste due to their experiences in which cotton wastes give higher yields than sawdust.

Figure 4. Cottonseed hull

However, using cottonseed hull alone is not desirable due to its low moisture retention capacity. The maximum water holding capacity of cottonseed hulls is about 55-58 %; therefore growers need to mix it with other substrate materials to effect a higher water content in the substrate.

[Example 3. The use of cottonseed hulls as a substrate material in different countries]

Korea - 150kg of cottonseed pellets are mixed with 30kg of beet pulp, 15kg of cottonseed residue, and 2kg of charcoal. 350kg of water is then added.
Zimbabwe - Cottonseed hulls are supplemented with lime and gypsum and then very slightly wetted overnight.

Filling and compressing

Figure 5. Bags filling and compressing

Figure 6. Bag plugging

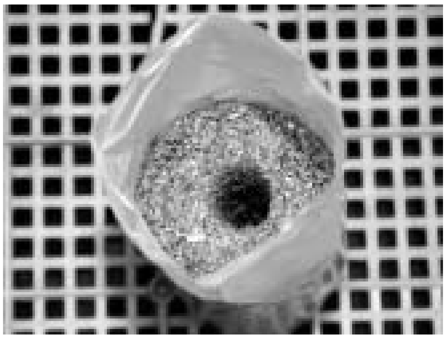

Figure 7. Inoculation hole

The prepared substrate mixture is usually filled into bags before heat-treatment, but some growers pasteurize or sterilize the substrate in bulk and then fill the bags. The first method is recommended to minimize contamination risk. The filled bags are then properly compressed for fast mycelial colonization. After filling and compressing, a 2-3cm diameter hole in the center is made that allows for inoculation down at the bottom of the bag. This permits deeper inoculation and a better oxygen supply, thus encouraging faster colonization. Growers who don't compact the bags don't always need to make an inoculation hole.

Closing the bags

Figure 8. Sealing the bags by rubber band

Figure 9. The plastic cap

The proper ventilated sealing of the bags is very important to good colonization. Mycelia need oxygen to breathe, therefore breathable plugs or stoppers are recommended for free air exchange. Plugs with cotton balls or breathable micro-filters will provide free air exchange and at the same time filter out possible contaminants.

[Example 4. Bagging in different countries]

Bangladesh - About 500g of mango sawdust is mixed with wheat bran in a ratio of 4 to 1, then watered and sterilized and then put into polypropylene bags measuring 25 × 20cm.

Nepal - Before filling, the polyethylene bags measuring 14 × 24 inches, or 18 × 26 inches are punched every two inches in rows all over the surface with a punching machine. The conditioned straw is filled about 4 inches thick at a time, pressed slightly, and then another layer of straw is added. This is called the "layer method."

Vietnam - Plastic bags measuring 20 × 30cm or 18 × 25cm are used as mushroom beds. Growers open the bags and put a handful of straw inside. They press the straw down tightly, to make a layer 3-5cm thick at the bottom of the bag. They put additional layers in the bags, and then they put a final layer of straw on top in such a way that the top of this final layer is 5-7cm below the mouth of the bag. They put a clean piece of cotton in the mouth of the bag, seal it, and then tie the bags together with a nylon rope (3-5 bags per rope) and hang them.

India - They use a wooden mold to make a bag. It is a wooden frame of 45 × 30 × 15cm size, having no top or bottom but having a separate wooden cover 44 x 29cm in size. They take the wooden frame and place it on a smooth floor, placing jute ropes underneath, two vertically and one horizontally. They then line the frame with a plastic sheet that has been previously sterilized by dipping in boiled water. They fill the frame with about 5cm of boiled straw and compress it with the help of the wooden lid, and then continue to add 4 or 6 layers.

S. Africa - Cropping containers are made of large clear or black polyethylene ducting cut into 2-meter columns (50cm in diameter) with a metal support. These hold approximately 50kg of substrate. Other growers use small plastic bags containing about 20kg of substrate. Holes are punched into the bags for aeration and mushroom maturation.

Heat treatment

Figure 10. Commercial Sterilizer

Substrate needs to be treated before spawning. Heat treatment is most frequently used to kill or reduce pests and microorganisms, and there are two categories: sterilization and pasteurization. Sterilization kills all microorganisms whether they are harmful or not to mycelial growth, while pasteurization reduces the number of microorganisms. The right pasteurization time and temperature depend on the possible pathogens in a given substrate material.

Normal pressure sterilization

Growers put the substrate bags in the autoclave or sterilizer. The desired sterilization temperature is maintained for 5-8 hours at 90-95℃, or 4 hours at 100℃ measured from the time the inside temperature has reached the target temperature. The substrates are then taken out and moved to a cooler room.

High pressure sterilization

Under pressure of 1.5kg/cm^2 or 20 psi (lb per square inch), the inside sterilizer temperature rises up to 121℃. When it reaches 121℃, the temperature is maintained for 60-90 minutes. Upon completion of sterilization, the pressure is released first. After steam comes out, the substrate bags are moved from the sterilizer to a cooler place.

Table 1. Advantages and disadvantages of high and low pressure sterilization

	Advantages	**Disadvantages**
Hight pressure	- time saving - fuel saving - complete sterilization possible	- considerable loss in substrate moisture - nutrient loss possible - high set-up cost
Normal Pressure	- little loss in substrate moisture - conditioning of nutrients for Increased absorption by mycelia - easy and low-cost to set-up	- insufficient sterilization effect - time consuming - fuel consuming

Oil drum pasteurization

Oil drums are cheap and easy to get and install in one's yard. They are widely used to pasteurize substrate bags. Usually they are mounted on bricks, rocks or any other heat-resistant material. This drum pasteurizer is an assembly of oil drum(s), metal or wooden grates, lids with steam escape hole(s) and kiln.

Oil drum pasteurization

- The first grate is fit into a notch in the drum (Fig. 13).
- Water is filled about 15cm below the grate.
- The grate surface and the drum wall are lined with linen to avoid bag burning (Fig. 14).
- The prepared bags are stacked in a layer and then on the next grates.
- The lid is placed and the lid rim is sealed.
- Water is boiled and the heating is maintained for 4-6 hours from the time when the vapor starts to rise. The pasteurization time depends on the bag size and substrate material.

Figure 13. Inside the drum sterilizer

Figure 14. Bags ready for sterilization

Outdoor, simple pasteurization

Bag pasteurization in bulk

- Substrate bags in stack and nest containers are placed on the shelf (Fig. 15).
- They are covered with plastic sheet, insulation and tarpaulin (Fig. 16).
- Steam fed into the tent-like structure by a steam boiler is passed through all the containers.

- After about 10-hour steaming, bags are left to cool to 25℃.

Figure 15. Bags ready to pasteurize

Figure 16. Bags under pasteurization. They are covered with a plastic sheet, insulation and a tarpaulin.

Figure 17. Electric boiler to feed steam into the bags in bulk.
Here is a simply way of bag pasteurization in bulk.

[Examples: substrate heat treatment in different countries]

India - Growers place a gunny bag of straw into the boiling water for 15-25 minutes. They then remove the gunny bag from the drum and let it sit for 8-10 hours to drain off the excess water and allow the straw to cool. Care is taken that the bag is not opened until the time of block making as this would possibly contaminate the boiled straw. The desirable moisture content of the straw can be tested by the "palm method."
Another method of pasteurization of straw is by steaming. This method requires little modification of the drum. Growers punch a small hole in the lid of the drum, and while boiling the straw, seal the lid with a rubber tube. They place a few stones in the drum and pour in water only to the level of the stones. They steam the wetted straw by keeping it in a bamboo basket that is placed over the stones inside the drum. They close the lid of the drum and seal the rim by means of a rubber tube. The steam generated from the boiled water passes through the straw and pasteurizes it. After boiling, they transfer the straw into a previously sterilized gunny bag and leave it sit for eight to ten hours to cool.
Nepal - The wetted substrate is steamed in a 200L drum for 1-2 hours at a temperature of 90℃. The steamed straw is then allowed to cool down. At this time some growers supplement the substrate with a protein-rich substance such as wheat or rice bran.
Vietnam - There is no special pasteurization except the fermentation is performed outdoors.
S. Africa - Substrate preparation varies from grower to grower ranging from hot water treatment to pasteurization, depending on the available equipment. Chopped wheat straw is mixed with lime, gypsum and water in rotatable pasteurization vessels. The substrate is pasteurized with live steam for 2 hours at 70-75℃ and cooled overnight.
Bangladesh Substrate is sterilized at 121℃ for 15 minutes in an autoclave and then cooled at room temperature for 24 hours.

Spawning

Mushroom spawn is a medium that carries mushroom mycelia. Most growers use spawn produced by cultivators or commercial spawn providers. Here is how to inoculate substrate bags.

Inoculation

- The work surface, inoculation room and gloves should be clean and disinfected with 70% alcohol solution. To make a 70% alcohol solution, some growers dilute methanol with water. It should be avoided since the prolonged use of methanol might cause a serious injury in the brain and eyes.

- A spoonful of spawn is put into substrate bags as quickly as possible for secure sterile operation. The spawning rate is about 2-2.5% of the dry weight of the substrate.

Figure 18. Spawning room, Swaziland

Figure 19. Additives, spawn bottles and spawned-bags at different stage

[Examples: Spawning methods in different countries]

India - Fill approximately 5cm of boiled straw into a wooden frame and compress it with a wooden lid and sprinkle spawn over the whole surface. After the first layer of spawning, put another 5cm of straw and again sprinkle spawn over the surface, compress it as in the first layer. In this way, continue to sprinkle spawn over the layers of straw for 4-6 layers until the straw is level with the top of the frame. Only one (1) packet of spawn should be used for 1 cube or block. Growers should inoculate in the dark at an optimum temperature of 24℃ until the straw is fully prepared.

Once inoculated, the plastic sheet is folded over the top of the frame and tied down with help of jute ropes previously placed below the plastic. The frame is then removed to access the block. Small holes of approximately 2mm are punched in the block for breathing. The blocks are later placed on the shelves in a single layer for incubation.

Vietnam - Mushroom spawn must be purchased commercially, unless it is provided by an extension center. Around 2.5-3.0kg of spawn is needed for 100kg of straw.

S. Africa - Spawn is inoculated at 3-4% of wet weight.

Bangladesh - Substrate is inoculated by one or two spoonfuls of spawn per packet.

Nepal - Initially conditioned straw is put into the bags in a layer about 4 inches thick and the spawn is spread uniformly all along the periphery of the bag. Then another layer of straw is added. In this method, two bottles (250g/bottle) of spawn are sufficient for three polyethylene bags (14 x 24 inches size) containing 3kg of rice straw (dry weight) each. In the same way, one bottle of spawn will inoculate an 18 x 26 inch plastic bag containing 4kg rice straw.

Hungary - After treatment the substrate is watered with a benomyl solution and spawned at 4-5% of wet weight.

A Low-cost Technological Proposal: from Mixing & Spawning to Bagging

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Figure 20. The equipment to pasteurize substrate

Growers here use a low-cost method to decontaminate the substrates. Decontamination of substrate is one of the first and most important procedures in mushroom production and can be accomplished in several ways. For small farms, autoclaving and steam pasteurization are expensive due to the high cost of the equipment. Pasteurization by immersion in hot water has some disadvantages, as it is time consuming and it is not easy to control the water content, and it makes amendment with additives difficult.

Thermal treatment in ovens usually takes 48 hours at 95℃ to decontaminate the substrate. Chemical sterilization / decontamination using formaldehyde in the range of 25-1,000 ppm was also studied (Earanna and Shetty, 1994) but this method could harm the operator, the environment, and possibly the consumer.

Some growers now propose a different and low-cost decontamination method using a piece of equipment which we constructed with the following characteristics: a metallic rotary 180L drum of 0.60m body diameter and 0.38m open end diameter (see Fig. 20, three fixed metallic bars inside to improve the mixing action in order to avoid formation of substrate lumps, the angle of the drum main axis was 11℃ with respect to the horizontal, helping to minimize substrate losses through the open end during operation. The open end of the drum was covered with a close mesh fabric to isolate the substrate during the decontamination process. The rotation speed was 32 rpm. A gas heater with 2 ring-shaped burners of 0.21m and 0.08m diameter was placed at 0.04m distance from the lower base of the drum. An electric motor of 0.75 HP rotated the drum and rotation was automatically interrupted every 15 minutes with the help of an automatic on/off device.

The decontamination process always began with the gas heater on and the drum (with 35-40kg wet substrate mass inside), in a stationary position, during the first 15 minutes. Heating is continued for 2.5 hours with the drum alternately rotating for 15 minutes and stopping for 15 minutes.

During this period, a threshold of 65℃ was reached at 45 minutes and the beginning of the plateau at 80℃ and 90℃ occurred after 50 minutes and 60 minutes, at the surface and at 0.30m depth, respectively. An additional heating period of 90 minutes after reaching 80℃ was considered appropriate for total decontamination. Thus, approximately 2.5 hours were enough to prevent contamination during the mycelium colonization and fruiting stages.

It is interesting to note that heating the drum during the periods without rotation greatly increased the temperature of the substrate near the heat source, and this, in turn, produced a vapor blow (or stroke) immediately following each activation of rotation. There was a more effective heat transfer when the overheated portion was mixed with the rest of the substrate.

In addition, an effective decrease in energy cost could be obtained by using a lower HP motor or placing a tandem system of 4-5 drums driven by a single motor. These considerations apply to the low-cost equipment already found on the market (USD130-150, in Argentina).

With this decontamination method, an estimated 5.5 hours are required for one skilled person to prepare 35-40kg of substrate ready to put in bags for mycelium colonization. This time includes 0.5 hour for weighing the components and filling in the drum, 2.5 hours for the decontamination process, 2 hours for allowing the temperature of the substrate to fall to 35-40℃ previous to spawning, and 0.5 hour (or less) for homogeneous mixing of spawned substrate. It is important to point out that this method has the very convenient advantage of effecting both the decontamination and the inoculation of substrate in the same recipient, saving spawn running time because of the better spreading of mycelium compared to top- or layer-inoculated bags that are time consuming to produce manually.

Finally, we consider that with three pieces of equipment, composed of 4 drums each, it is possible for two workers to decontaminate 430kg substrate in twelve hours. Of course, the proposal of the gyratory drum could be scaled up to higher volume. Growers should remember that in order to effectively decontaminate the substrate it is necessary to treat the materials for a minimum of 90 minutes following the reaching of the 80℃ threshold temperature. A similar protocol could be effectively applied for decontamination of other agricultural waste-based substrates.

Incubation

The inoculated bags are moved to the growing house, or if one is available, to the incubation room. Growers can have a separate incubation room or they may use the growing house as an incubation room by providing higher temperature and higher humidity, which are proper room conditions for mycelial growth.

Bags are incubated at an optimum temperature of 20-25℃ in darkness since spawn run does not require light. Full colonization takes 15-25 days depending on the bag size and substrate material and condition.

Figure 21. Partial colonization

Figure 22. Full colonization

[Examples: incubation in different countries]

Nepal - The inoculated bags are incubated at 20-25℃ for 10-15 days for spawn run. As soon as the substrate is fully covered with a whitish mycelial growth, the polyethylene cover is removed.

India - Spawned bags are placed slightly apart from each other on shelves in an incubation room, lest they should generate excess heat. The temperature of the substrate bag is maintained at 25℃. Temperature is measured by inserting a thermometer in the bags. If the bag temperature rises above 25℃, it is advisable to lower the room temperature. If the bag temperature is low, the room should be warmed slowly. The completion of spawn run, when the entire bag turns white in color, takes about 12-15 days.

Vietnam - Bags are tied one atop the other with a nylon rope (3-5 bags per rope) and hung from a perch. The mouth of each bag points upwards. Bags are a few centimeters apart in order not to touch each other. After 25-30 days, mycelium will develop throughout the bags. Growers use a sharp knife to cut 4-6 slits in the sides of the bag. Each slit should be 3-5cm long, and an equal distance from the other slits. The cuts should not be in a line around the bag, as this will weaken the bag.

Bangladesh - After inoculation, the bags are incubated for 15-25 days at room temperature. When the mycelium is growing, the incubated poly bags containing the substrates are punched on the top sides of the packets for facilitating the luxuriant growth of mushrooms.

Hungary - Bags containing the spawned substrate are either placed in incubation rooms or directly in production rooms for spawn run. During this period, substrate temperature is maintained at about 25℃. Care is taken to avoid overheating of spawned substrate. There are two critical points when overheating may be a particular problem. The first is shortly after spawning (accelerating growth of microorganisms), and the more intensive second peak is 7-15 days after spawning (caused by metabolism of *Pleurotus* sp. mycelium growth). The relative humidity is maintained between 90-95%, and no light provided during the spawn run.

S. Africa - Cropping containers used for *Pleurotus* production typically are made of large clear or black polyethylene ducting cut into 2-meter columns (50cm in diameter) with a metal support and holding approximately 50kg of substrate. Other growers may use smaller plastic bags containing about 20kg of substrates. Regardless of the sizes of the bags used, holes are punched into the bags for aeration and mushroom maturation. Upon completion of spawn-run, growers usually move the bags into the production room or the growing room.

U.S.A. - The pasteurized and supplemented straw or hulls are spawned and filled (12-15kg) into clear or black perforated polyethylene bags and then incubated at 23-25℃ for 12-14 days. Some growers use bags with pre-punched holes while other growers cut holes in the bags after spawning.

Fruiting and harvesting

Unlike other crops, mushrooms - fruit bodies of fungi are quite sensitive to the growing conditions including temperature, humidity, light and ventilation. The correct temperature enables them to grow well in growing house. The light and ventilation influence the color, size and texture of the mushrooms.

Temperature

Mycelia of oyster mushroom grow best at a temperature range between 20 and 25℃. In order to induce fruiting after full colonization, the room temperature must be lowered to below 15℃ or colonized bags must be moved to a growing room. Otherwise, growers cannot expect good primordial formation despite good colonization.

Figure 23. Simple structure for mushroom growing

Figure 24. Thatch growing house covered with a shading net

Light

Unlike mycelia, which do not require light, primordia are formed under light. Mushroom formation and growth stages require 80-210 lux of light. Without light, fruiting bodies of oyster mushroom would abort or malformed. Light influences on the fruitbody color and stipe length. Under poor light, mushrooms with an elongated stipe and light-colored cap are produced while under excessive light, they will be short and dark-colored.

Ventilation

Oyster mushroom growth is stunted under high CO_2 concentrations. Young mushrooms suffocate due to lack of oxygen. Mushroom stipes become enlongated and twisted and cap growth is very poor. Excessive ventilation, however, causes heavy water loss, resulting in lower room humidity and drier substrate.

Humidity and substrate moisture content

After ventilation, the room humidity drops. Spraying water onto corridors and into the air is recommended. The proper room humidities for pinning and fruitbody development are 90% and 80-85%, respectively. Once pinheads appear on the substrate, indoor humidity must be lowered to 85%.

Excessive substrate moisture content could cause the lack of oxygen in the substrate, which, in turn, could keep mycelia growing vigorously. In this situation, the growth of fruitbodies in the substrate bags is delayed and stunted. When both the substrate moisture content and room humidity are low, mushroom growth will also be stunted due to the lack of water. In this situation young mushroom caps may upturn earlier and release more spores.

Watering

Because most edible mushrooms are 90% water, humidity is critical during the fruiting stage. Growers should water the growing room frequently in order to raise the relative humidity during this reproductive growth phase. Watering frequently, using small amounts of water is desirable. For example, 2 or 3 buckets of water 5 or 6 times a day is better than 10 to 15 buckets of water twice a day. Applying water directly to the mushroom bags should be avoided because drops of water are harmful to pinheads and standing water attracts a variety of pathogens. Growers should water the floor of the growing room and around the bags. Some growers utilize humidifiers to increase the relative humidity inside the growing rooms. Watering is especially important during the dry season when the ambient humidity is very low.

Figure 25. Bags laid on their side in row on the wall.

Figure 26. A-frame rack

Figure 27. Bags bound and hung with wire

Bag arrangements

Various practices of bag arrangement are found worldwide. Some growers arrange bags so that they are not touching each other to avoid overheating of the bags. Mushroom mycelia emit heat during incubation, so the bags can be easily overheated if they touch each other. Air can easily flow through the spaces between the bags, preventing the temperature of the bags from increasing.

However, many growers still arrange bags stacked against each other in order to grow more mushrooms in a small growing room. Shelves and A-frame racks (Fig. 26) are used for efficient utilization of space inside growing rooms. In some countries growers bind bags with wire and hang them (Fig. 27).

[Examples: Fruiting and harvesting in different countries]

Bangladesh - Growers cultivate mushrooms at room temperature.
Nepal - When the substrate is fully covered with a whitish mycelial growth, the polyethylene cover is removed. The open bags are transferred into a new room with good ventilation. The bags are kept about 15cm apart from each other on a wooden block or brick. Watering is done 3-4 times daily. Mushroom primordia start appearing 2-3 days after the removal of polyethylene and they reach maturity 5 or more days later. Oyster mushrooms have a shorter growing cycle and a total of 3-4 flushes could be harvested during this period.
Mushrooms are picked carefully without disturbing other developing mycelia. Then harvested fresh mushrooms are packed into plastic bags for the fresh market.
Under commercial cultivation, there is a great variation in biological efficiency from farmer to farmer. Usually they produce mushrooms equaling from 40-100% of the initial dry weight of substrate.
Vietnam - After the bags have been cut with 4-6 slits in the sides of each bag, they are sprayed with water 2 or 3 times a day to keep the mushrooms moist, and the growers are careful not to give them too much water. No water should collect inside the bag. Growers take the cotton out of the mouth of the bag and suspend the bags on a wire or rope, with the mouth of the bag pointing downwards.
The mushrooms will begin to appear in the slits, looking like small round buttons. As soon as they begin to appear, growers should move the bags to the growing or harvesting area. The bags should be placed 7-10cm apart.
The first oyster mushrooms can be harvested 7-10 days after the bag is cut. After the mushrooms are harvested, growers stop spraying water for several days. When the young fruits begin to appear again, they begin to spray the water again. This cycle can be repeated three or four times, giving a total harvest of 50-80kg of oyster mushrooms from 100kg of straw.
Hungary - Air temperature is maintained at 15-20℃ and the CO_2 level is lowered to 600-1,000 ppm by ventilating with fresh air. The spawn run usually takes 2-3 weeks after spawning. During this period, the humidity is maintained at 90-95% to provide for optimum condition. Subsequently, relative humidity may be lowered to 80-90% in order to minimize development of bacterial blotch. 8-10 hours of 50-150 lux light is provided daily to allow for normal fruit body development.
India - Once the blocks are fully colonized during the spawn run, they are hung after removing the polythene in a room where the relative humidity is maintained above 85%. The humidity is normally maintained by frequent spraying of water on the blocks and room environment. The pins are visible on the ninth day after the opening of the blocks. Proper relative humidity and proper ventilation is maintained in the room during pin growth and picking. The mushrooms are picked generally for the fresh market. Most of the growers take three flushes. Mushrooms picked in the third flush are mostly used for sun drying, where maximum dry matter is achieved.

REFERENCES

- Agriculture in Meghalya. Oyster Mushroom.
  available at http://meghalaya.nic.in/agriculture/oyster/method.htm
- Bania. Indu. 2001. Oyster mushroom cultivation in Nepal. *MushWorld.*
  available at http://www.mushworld.com.
- Davis, R.A., and B.J. Aegerter. 2000. Edible Mushroom Cultivation. Handout from SOMA meeting (Nov. 17, 2000).
- Food and Fertilizer Technology Center. 2002. Growing oyster mushroom (*Pleurotus* sp.) on straw in plastic bags.
  available at http://www.agnet.org/library/abstract/pt2002024.html
- Kim, Duk-hwan. 2001. Optimal Growth Conditions for Oyster Mushroom, Especially during Fruiting. *MushWorld*. available at http://www.mushworld.com

- Kim, Duk-hwan. 2001. Oyster Mushroom Cultivation in Summer. *MushWorld*. available at http://www.mushworld.com.
- Geml, J., P. Labuschagne, and D.J. Royse. 2001. Oyster Mushroom Production on Three Continents: An Overview of Cultivation in Hungary, South Africa and United States. *Mushroom News* 49(2): 4 -13.
- Rahman, H., and M.Q. Zaman. 1996. Cultivation technology of *Pleurotus* species production in Bangladesh. *The Proceedings of 2nd ICMBMP* pp 2-3.