Chapter 3

OYSTER MUSHROOM CULTIVATION

If those who plan to grow mushrooms are split into groups based on the several factors mentioned in Chapter 1.

1.Expertise – a person who has worked on a mushroom farm.
2.Waste materials he sees.
3.Waste materials from his own farm or other business.
4.A building he owns, or can get cheaply.

After reading the previous chapters, the reader should have gained knowledge that will make him more expert and more able to succeed, as though he was a member of our group 1.

By now we will assume that you understand all of the environmental needs and are ready to beging growing oyster mushrooms. To do that, you

need to chose waste materials as your substrate and pasteurize as instructed in Chapter 2. Then from this chapter, you must gain additional knowledge of all of the steps of growing from preparation of the substrate to picking, and cleaning up when the crop is finished.

CHOSING A SUBSTRATE

Before any growing can happen, we need something to grow on. A large number of wastes have now been used with some success:

1.*Agaricus* compost
2.Hardwood logs
3.Hardwood chips and sawdust
4.Seed hulls
5.Broadleaf "straw"
6.Paper
7.Cotton wastes
8.Rice straw
9.Wheat straw
10.Maize stalks & cobs
11.Other straws
12.Coffee consumer-country wastes
13.Coffee growing-country wastes
14.Linen boon - waste from flax used to make linen

Although hardwood logs are the natural substrate, probably the only thing that is a poorer choice in my list is the *Agaricus* compost. For Oyster mushrooms, anything that has had microorganisms growing on it, before pasteurization, is a damaged substrate. Other undesirable materials are clover, alfalfa, beans, anything containing simple sugars or any "mushroom supplement." Based on the experiences of many and published yields of mushrooms we can list the desirable qualities for the substrate:

1.Clean – it has been kept dry and nothing has grown on it.
2.Comprised of lignin and cellulose
3.Holds considerable water, tightly
4.Holds air

The need for clean starting material has been mentioned, but to emphasize the importance, more must be said. Anything growing on the substrate will decrease the food available to the mushroom. Some things may leave poisonous residues. Others may be pathogens and will not be completely killed during pasteurization. Organisms that are already established are more difficult to destroy than those that are there in small numbers.

Most plant wastes are composed of lignin, cellulose and hemi-cellulose. Hemi-cellulose is a "catch-all" that includes pectin and for convenience I include starch. Large amounts of hemi-cellulose and some other materials in plant wastes are undesirable, but small amounts may be helpful if properly managed. Paper and cotton wastes, in our list of possible substrates may be almost 100% cellulose, but in mixtures, that can be an advantage.

We want our substrate to hold the water; that will be the water in the mushrooms, but some water will also evaporate and some will form from metabolism. The substrate should hold water tightly because we want air and if the water is not held and flows, it will plug the air spaces and growth will be limited. Soft matterials used in substrate, often pack so tightly that although they hold water tightly, there is still no air space. If a matterial that packs tightly is used for substrate, it is especially importrant to mix it with another sustrate that provides space for air. Straw is among the best substrates for providing air.

SPAWN

Spawn is the other important ingredient. It is wise to purchase the best quality spawn available. Even if it costs much more, it is probably worth the extra money. The large spawn producers keep very fresh inoculum, they sterilize carefully and check everything at every stage. A lesser supplier may

unknowingly introduce viruses or sell spawn that is already old.

You should read the spawn producers material carefully. Normally, the spawn company will specify the best growing temperature and other factors.

SUBSTRATE PREPARATION

Some substrate will need a preliminary treatment. Straw generally needs to be chopped. Paper will also need to be shredded. Maize cobs and stalks must be broken up. The best equipment for this kind of work is a hammer mill with a "screen." "Screens" for hammer mills are heavy steel plates with holes cut into them (**Fig. 6**). Small pieces of wood, tree branches, etc. can also be handled by the hammer mill. There are several reasons to shred things. The most important is to increase the surfaces where the mushroom mycelium can grow, but another is to make the substrate a little more compact and easier to handle.

The next two things that must be done are wetting and pasteurization. The two basic methods of wetting and pasteurization are describe in Chapter 2. The most efficient for space, time and heat, we can call the hot water method. In the hot water method, water is heated in a large container to 55-60°C (131-140°F). **NOT MORE THAN 60°C (140°F) (Fig. 17)!** Then dry substrate materials is added to the water. Ideally the water should just cover the substrate. Let that stand for 30 to 60 minutes. **NOT MORE THAN 60 MINUTES!** At that time drain the substrate and place it where it will cool slowly. It should be 25°C (77°F) 16 to 20 hours later. At the end of those 16 to 20 hours, and at 22-25°C (71-77°F) the substrate will be spawned.

The hot water method can be used for substrate that has gotten wet, but more care is required and some of the advantages are lost. If any of the substrate is wet, the water should be closer to 60°C (140°F) than to 55°C (131°F) the temperature must be monitored closely as the substrate is added and never allowed to be less than 55° (131°F). When dry material is used, everything that is wetted with the 55-60° water is pasteurized. If it is already wet, we can not be completely sure it has been adequately heated. For that reason wet material should be held for nearly the full 60 minutes. One

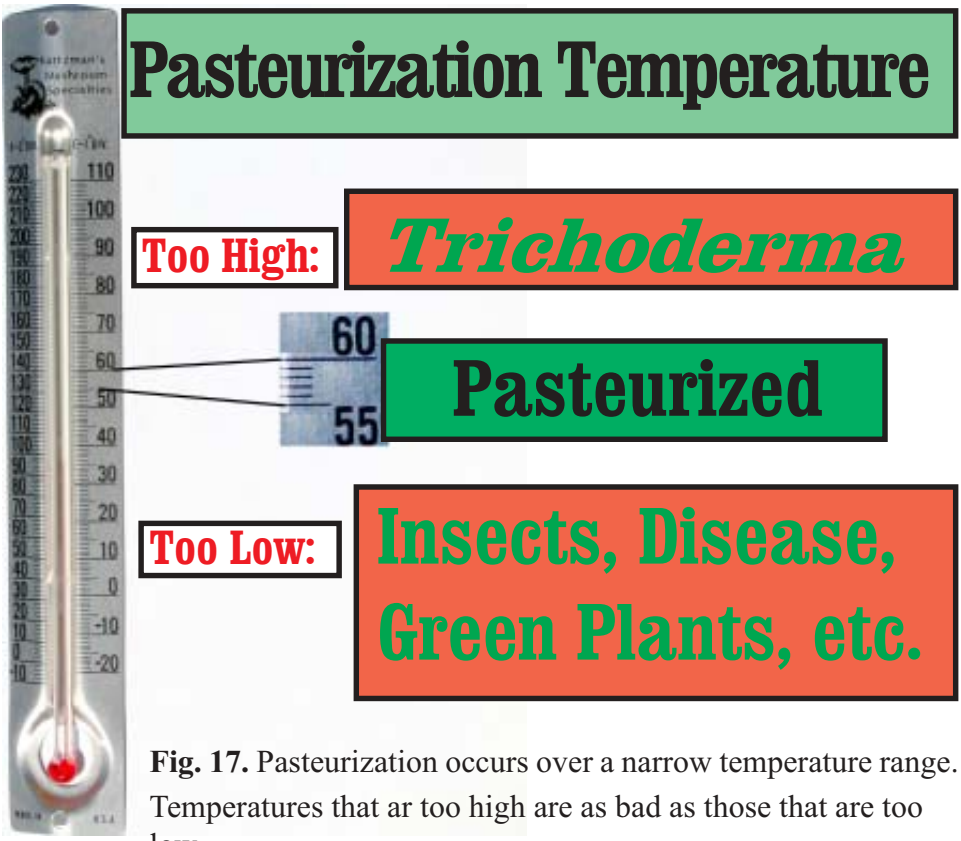


Fig. 17. Pasteurization occurs over a narrow temperature range. Temperatures that ar too high are as bad as those that are too low.

additional advantage to the hot water method is that everything is easily wetted. The heat melts natural plant waxes which tend to exclude water.

For the steaming method, the substrate must be wetted for a few days before it is pasteurized. During that time foreign organism can begin to grow, so time must be limited. The substrate is then placed in a large container, possibly a room, and steam is added from the bottom. Stirring is required and care must be taken so all of the substrate reaches 55-60°C (131-140°F). More steam must be added over the next four hours to hold the temperature

at 55-60°C (131-140°F). **NOT MORE THAN 60° AT ANY TIME, OR IN ANY PLACE!** At the end of four hours, the substrate is allowed to cool for 16 to 20 hours until it reaches 25°C (77°F).

I have emphasized that the temperature should not exceed 60°C (140°F). That may sound strange, but experience has taught us that any higher temperature will allow *Trichoderma* to come in and destroy the crop. However, 55°C (131°F) for 30 minutes kills all harmful organisms that are in the substrate. Even though we are very careful, we can not trust steam to warm everything adequately in such a short time, which makes four hours necessary. We refer to *Trichoderma* as an opportunist organism. Others fit the description, but it is the most likely and most damaging. It would be well to also explain the limit of 60 minutes in the hot water treatment. Water at that temperature contains little air and by the end of 60 minutes, anaerobic organisms begin to grow and they are harmful to the mushrooms.

SPAWNING

When the pasteurized substrate has cooled to 25°, we are ready to spawn. At this time excellent sanitation is required. Everything in the room should be clean. Everyone in the room should have very clean clothes, and clean hands. A covering over their hair, a surgical mask on their face, and latex gloves are desirable. Ventilation may be required for the workers comfort, that air must be filtered, preferably with a High Efficiency Particulate Air (HEPA) filter. Germicidal lights that are kept on over night before spawning are helpful. The substrate must be mixed with the spawn and then placed in the growing containers. The exact ratio of spawn to substrate depends somewhat on the nature of the substrate, but spawn should be in the range of 1 to 5% of the dry weight of the substrate.

The quantity spawned at one time should depend on how quickly it can be place into the growing containers. It is desirable to have the substrate open in the room for as little time as possible and the growing containers should be closed as quickly as possible.

Fig. 18. Oyster mushrooms growing on a full bale of straw.

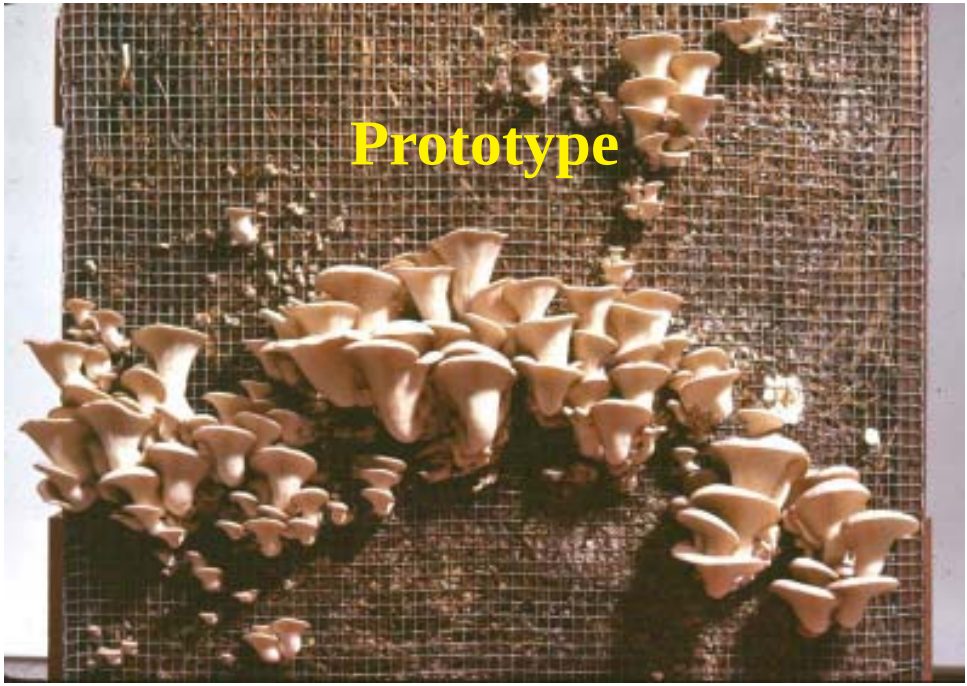
GROWING CONTAINERS

A number of containers have been used to grow oyster mushrooms:

1.Open (straw) bales (**Fig. 18**)
2."Trays" of various descriptions (**Fig. 19)**
3.Plastic bags (**Fig. 20**)
4.Plastic tubes (**Fig. 21**)

It is probably senseless to try to pick the best or the worst container from that list. The best might easily combine features of several. Probably the best approach is to list the desired characteristics that we know about. The container should:

A) Enclose the substrate during the spawn run
B) Keep light from initiating mushrooms in inaccessible places
C) It should not break or puncture from handling
D) Avoid excessive self-heating
E) Allow the maximum production in the space used.



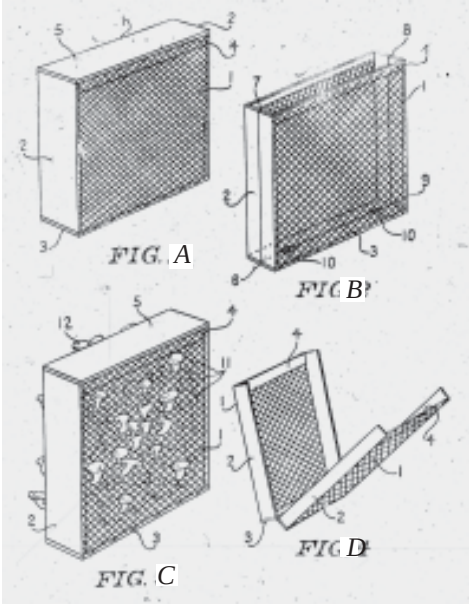


Fig. 19. Above is a prototype of a tray with oyster mushrooms growing on straw. Variations in the construction of the tray are shown in FIG. A-D at left. The prototype worked well for the first flush. However, the wire mesh must be larger; 10 cm (4 in) is recommended. It is also recommended that black plastic film should cover the inside of the wire.

Fig. 20. Bags as growing comtainers. **A**.Bags placed on shelves. **B**. Bags hung on a rack. The grower was a beginner. **C**. A black bage used to control formation of initial pins. **D**. Similar to **C**., but a clear bag that allows random initial pins.

It would appear that 3. plastic bags and 4. plastic tubes could both provide character A). Black plastic has generally been used to provide character B). The requirement for character C) depends upon what substrate is used and how big the container is. However, polyethylene plastic will generally need to be at least 2 mils (0.05 mm) thick. It has been found that substrate must be

Fig. 21. Cultivation in plastic tubes. **A.** Initials begining around dry substrate at holes. **B.** The mushrooms are ready. **C.** Tubes laying horizontally in the racks start the 4th flush. **D.** A tube fron **C** with mushrooms.

20 cm (8 in) or less vertically or in one horizontal direction for character D), avoiding self heating. Even with the 20 cm (8 in) limit, spawn run must be in a cool place with good air movement, so a 15 cm limit might be more practical.

Character E) is the most difficult to define and to attain. A quite successful method is to pack the substrate in plastic tubes and stack the tubes in racks. One idea that has been used and might have potential with modification is a tall 15-20 cm thick tray with wire mesh sides (**Fig. 19**). If the mesh was very course and covered with black plastic on the inside, all five characters A)-E) might be provided.

One other idea that has been used is to put a plastic pipe down the center of the substrate. The pipe will be perforated with many holes so that heat can escape, oxygen can enter, and carbon dioxide can leave such a device can probably be 30 to 40 cm in diameter. If the pipe extends from both ends they can be used to hang the device from vertical posts so that the pipe is horizontal. One would use plastic tubing to wrap the whole substrate.

SPAWN RUN

Spawn run is the period when the mycelium grows to cover all of the substrate. During this period, carbon dioxide is actually beneficial, although oxygen is also needed. It is also a time when some excess water may slowly drain from the substrate. That water should never be allowed to accumulate in the growing containers, so a small hole for drainage should be provided. After the mycelium begins to grow a larger hole is needed to allow some oxygen to enter. That hole is best placed at the top.

As mentioned above, the temperature must be low enough to avoid excessive self-heating. Such temperatures will be between 15 and 20°, but will depend on the substrate and the shortest dimension of the growing container. Ventilation needs to be adequate to keep the temperate constant. Access and light are needed only to monitor growth and temperature, so containers can be arranged with only a little space between them, if they will be moved to a larger room for production. The only light in the room might be hand carried and battery operated.

PRODUCTION

Once the substrate has a strong growth of mycelium, cross-slashes of a about 2.5 cm are cut to allow the mushrooms to grow out. Fluorescent lights are turned on and the full ventilation system is turned on. It is best to have all growing containers about 10 cm or more above the growing floor. If electric power is restricted, and ventilation is stopped, carbon dioxide will first gather near the floor and will do little damage for some time. Raising the containers above the floor will also restrict the access for some larger pests.

Once openings are made, and especially as mushrooms form more water will be needed. If any large openings are available in your containers, you will want to add water there, but even the openings cut to allow mushrooms to form are a place to add water. “Rose cone” sprinklers have often been recommended because the water from them splashed little and reduces the spread of disease. Mist sprayers, however, give no splashing.

The mushrooms should be harvested as soon as the gills are well formed and while the edge of the mushroom is still curled under. When the edge flattens, spores are released, the mushrooms lose weight. Spores that have been released are a hazard to the health of both the crop and workers. The mushrooms will look poor and will not keep. Mushrooms that are picked slightly early will leave more food behind for the next flush, will look good for a maximum time, and will avoid problems with the health of workers and your crop. Waiting a little longer may give a little more harvest, in that flush, but not subsequent flushes. If you wait an extra day, it is almost certain that the weight of the harvest will decrease and many problems will be created.

It is wise to provide all of those in the growing area with particle masks, latex gloves and rubber boots that have been bathed in saturated salt or hypochlorite (laundry bleach). Clothes and hands must be clean so that they will not carry diseases or pests.

Harvesting should be done by pulling the mushrooms from the substrate. If they are cut, the cut surface, remaining on the substrate is an ideal place for *Trichodema* (green mold) to enter. The mushrooms will be trimmed before

they are packed for market.

It is the general experience that the second flush (about 10 days after the first harvest), will be the largest. It is not uncommon for the first flush to be the largest and with a few substrates, the third flush may occasionally be the largest. It is generally desirable to destroy the remaining substrate after the third flush, but occasionally it is kept for a fourth flush.

Although mushrooms will always continue to appear after third flush and usually there will be more after the fourth flush, there are several reasons to end the crop. First, everyday gives diseases and pests more time to get in and become established. Once established they are more difficult to keep from the next crop. The space will be needed for the next crop. Harvesting cost depends primarily on the space, so it will cost less per kg. to bring in fresh substrate.

"COOK-OUT"

After the last flush is harvested, the growing room must be cleaned. The traditional method is to inject steam and raise the temperature of the room to 60° and hold it for 4 hours. After that all spent materials are removed and disposed of. In this case, exceeding 60° or the 4 hours may be wasteful, but will seldom cause problems.

Disposal means that the materials should be removed at least a few km from all of the mushroom facilities. With oyster mushrooms if optimum conditions have been attained, the materials discarded will be a very small fraction of the initial substrate. It may be little more than minerals. The cook-out should have killed any diseases and pests, however, disposal at a distance assures that any diseases or insects will be removed from the growing facilities.

PREPARATION FOR THE NEXT CROP

Once all spent materials are removed, the room must be thoroughly cleaned. All plastic, floors and other hard surfaces should be thoroughly washed and

rinsed with a hypochlorite solution. The solution should be 0.525% sodium hypochlorite or 10% laundry bleach. Wood and some other materials can harbor diseases and pests within their pores. Steaming for 6 hours or more, rather than the 4 hours at cook out is the easiest and safest way to handle those surfaces. Formaldehyde, methyl bromide and some other fumigants may be used, but they are dangerous and those working with them must be well trained. Hypochlorite can cause burns so must also be used with care. That care must include an operating ventilation system, the fumes from hypochlorite can damage lungs.

SUMMARY

Every step in the production of mushrooms must be done with care. Production will be maximized if the facilities are good and the standard procedures are well established. Pasteurization, spawning and clean out will require the most care to obtain high production. However, if a poor substrate or poor spawn are chosen, the maximum production will still be poor. Sufficient water is also of great importance.

Picking practices will determine the quantity produced, the quality of the product, and the health of the workers. Mushrooms must be picked before they release spores. If that is done, mushrooms will weigh more, look nicer, and last longer on the shelf. If that is done spores can not carry viruses to other mushrooms and workers will not develop respiratory problems (asthma, hay fever) from spores in the air they breath.