Chapter 1

PREPARING TO GROW MUSHROOMS: FACILITIES

The cultivation of mushrooms is an art, but it is based on science and technology. Any indevour, which is both an art and a science requires both study and experience. However, those who plan to grow mushrooms can be split into groups based on several factors. Maybe the most useful way to split them is to consider what they want to use:

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.

Most people would expect the first to be the most likely to succeed, but you may be surprised to learn that the entire list is in order of expected success. Many waste materials work, but mixtures are generally better than any single waste. Most farmers who have wastes have other activities that they must pay attention to. So although they may be dedicated in spirit, they can not be completely dedicated to mushrooms. There are exceptions, but most buildings looking for a use, are not good places to grow mushrooms.

It is good to have wastes that mushrooms like to grow on, but there are plenty of wastes in almost every culture. The most important thing a mushroom grower needs is knowledge of how to grow mushrooms. Mushrooms are more like pigs and cattle than like wheat, or potatoes. Yet, like wheat and potatoes, everything they need must be available exactly where they are. However, it is not even that simple. Food for mushrooms is food for other things and mushrooms themselves are easy prey. Animals and plants both have skin that protects them. Mushrooms have little protection except that once established they are fierce competitors. The most important tool that the mushroom grower has is sanitation.

Even if the experienced individual needs help, discussing his needs will do little help others. More discussion of wastes will be useful, but we need to have a place to grow the mushrooms, or it will be difficult to do much. So let us begin by discussing buildings. The buildings are the physical protection for the mushrooms.

The reason most building looking for a use are a poor choice is because they do not provide the things the mushrooms need. It should be apparent that if most building are inadequate, mushrooms have special needs. How will we learn their special needs? One of the very best ways to learn the needs of living things is to observe the conditions where they grow normally.

THE NATURAL ECOLOGY OF MUSHROOMS

Oyster mushrooms are found wild in temperate forests and some species in tropical forests (**Fig. 1**). Typically, they grow on dead logs, one relatively uncommon species attacks weak living trees. We would, therefore, expect logs to be the best substrate, but we have found that straw and some other ligno-cellulosic wastes are better for cultivation. Forests are generally moist

Fig. 1. Oyster mushrooms (*Pleurotus*) in a natural, wild environment.

Fig. 2. *Agaricus* growing in the wild - grass.

places with dim light. Logs are sometimes buried by other forest debris. The survival of the species depends on the ability of mushrooms to protrude above the surface. Oyster mushrooms have evolved to use low carbon dioxide concentrations and light as indicators that they have reached above the surface. However, the trees filter out much of the light and blue light predominates, so mushrooms respond only to blue light. Many other wood inhabiting mushrooms have very similar needs.

Relatives of the common commercial mushroom are found in more open places and are associated with manure and already rotting debris (**Fig. 2**). While open places might suggest a need for light, we have found that *Agaricus* and other mushrooms associated with already rotting materials do not use light, but depend primarily on gravity as a signal to grow away from.

Carbon dioxide is also avoided. Wind is more likely to remove carbon dioxide in the open. Probably, it is also more likely to benefit from photosynthetic removal of carbon dioxide by grass and other small plants.

We can not get all answers necessary to describe the environment, simply from observations in the wild, but we can see that there are special requirments for envionments that we should be prepare to deal with in our buildings and in the other parts of our cultivation environment.

BUILDINGS AND OTHER FACILITIES

We have said that most ordinary buildings are not suitable for mushrooms. Oyster mushrooms have some basic requirements for the environment provided by the growing-buildings:

1. A temperature of 15 to 20°C (59 to 68°F)
2. A humidity of 80 to 95%
3. Good ventilation
4. Light
5. Sanitation

Temperature and humidity should be kept as constant as possible and the exact needs may depend on the variety. Any rapid changes in temperature will cause disastrous changes in humidity. At 20°C (68°F) and 90% humidity, if the temperature drops to 19°C (66°F) the humidity rises to 100%. If the temperature rises to 21°C (70°F) the humidity drops to 82%. At 15°C (59°F) the change will be approximately 1% less. That is 99% for 1°C loss and 83% for 1°C increase. The relation between temperature and humidity make insulation a must. Insulation may be a commercial material, but a thick layer of soil over a masonry building or straw or even paper between the inner and outer wall surfaces can be adequate.

At 100% humidity, everything is suddenly wet. Conversely, at 80% humidity, the mushrooms begin drying. If everything becomes wet, then many building materials will rot and others will corrode. So growing conditions limit our choice of building materials. Concrete and plastic are two materials that will withstand considerable moisture with little damage. Some growers use wood or metal structures and cover them with plastic. Others just use wood or metal and accept its very limited life. The biggest problem with wood and some other porous materials is that they can harbor diseases and pests.

Both a good vapor barrier like polyethylene and insulation are needed to maintain temperature and humidity. In **Fig. 3** we see commercial insulation in plastic between the ribs (rafters) of a metal building. In Asia they have built houses of bamboo, polyethylene sheet and used straw for insulation (**Fig. 4**).

Good ventilation is needed for healthy mushrooms and for healthy workers. Low carbon dioxide is required for mushrooms to form. The stems *of Pleurotus* as well as other wood inhabiting mushrooms will grow until the carbon dioxide is very low. Centrifugal blowers are generally used to supply air. The air should be heated or cooled first and then humidity added before it enters the room. Of course, steam can humidify and heat at the same time. Ventilation must remove the carbon dioxide formed by the mushrooms, people and anything else. People can stand almost 10% carbon dioxide, but the mushrooms are more sensitive. Mushrooms should be picked before spores are shed, however, even with good management some spore will be released. Spores can cause asthmatic and hay fever reactions, ventilation can help reduce the spores in the air.

Light is required for oyster mushrooms and most other tree inhabiting species. One may read many things about the amount of light, but there have been very few carefully done experiments. I mentioned that forest light is blue. I have tried and failed to produce mushrooms with incandescent light. It is a rather yellow light. Fluorescent lights come in a variety of colors, The most common are “cool white.” With cool white if there is enough light to read and they are lit 8 hours each day you will have enough light. Natural daylight does not work well because the temperature will be affected by the sun. Algae and other plants are more likely to cause trouble in daylight.

Agaricus, the common commerial mushroom, does not require any

Fig. 3. Building with insulation covered by a plastic vapor barrier.

light and some of the older varieties change color with light. Generally the only light in the houses are battery operated lights on workers' helmets.

So, we generally do not want windows in any mushroom growing buildings. If light is needed by the mushrooms, fluorescent lights are generally the best light to use. If light is required only by people, battery operated lights are ususally the most satisfactory.

Sanitation is the most important thing that must be provided by the building. Sanitation will include:

1. Filtered air in
2. Screen or filters at air exits
3. "Air-lock" changing room
4. Foot bath
5. "Air tight"

ALL openings should provide some means to keep out diseases and pests. Air exits should have a fine mesh screen or a filter. Air inlets should be filtered to keep out pests and diseases. A High Efficiency Particulate Air (HEPA) filter is ideal, but other filters may be completely adequate. **Fig. 5**

Fig. 4. Growing buildings constructed of bamboo, polyethylene sheet and straw.

Top: Thailand

Bottom: Taiwan

shows two excellent furnace/air conditioner filters. If no commercial filters are available, three layer of muslin or similar fabric will be a good substitute. Screens or filters should also keep insects out of the air exits. Power failures and other problems may interrupt ventilation and insects will enter. They can even fly against the flow of air if it is not fast.

A room for workers to enter the growing facility can be built very cheaply with a light framework and black plastic film. It can contain rubber boots, a salt or hypochlorite foot bath and maybe clean clothes, masks or rubber gloves. The poorest possible source of light for mushrooms is sodium-vapor lamps. However, they are extremely efficient for outdoor lighting. While they are efficient for people. Insects can not see with them, so they are also

Fig. 5. Two high quality furnace/air conditioner filters.

good for “air-lock” changing rooms. Yellow colored incandescent light bulbs are also available, and are adequarte for humans, but are not seen by insects.

If the building can be made air tight, except of the controlled air inlets and exits, most diseases and insects can be kept out. Insulation foam, silicon or other caulk can be used to close small openings.

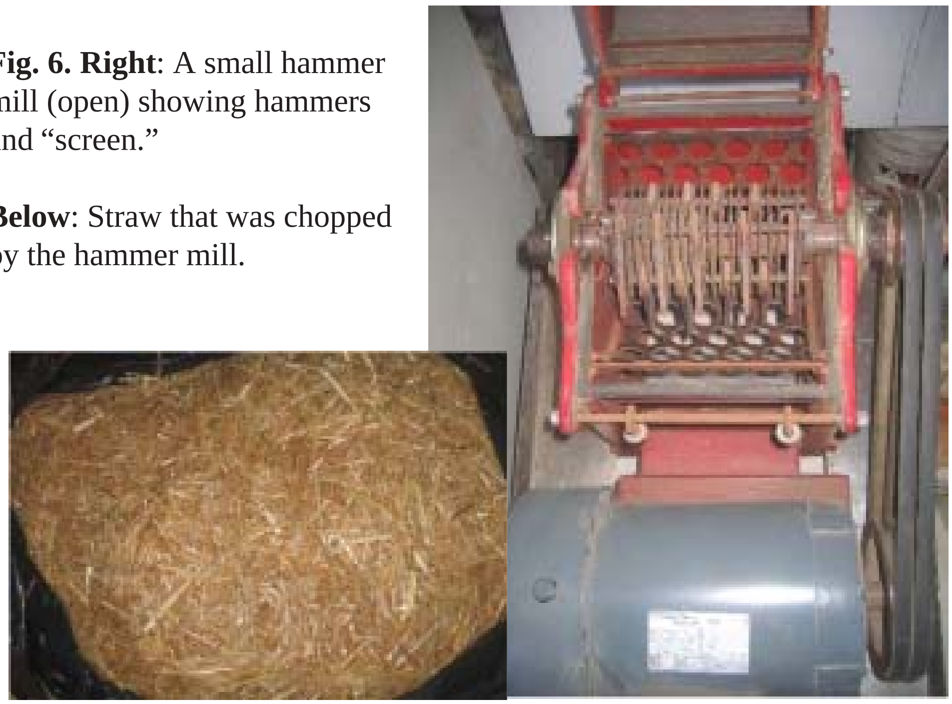
SUBSTRATE INITIAL PREPARATION AREA

Agaricus requires an area where substrate is wetted and ingredients mixed. That area is almost always outdoors although often there is a roof with no walls where front loaders and other machinery can do the heavy work. The area should always have a concrete surface that can be decontaminated, if it becomes a source of insects or disease.

Following mixing, the substrate must be composted. That may be done in the open, usually with heavy machinery to turn it. However, men with

Fig. 6. Right: A small hammer mill (open) showing hammers and "screen."

Below: Straw that was chopped by the hammer mill.



hayforks can do the job. Today most farms are using tunnels or "bunkers". These are indoor facilities where air is blown up throught the substrate as it ferments to compost. It is possible to add steam and pasteurize in the tunnels, as well.

Wood inhabiting species often use substrates which are more easily handled if they are first chopped in a hammer mill. Usually the best substrates are mixtures of several ingredients. The area should be dry, so a roof or more protection will be desirable for chopping and mixing.

In some cases, the substrate will remain dry until pasteurization takes place, in others it will be wetted before pasteurization. In still others it will be wetted and placed in the growing container as part of the preparation.

No mater how the substrate is handled after preliminary preparation, appropriate space must be available.

FINAL PREPARATION AREA

Pasturization requires equipment that can assure that the temperature of **ALL** the wet substrate is 55° to 60°C (131º to 140ºF) for at least 30 minutes. **IT MUST NEVER BE AT A HIGHER TEMPERATURE!** It must also provide conditions to protect the substrate from fresh contamination and allow it to cool slowly so that it is about 25°C (77ºF) after 16 to 20 hours.

Sterilization requires equipment that can assure that the temperature of ALL the wet substrate reaches 121°C (250ºF) for about 15 minutes. A pressure vessel is require to reach such temperatures. The substrate must be in containers the exclude the entrances of all microorganisms. Cooling must be slow enough so that there is little difference between atmospheric pressure and the steam or water vapor in the container of substrate.

Sterilization requires much more expensive equipment, much more fuel and much greater care at every step than pasteurization. It is almost universally recommended for some species that bring high prices. A few recommend it for *Pleurotus*. However, that suggests that they do not know proper pasteurization proceedure.

SPAWNING FACILITY

The place where the substrate is pasteurized, cooled, or sterilized must be maintained with greater sanitation than the growing area. It will probably be the best place to spawn as well. The air needs to be reasonable for those working there. But air temperature and humidity need not be controlled closely. It is ideal to have pasteurization or sterilization and spawning several kilometers from the growing area. Such an arrangement avoids many sources of disease and pests. The equipment at this facility is a substantial part of the whole. However, it will be discussed under the process because there is a choice of methods and equipment.

SUMMARY

Mushroom cultivation has many facilities requirements. There are no shortcuts to those requirements. If the requirements are not met, failure, or at least poor production is assured. The facilities must provide the environment required for mushroom growth. The facilities must also provide the primary protection against insects, other pests and disease. Without the environment and protection provided by the facilities, management can not protect the crop or obtain good yields.

Chapter 2

PASTEURIZATION

It has been said that anyone can grow *"champignon" (Agaricus* mushrooms), if they have properly prepared compost. Although the substrate is much different. The same idea is largely true for oyster mushrooms, if properly prepared substrate is used, other things are quite simple. Preparation must include the contents as well as pasteurization, but the parameters of proper pasteurization are much more limited than the choice of contents. Substrate is very important, but maximum yield also requires that many other factors are optimized.

WHY NOT STERILIZE?

Let us begin by considering what pasteurization is and is not. First it is not an attempt to kill all organisms. The process of killing all organisms is called sterilization. Contrary to what many believe, sterilization is inferior to pasteurization for oyster mushroom production. Many people believe that if a little of anything is good, more must be better. In fact, in growing mushrooms, more than a well defined optimum of almost everything will cause losses. Pasteurization is heating wet material to 55º to 60ºC (131º to

140ºF) for 30 minutes. No part may be at less than 55ºC (131ºF) or more than 60º (140ºF).

One advantage of pasteurization is usually apparent; cost. In order to sterilize, high pressure equipment is required. High pressure equipment is very expensive and commercial production requires equipment of large capacity. Sterilization also requires more heat for longer periods of time. Thus, fuel costs for sterilization are several times those for pasteurization.

The extra costs might be acceptable if there was greater production or less danger of disease. In fact, sterilized substrate will yield fewer mushrooms with a greater likelihood of disease. There are several reasons that disease is more likely. First, it is impossible to keep large scale cultivation rooms and the substrate sterile during production. Second, disease organisms compete poorly with organisms that remain in the substrate after proper pasteurization. Since sterilization kills everything in the substrate, those organisms are not present in the sterile substrate, so there is no competition. Third, the remaining organisms consume little or no cellulose or lignin, the materials that the mushrooms use to grow, but they do use "hemicellulose," the natural materials in most substrates that the disease organisms grow best on.

The greater production on pasteurized substrate is due to the organisms left after pasteurization and because those organisms use the hemicellulose. In using the hemicellulose, the beneficial organisms that are left after pasteurization multiply. The organisms that have multiplied form a kind of food that the mushrooms can use. That is, oyster mushrooms "eat" the organisms that have grown on the hemicellulose that the mushrooms could not use directly. There are indications that organisms, which are left after pasteurization provide much of the nitrogen required by the mushrooms. They may fix nitrogen from the atmosphere. So the purpose of pasteurization is not to get rid of all organisms, but to get rid of those that compete with the mushrooms and to INCREASE the organisms that discourage diseases, consume hemicellulose, provide nitrogen, and become food for the mushrooms.

If we are going to produce the ideal substrate, then we must learn how to destroy the disease organisms and favor the ones that are food for the mushrooms. It should be clear that if we kill everything, beneficial organisms can only come from the air or be added by the grower. Organisms that come from the air are likely to be the ones that cause disease, rather than the beneficial ones.

Agaricus mushrooms, in nature, grow in grassy areas. Those areas are places that usually have rotted animal feces and urine. In order to imitate and improve on the natural substrate, *Agaricus* growers use carefully prepared compost. The composting process requires that the substrate is kept wet for several weeks. The process of composting consumes much of the substrate and generates considerable heat. By the time they are ready to pasteurize most, but not all, of the capacity to produce heat has been expended. The inside of the compost will heat, but the outside will lose heat faster than it is generated. In order to eliminate diseases and pests, the compost is heated with hot air saturated with steam. It is difficult to think of another way that materials like *Agaricus* mushroom compost could be pasteurized.

Pleurotus mushrooms grow on dead trees or logs in nature. There is little similarity between the wood of trees and animal feces mixed with grass. The grass does supply lignin and cellulose for *Agaricus* and the logs supply lignin and cellulose for *Pleurotus.* Also, like all living things, all mushrooms require water. However, that is where the similarity between *Agaricus* and *Pleurotus* ends. As mentioned in the previous chapter, many plant materials make good *Pleurotus* substrate. However, it is always preferable to have dry material and generally it will be material that has no food value for most animals and little food value for cattle and other ruminants. Wet materials will often have disease organisms growing on them and will be much more difficult to pasteurize. Anything that has animal food value will tend to favor disease.

Many *Pleurotus* growers first grew *Agaricus* and tried to grow *Pleurotus* in the same manner. As I have already mentioned there is no similarity in their natural environment; it is not reasonable to grow them using the same methods. In order to be successful, growers must “think” as thought they were the mushrooms they are growing. That need is true for *Agaricus, Pleurotus* and all other mushroom species.

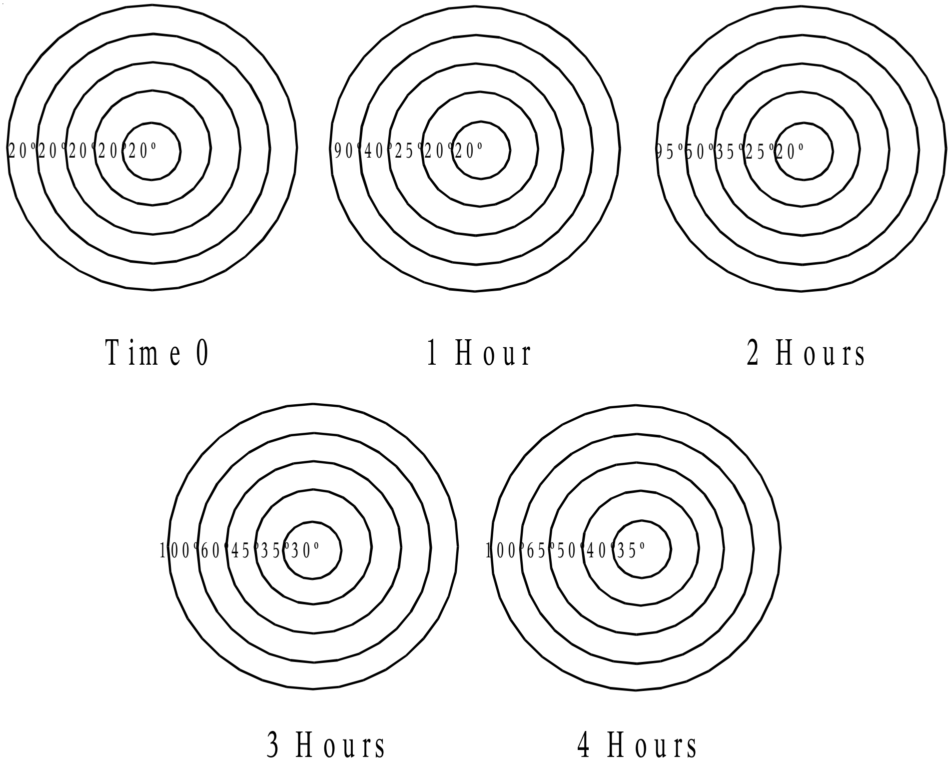


Fig. 7. The diagrams represent the problem of using steam to pasteurize substrates.

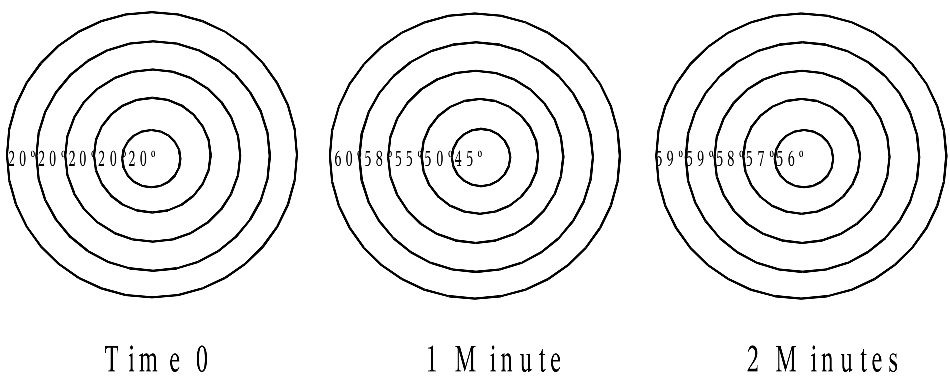


Fig. 8. The diagrams represent heat flowing with the water to pasteurize substrates.

WHY NOT USE STEAM?

The substrate must be wet before the mushrooms can grow. Steam will not add sufficient moisture, so water must be added. Those who use steam usually add cold water for several days. Straw, most seed hulls and some other good substrates are coated with natural wax. The wax keeps the water from wetting the substrate, but after a few days the water will begin to penetrate, however, by that time pathogens have had time to start growing.

With most dry materials of little animal food value, simply wetting them will not generate much heat. For that reason it is very difficult to pasteurize *Pleurotus* substrate with steam in the same manner that *Agaricus* substrate is pasteurized. In the ideal pasteurization all of the substrate will be at 55º to 60ºC (131º to 140ºF) for 30 to 60 minutes. None of it will ever be more than 60ºC (140ºF). *Pleurotus* substrates are good heat insulators, so if heat must enter as steam and air, it will require many hours and we can never be certain that there are not pockets of cold air. Consider the time required to roast a whole chicken, and remember that when the chicken is ready to eat, the inside is not nearly as hot as the oven air. Roasting a chicken and steam pasteurization of substrate are, in many ways, similar. The progress of steam heat in a typical container of pre-wetted substrate is shown in **Fig. 7**.

Since we must wet the substrate and since it is not difficult to heat water to 56 to 60º, we can pasteurize by simply adding hot water. **Figure 7** shows the progress of water in heating a typical container of substrate that is dry until the hot water is added. Compare **Fig. 7 and 8**. We are now using 56ºC (133ºF) rather than 55ºC (131ºF), because we need to make some allowance for the heat used in warming the dry substrate. It is preferable to use more water, rather than water hotter than 60ºC (140ºF). If a small portion of the substrate is exposed to more than 60º (140ºF) for a short time and the substrate is well mixed, the beneficial microorganism will be able to recover, but there will be a small loss in yield. However, if any portion remains at less than 55ºC (131ºF), or is not wetted it will be a potential source of disease and pests.

SMALL GROWERS

Small growers can use very simple equipment for pasteurization and be very successful. All that is required is a large container and either a supply of hot water (**Fig. 9**) or a means to heat the water in the container (**Fig. 10**). Clean steel drums with a heating device beneath them works well. It is also possible to inject steam into the water to heat it. First the water is heated (56 to 60ºC) when the water is hot, the substrate is added and allowed to remain in the water for 30 to 60 minutes. It is then drained or the substrate is removed from the water. It is necessary to remove the excess water after 60 minutes, because there will be only a little oxygen in the hot water and the “good” microorganisms will use the oxygen and the substrate will become anaerobic. A similar method is to have a container filled with substrate and add hot water (56 to 60ºc) to it until the substrate is covered with the hot water. As in the first method, in this method, the water must be drained after 30 to 60 minutes. The water must be hot before it contacts the substrate! Time and temperature are both very important in both the water added to substrate method and the substrate added to water method.

While water is important and excess water will drain from most substrates, excess water can cause a loss in yield. Maximum growth requires a good supply of air in the substrate. Studies have shown that carbon dioxide is beneficial during the “spawn run” period, before the fruit bodies (mushrooms) begin to form. Few openings in the growing container are desirable to hold moisture and natural carbon dioxide in. However, with some substrates, other gasses may be formed and some of those may reduce growth. It is necessary to seek advice on the optimum water content and the ventilation provided in the plastic or other growing contianer, from those familiar with the substrate you are using, or to learn the best amount of water and container-openings required for maximum growth and yield by trial of several moisture concentrations. Substrates containing two or more kinds of plant waste are recommended. Mixtures generally will allow some air space, but will pack quite firmly.

Fig. 9. A simple vat that used to pasteurize straw by adding water that had been heated before it was added. In the picture, the straw substrate has been spawned after cooling and it is being placed in plastic bags for growing. (Russia).

After the substrate is drained, it must be allowed to cool slowly in a clean (or covered) place. Cooling to 25ºC (77ºF) should be done so that it takes at least 16 hours and generally not more than 20 hours. The cooling period is the time when most of the beneficial microorganisms will grow. The resulting substrate should have a sweet-sour smell. Once it cools to 25º it is time to mix in the spawn and pack it into plastic bags or other growing containers. Everything, air, room, worker's clothing, and workers, themselves must be clean. The workers should wear rubber gloves.

Fig. 10. Steel drums with gas burners under them to heat the water. **Fig. 10A**, the pasteurized substrate is being removed from the water with a chain hoist. It will be cooled slowly by covering it with a clean box. (Mexico)

Both of the above methods of submerging the substrate in hot water work well for straw and other substrates, which will have good air space after draining. However, it can not be used for waste paper, cotton, linen boon, sawdust, or other substrates, which pack tightly with little air space. Machines capable of mixing the substrate during pasteurization are required for substrates that pack tightly.

LARGER GROWERS
and some substrates

Mixing machines allow even heating and control over the amount of water in the substrate. While it is impossible to properly pasteurize substrate in a simple container by using steam, mixing machines and great care in controlling the temperature make even steam pasteurization possible.

A mixing machine can be used to pasteurize by putting hot water in the machine and then adding substrate, or by adding hot water to the substrate. While it is necessary to use an excess of water, in containers that do not mix, in a mixing machine you need only the quantity of water required to wet the substrate. The ability to control the quantity of water provides several advantages. First, it is the only way that we can use substrates that do not naturally drain off excess water. Second it means that there is no waste water. Excess water drained from most substrates will be quite unpleasant and can be difficult to properly dispose of. However, the mushrooms need a great amount of water so add as much water as the substrate will hold without closing the air holes. It may be very difficult to judge the air holes by only looking at some substrates; experience may be the only way to learn. The dry substrate should be weighed and the water measured so that percent of water in the pasteurized substrate is known. Once the optimal water content is determined the same percentage should be used every time. If the materials used in the substrate change, then the optimal water content will probably also change.

When more water in used to pasteurize than is needed for optimal growth, the dry substrate will only cause a small decrease in temperature. However, if only enough water is used to give optimal growth, the temperature of the wetted substrate may be much less than the water being added. There is danger that if the added water is at a temperature greater than 60ºC (140ºF), the "good" microorganisms will be killed. There may be a need to compensate for the decreased temperature. Probably the best method of adding heat is a hot water jacket on the bottom of the mixing machine. The jacket may be at a temperature somewhat greater than 60ºC (140ºF) while the substrate is dry. During the time that the dry substrate is being heated, it should be mixed constantly. As long as they do not have sufficient water to grow, microorganisms are able to withstand more heat. When the water is added the temperature of the jacket should not be greater than 60ºC (140ºF) and mixing should continue. After the water is added, the substrate should remain at 55º to 60ºC (131º to 140ºF) for 30 to 60 minutes.

Fig. 11. End of a double shafted mixer. Note the bearings, which are at the ends of the mixing shafts and the screw conveyor at the bottom. (Belarus)

As with all methods, the pasteurized substrate should be allowed to cool slowly for 16 to 20 hours. Cooling can be accomplished by simply turning off all sources of heat, after any excess water is drained off, and leaving the substrate in the pasteurization mixer or transferring it to another clean container. If it is transferred, another batch of substrate can be pasteurized. Cooling will depend on a number of conditions: the amount of substrate, the temperature of the surrounding air (the room), any insulation, any movement of the substrate during cooling, and other conditions.

It is useful to have cooling take place in a mixing machine. If cooling is too slow, or if the substrate begins to self-heat, mixing will help to cool it. When the substrate is cooled and ready to be filled in to the growing containers

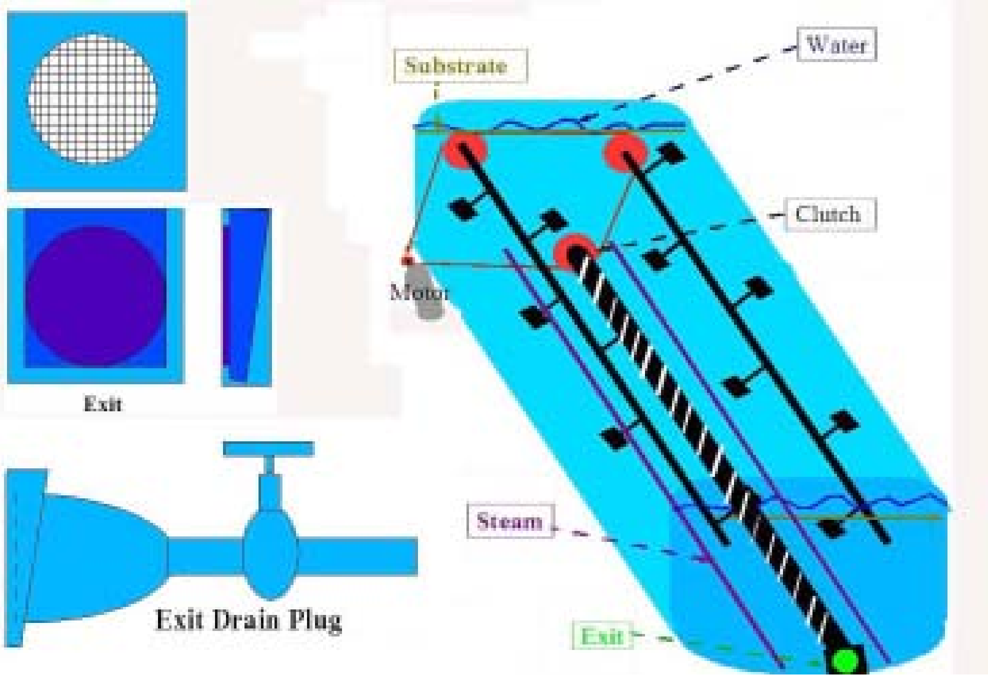


Fig. 12. A diagram showing the parts of the double shafted mixer and the drain plug needed to use the device with excess water.

(bags, etc.) the mixing machine can also be used to plant the spawn/mycelium in the substrate.

Figure 11 shows the end of a double shaft mixing machine with a screw-conveyor. **Figure 12** is a diagram of a double shaft mixer and accessories that will allow it to be used with excess water. The machine in **Fig. 10** replaced a smaller similar machine. Both have been used quite successfully to pasteurize with steam.

Figure 13 shows the ends of two single-shaft mixing machines. The one on the right is used to pasteurize, then a screw-conveyor moves the substrate to the mixing machine on the left where it is cooled. When it has cooled spawn/mycelium is added to the mixer on the left and another screw-conveyor

Fig. 13. The ends of two single shafted mixing machines used to pasteurize, cool, spawn and fill plastic "giant sausage" growing containers. (Russia)

pushes the spawned substrate into "giant sausages." **Figure 14** shows the inside of the pasteurizing (on the right in **Fig. 13**) mixer. **Figure 15** shows the process of filling "giant sausage" growing containers with spawned substrate. There is a heating jacket on the bottom of the pasteurizing mixer and the box at the far left is a High Efficiency Particulate Air (HEPA) filter for cooling air that is blown into the mixing machine on the left, when extra cooling is needed. This machinery allows the complete process from raw, dry substrate to filled, spawned growing container with no human contact

Fig. 14. A view of the inside of the pasteutizing mixer (mixer on the right hand side in **Fig. 13**).

and little contact with unfiltered air. It is never possible to be certain that disease and pests are eliminated, but this equipment makes disease and pest problems much less likely.

SUMMARY

Pasteurization is the most critical step in growing mushrooms. The grower must pay close attention to the time and temperature. None of the substrate

Fig. 15. Filling a “giant sausage” growing container with substrate that was spawned in the cooling mixer (mixer on the left hand side in **Fig. 13**).

can be less than 55ºC (131ºF) during the 30 or more minutes when the substrate is pasteurized. The substrate can never be more than 60ºC (140ºF) at any time when it is wet. Very simple equipment can be used with substrates that will allow all excess water to drain off. Those growing more that approximately 250 kg. (1/4 ton) each month, will usually find a mixing machine to save them more than it costs in a very short time. Machines capable of pasteurizing, cooling, spawning and filling the growing containers will cost more, but they will provide more protection against diseases and pest, and also save a great amount of human labor.

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

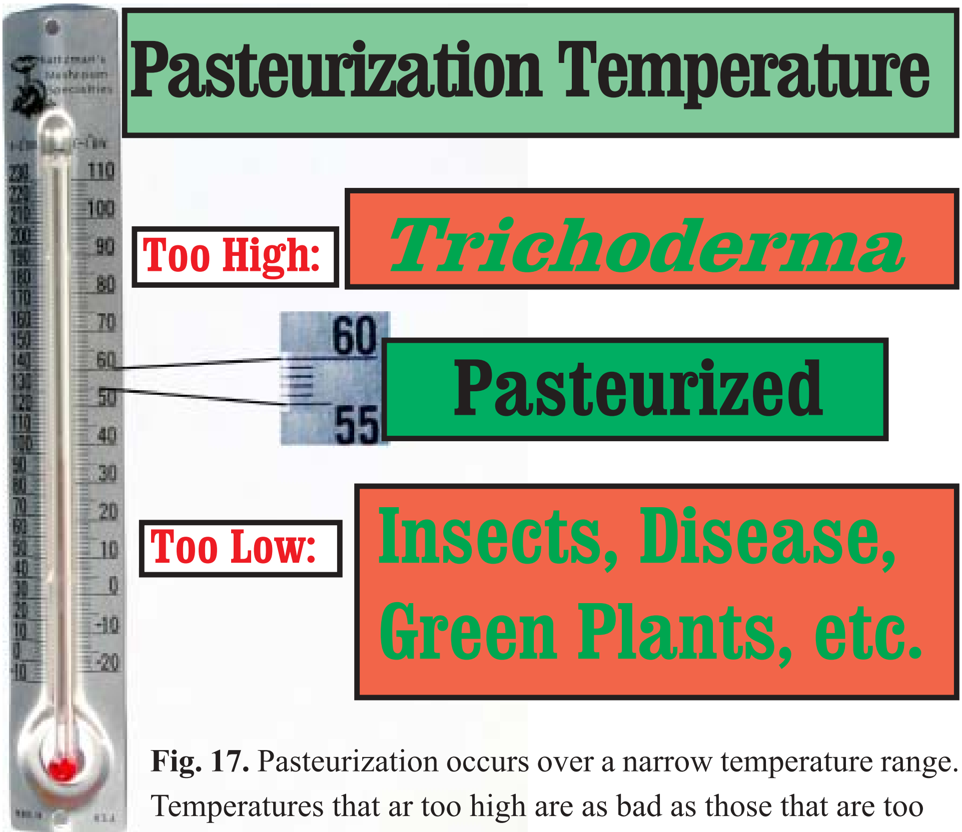


Fig. 17. Pasteurization occurs over a narrow temperature range. Temperatures that ar too high are as bad as those that are too low.

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.

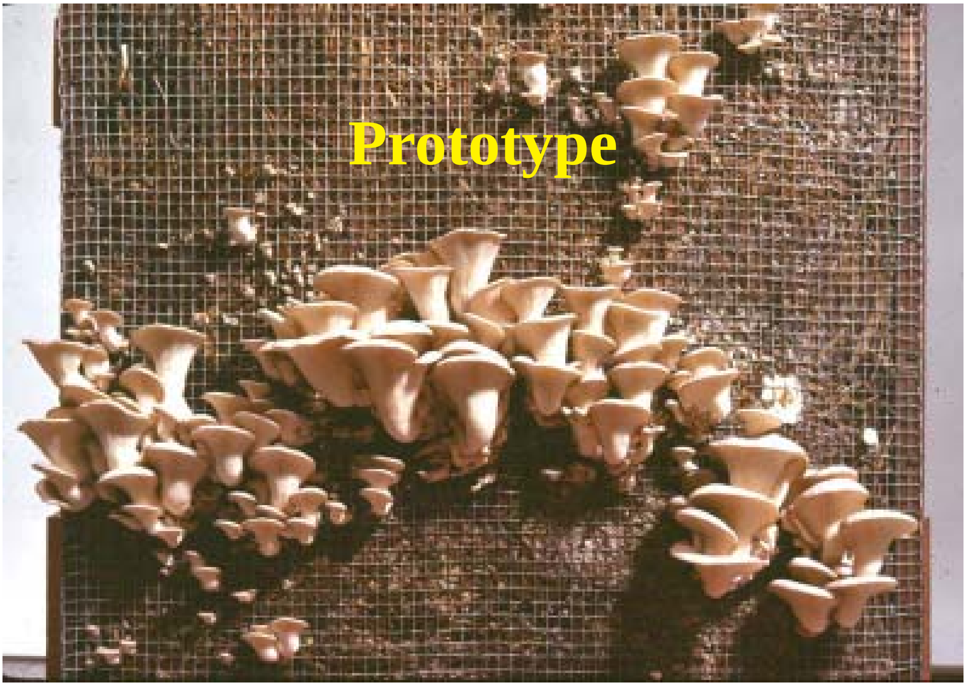
GROWING CONTAINERS

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.



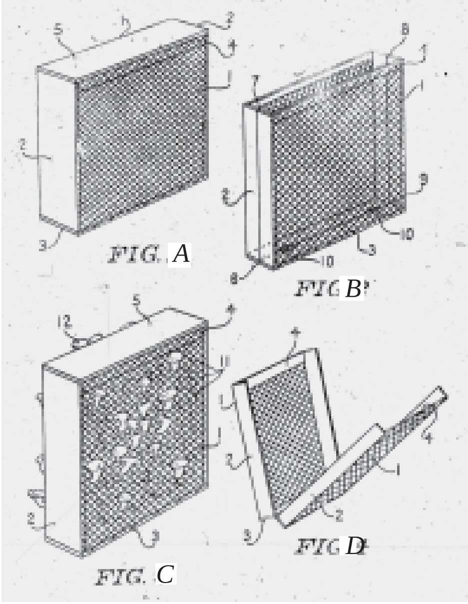


Fig. 19. Above is a prototype of a tray with oyster mushrooms growing on straw. Variations in the construction of the tray are shown in FIG. A-D at left. The prototype worked well for the first flush. However, the wire mesh must be larger; 10 cm (4 in) is recommended. It is also recommended that black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

Chapter 4

PACKAGING and PRESERVATION

The primary reason for growing mushrooms is to sell them and make profit. If we think of clean-up as the first step in growing, then the last step in growing is harvesting. We might also think of harvesting as the first step in preparation for selling. Then the steps in preparation for selling might look like:

1. Pick the mushrooms
2. Cool the mushrooms (3 – 5°C, 37 - 41°F)
3. Trim them
4. Pack them
5. Ship (Sell) them

Fig. 22. Tills of freshly picked *Agaricus* mushrooms stacked on a cart, to be thaken to packing area. Oyster mushrooms are more fragil.

You must pull the mushrooms to harvest them. You must not cut them. It is very important that the edge of the mushrooms are still curled under when they are picked. When the edges flatten, the spore will be released into the air. The release of spores does two things, it makes the air dangerous for workers, it can result in severe hay fever or asthma when workers breath

Fig. 23. Triming *Agaricus* mushrooms, Taiwan, 1974.

them. Spores represents a significant weight, so there is less to sell. Errors are often made in picking, so although you believe you are picking all, before they release the spores, it is wise to wear a surgical mask in growing rooms. An additional reason to pick early is that after the spores leave, the mushroom has no biological purpose, so it will begin to decline rapidly and will soon look old.

Cooling mushrooms helps them last longer and look better. The best way to cool mushrooms is to place them in a chamber and draw a vacuum. That process is used for leafy vegetables. Of course, expensive equipment is required, but it will cool faster than any other method. The cooling is the result of water being evaporated, that suggests that you will dry the mushrooms, but less water is used than will be lost by evaporation with

Fig. 24. Applying the plastic overwrap to retail trays of *Agaricus*, 1973.

other methods. Faster cooling means that the mushrooms will last longer for the customer. Cooling may also be done with mechanical refrigeration or even by putting them in a container with ice. However, once they are picked they should not be in direct contact with water, including melted ice.

Oyster mushrooms are much more fragile than *Agaricus.* Although it is common to harvest into large tills, it is very unwise with oyster mushrooms, **Fig. 22**. *Agaricus* may even be poured from till to till. Such treatment would break and destroy the appearance of oyster mushrooms.

STEMS AND TRIMMING

Because the mushrooms have been pulled, they will often have a little substrate attached. The substrate must be cut away, **Fig. 23**. Most *Pleurotus* will have some stem. Stems are generally difficult to chew, so not favored by customers. So you will have a better product, if the stems are removed by trimming. Of course, the stems add weight and if customers do not understand that they are getting a better product, it may be wise to leave the stems. Stems can be used to make other products, but that requires extra equipment and people to do the work. It is not practical with small amounts of stems.

PACKAGING

If we observe the average shopper for a short time, we notice that they will generally buy items that look good to them. It is true for almost everything they purchase. If you do not cut off the stems, you should be certain that they do not interfere with the appearance of your mushrooms. We break eggs in preparation for cooking, but how many people will buy broken eggs to take home? Mushrooms may be broken and bruised by people handling them, so an attractive package will sell more mushrooms than if they are displayed loose.

Some sales may not require an attractive package. Generally bulk sales to restaurants will be loose. Chefs or other restaurant operators usually consider that it is their job to make appealing displays of food. Also, they will not wish to open many small packages. However, they are not much different than other people, so it may be easier to sell them if they see mushrooms in appealing packages first.

It has become almost a universal practice to pack mushrooms in plastic or paper trays and to over wrap the trays with plastic film, **Fig. 24**. The film protects them from the hands of customers and holds in moisture. Mushrooms are still alive as long as they continue to look good. The film will also restrict the oxygen that the living mushrooms require, so we must be certain that there is some place were oxygen can enter the package. Over wrapped trays have been used for more than 30 years for *Agaricus*, but it has now become almost universal for all kinds of mushrooms, **Fig. 25**.

Packing rooms should be clean and comfortable for workers, but then need not be elaborate, **Fig. 26**.

Fig. 25. Retail packages of oyster mushrooms from three continents.

Fig. 26. Simple packing rooms.

Fig. 27. Canned oyster mushrooms, left. Dried oyster mushrooms, right.

EXCESS PRODUCTION

A grower may not be able to fill demand for months and then suddenly find that things go so well that they have more mushrooms than can be sold. There are also times when the demand decrease suddenly. For example, in many places wild mushrooms become abundant and people hunt them, or buy them from those who hunt them. With more more mushrooms suddenly available, some will not be purchased.

No mater why there are more mushrooms than can be sold, the grower will want to save the extra that he has, so that they can be sold later. Mushrooms are often "canned," that is, sealed in a glass or metal container and cooked under high temperature so that they are sterilized, **Fig. 27**. Some mushrooms, including *Agaricus* are quite nice when preserved in that manner. However, oyster mushrooms have a poor appearance after being cooked in water. Oyster mushrooms, like most mushrooms, will look quite good when they are dried. It may seem strange, but the one mushroom that dries poorly is *Agaricus*. When *Agaricus* is dried, it "bleeds" and a large part of the solid matter drips out with the moisture.

A third method that has been used is freezing. No mushroom looks good when preserved in this manner, however, a colorful, opaque wrapper may make the product more appealing.

DRYING PROCESS

A number of ways have been developed to dry foods, sun, ovens, vacuum, etc. All are possible with mushrooms, the highest quality is produced by freezing the mushrooms, then placing them in a vacuum where they remain frozen until all water is removed. That process is called freeze-drying and is very expensive, both for energy and for the required equipment. The most efficient drying is called tunnel drying. Tunnel drying will give a high quality product. A tunnel drier can be constructed from ordinary materials, and will use less energy than most other driers.

In some communities, the grower will be able to find a company who dries other food and arrange to have the mushrooms dried by them. However, if the drier's business includes wild mushrooms, the grower may find that the drier is too busy with wild mushrooms to bother with his mushrooms. That suggests an additional activity. Someone must sell the grower's dried mushrooms and if wild mushrooms are dried in the same drying facility, the various mushrooms could be sold at at the same time.

The cross section of a tunnel dryer with dampers to control the amount of fresh air and the exit of moist air, is shown in **Fig. 28**. Thermometers, hygrometers and thermostats are also needed to control the temperature and humidity. Re-circulating the air not only saves the heating fuel, but the somewhat moist air actually dries the food faster.

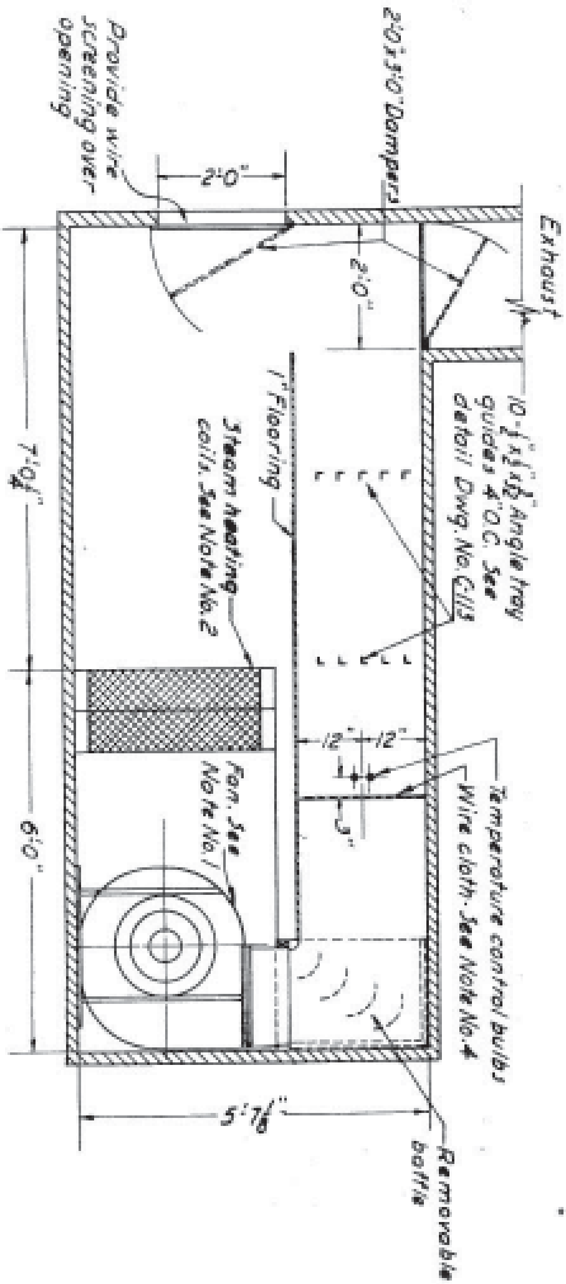


Fig. 29. The main features of a tunnel dryer in a front cross section. Any enclosed heat can be substituted for the steam.

Fig. 29

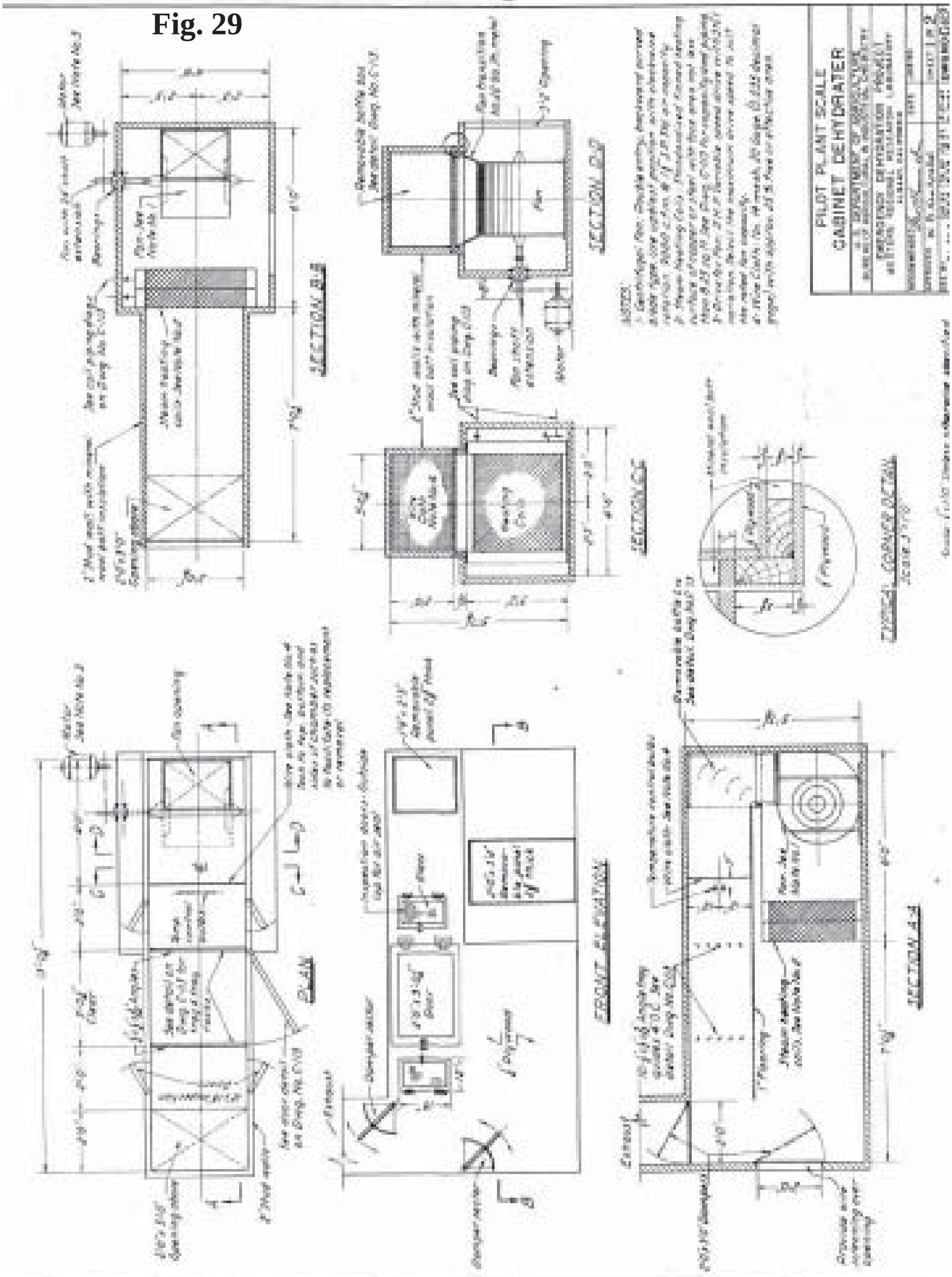

PILOT PLANT SCALE CABINET DEHYDRATER
SECTION B-B
SECTION D-D
SECTION C-C
PLAN
FRONT ELEVATION
SECTION A-A

Fig. 30

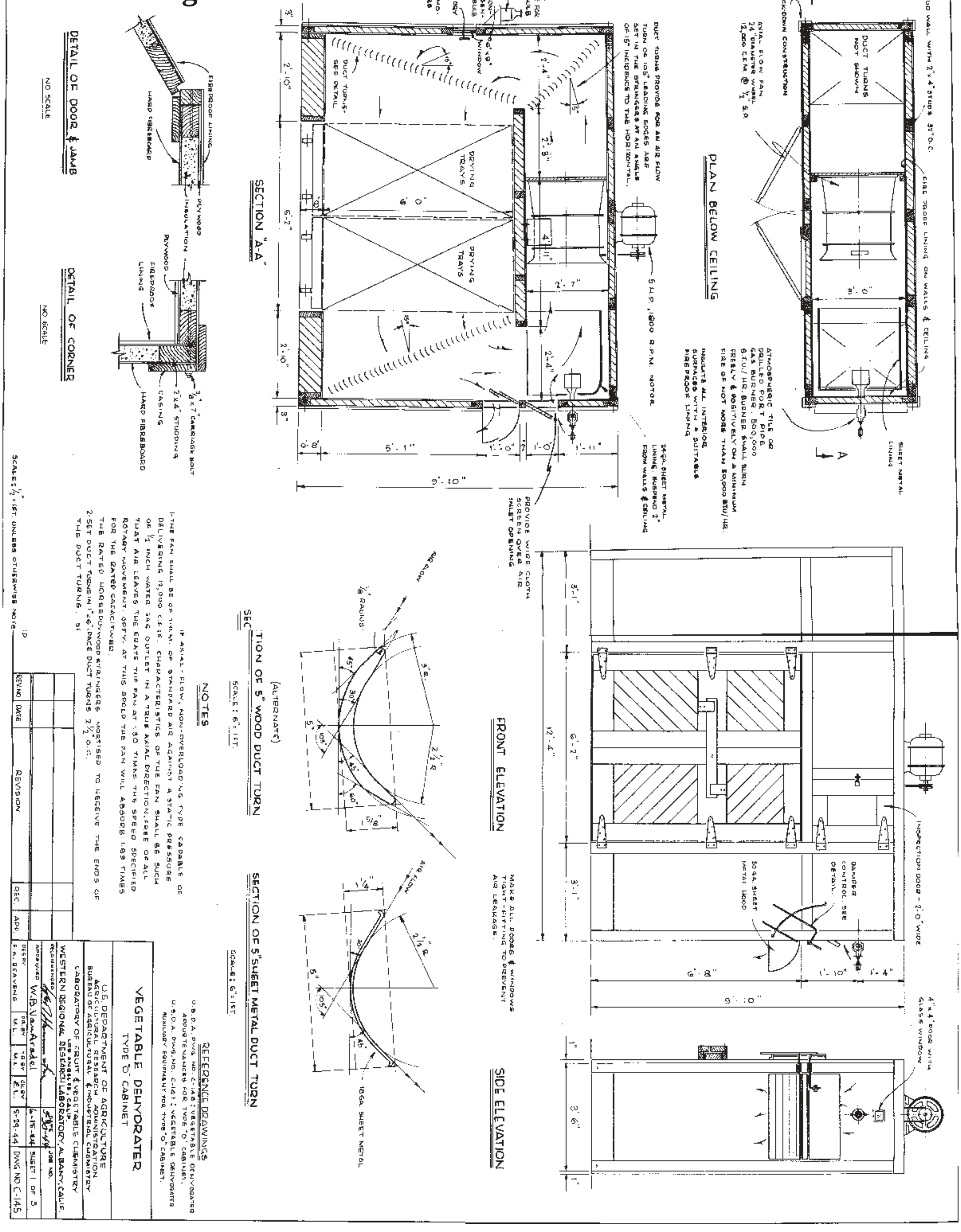

DETAIL OF DOOR & JAMB
DETAIL OF CORNER
SECTION "A-A"
PLAN BELOW CEILING
FRONT ELEVATION
SIDE ELEVATION
SECTION OF 5" WOOD DUCT TURN
SECTION OF 5" SHEET METAL DUCT TURN
NOTES
REFERENCE DRAWINGS
VEGETABLE DEHYDRATER
TYPE "D" CABINET
U.S. DEPARTMENT OF AGRICULTURE
WESTERN REGIONAL RESEARCH LABORATORY, ALBANY, CALIF.

Fig. 31 Tunnel dried oyster mushrooms packaged in a plastic bag for retail sales.

The design for two driers of different sizes are shown**, Fig. 28, 29, 30**.

TUNNEL DRIER CONSTRUCTION

A tunnel drier consists of a blower to circulate air, a heater to increase the temperature of the air to approximately 40 to 50°C (104 to 122°F), a place to put the food to be dried and is shown in a large cross-section (**Fig. 28**)**,** as well as in all views combined, **Fig. 29**. Anyone contemplating the construction of a drier would do well to study these drawings carefully. If the second is built as a mirror image of the first, they can share a common wall and access will be through the walls opposite.

THE DRY PRODUCT

Like the fresh product the dried mushrooms should appeal to the shopper, **Fig. 31**. If they are sealed in a clear plastic bag, they will show off well.

However, dried mushrooms are fragile too, so placing them in a tray with a sealed over-wrap may be of value.

If mushrooms are well dried at the low temperature of a tunnel drier, they may have little smell. Some people may expect them to have a smell and be dissatisfied. It may be necessary to alter the conditions to sell to such customers.

SUMMARY

Mushroom growers need to avoid wastes and sell the best possible products. It is necessary to pick mushrooms at the proper time, handle them with care, packaged them and save all that can not be sold while they are fresh.

Picking affects quality and quantity. Handling may make some difference in quantity, but it will have a great influence on quality. Packaging will have a great affect on the quality. Preserving may have a very large affect on quantity and the resulting profits.

Chapter 5

MUSHROOM DISEASES and PESTS

If the cultivation of mushrooms is an art, then we must give them the best care we can, as an artist cares for his pictures. If it is a science, we must learn how to care for them, so that we get the highest yields. Those two aims are clearly compatible, in either case we need to understand what is required to give the best result.

Diseases and pests often happen by themselves. A growers job is to keep them from happening. Fungicides, insecticides and other chemicals may help, but as Benjamin Franklin said, “an ounce (28 g) of prevention is worth a pound (454g) of cure.” We might say, prevention is worth 16 times as much as a cure.

Before we can understand what is needed for prevention we need to understand how diseases and pests get into our crop and how they are spread.

There are five primary ways that things get in and are spread:

1. Air
2. Water
3. People
4. Substrate
5. Spawn

Fungal spores, bacteria and viruses can all be blown in with our required air supply and insects can fly in, sometimes even against the flow of air. Viruses may be carried, by fungal spores and the insects can carry all of the other problems.

Water can carry almost the same things air carries, but insects may only arrive as eggs, in water. Water may also carry nematodes.

All of our problems can hitch a ride on people. Clean hands and clothing are particularly important. It is wise to keep those who do the pasteurization and spawning away from growing rooms, especially as the crop gets older. It is also wise to keep those who work in growing rooms away from the spawning area.

If substrate is properly pasteurized, it will start out free of diseases and pests. Proper pasteurization assumes that the material used was not already heavily contaminated with microorganisms before it was pasteurized. Although freshly pasteurized substrate should never be a source of diseases and pests, if any diseases or pests get started growing in it, the substrate becomes a source of more problems. If you have problems with pests or diseases, your substrate is a problem.

Spawn should never be a source of problems, but sometimes it is. The best spawn makers are very careful to keep out all diseases. If spawn does not look good, it should certainly be rejected. It should never have insects, but some diseases are difficult to detect. Viruses are particularly difficult and will probably not be detected by any, but the most sophisticated suppliers of spawn. Spawn is where the crop starts, so growers must be careful to only get the best.

HOW TO KEEP DISEASES AND PESTS OUT

While most diseases and pests happen by themselves, we know how most happen and we know that if we pay close attention to sanitation or, if you prefer hygiene, we can prevent them. The simplest description of sanitation is keeping everything clean. What I mean is that plus a little more.

We can break it down into the important parts:

1. Clean water
2. Filtered air
3. Careful pasteurization
4. Clean workers
5. Clean surroundings

CLEAN WATER

Clean water is needed for every other sanitation need. Water that is not clean can carry diseases and even pest eggs. Obtaining clean water can be difficult. In most places a deep well (ca 30 m or more) will be good. Surface water (river, lake, etc.) should be filtered and chlorinated. The best and proper way to install a good water supply using surface water is really the job for someone well trained in water treatment. However, anything that can be done to have clean water is desirable. Clean water is probably less important for pasteurization than for any other growing need! That might suggest a way to treat water for other purposes.

WATERING

Even clean water can spread disease if it is sprayed on a diseased area and it splashes. While the Rose-head sprinkler is often recommended, it does splash. A mist sprayer will not splash, so it is better.

CLEAN AIR

All air coming into spawning and growing areas must be clean. The only way we have to make it clean is through filtering. Various filters have been used in the past. Today, the best filters are High Efficiency Particle Air (HEPA) filters. If HEPA filters are not available, forced air furnace filters of various descriptions are possible. Three layers of muslin cloth is a possibility if commercial filters are not available.

Building as Protection

1.Filter air into building
2.Screens of filters at air exits
3.“Air-lock” entrance room
4.Foot bath
5.“Air-tight”

We must pay attention to all places where air can leave the room as well as the places it enters. It is good to have filters in the air exits. It should be remembered that every hole or crack is a place where air exits. It is wise to caulk all cracks and unwanted holes.

It is necessary to provide humid air in the growing rooms, clean water is needed, although, if the room must be heated, steam is a good way to add humidity. If cooling is required “swamp coolers” which are devices that blow air over a continually wetted loose packing can be helpful. However, that wet packing must be carefully maintained. If it is not, it can destroy your sanitation efforts. There are many other good humidifying devices, but they must all be kept clean.

CAREFUL PASTEURIZATION

Many believe that if a little is good, more is better. In the case of diseases and pests, that is almost always wrong. Pasteurization, is the process of holding

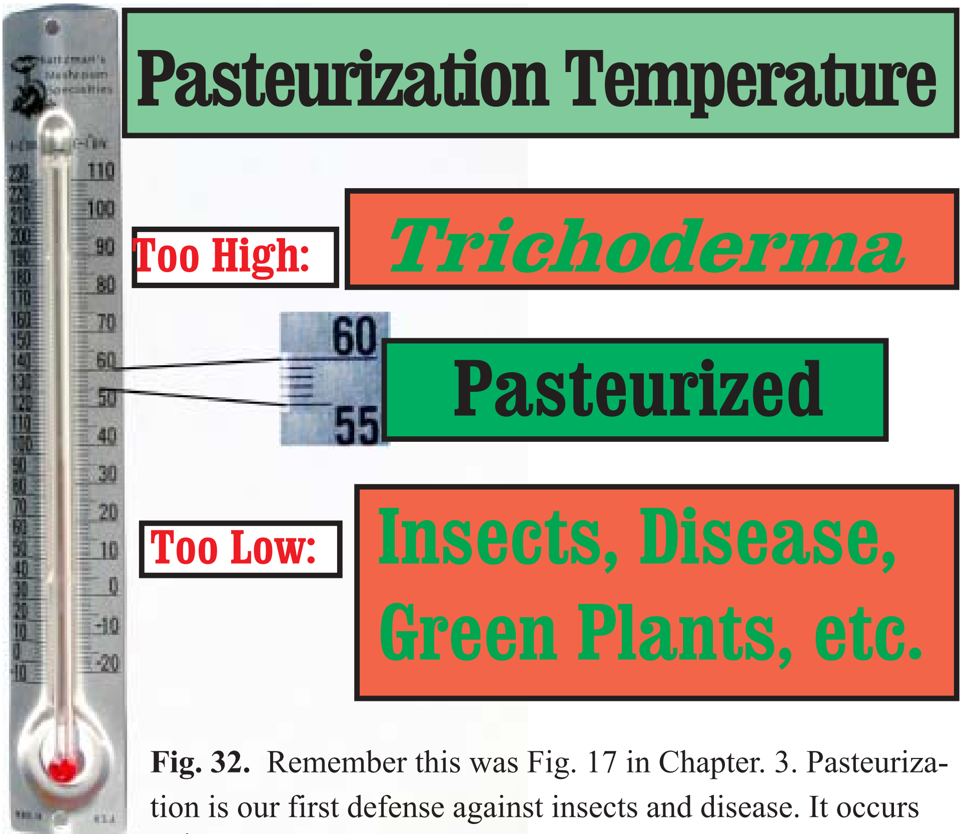


Fig. 32. Remember this was Fig. 17 in Chapter. 3. Pasteurization is our first defense against insects and disease. It occurs only over a narrow temperature range.

ALL THE MATERIAL to be pasteurized at 55-60°C (131-140°F) for 30 to 60 minutes. If there is plenty of oxygen the time can be extended, but **NEVER** increase the temperature **ABOVE 60°C (140**°F)**,** and generally it should not be more than 55°C (131°F) for more than 15 minutes. It is also the general practice to cool slowly so that it requires 12 to 20 hours to decrease to 25°C (77°F) (**Fig. 32**).

I hope my temperature specifications are what you expected. People who use 55-60°C (131-140°F) generally have little problem. However, if my times seem strange, you may not yet be aware that there are two common methods of pasteurization. I like to refer to them as the steam method and the hot water method. The steam method is used for *Agaricus* and *Pleurotus*. When used for *Agaricus* composting supplies part of the heat and cooling is slower. My descriptions today are for *Pleurotus*.

The Steam Method requires that we first wet the substrate thoroughly. Wetting may be difficult, but it must be done in a very few days, or our substrate will begin to rot and may be nearly impossible to adequately pasteurize. Once wetted it is placed in a chamber, possibly a room where steam is injected until it is 55-60°C (131-140°F). It is wise to stir it, and the temperature should be measured in many places to be sure that it is all warm and none too warm. Although one is very careful to measure the temperature, small spots may not reach the desired temperature. For that reason, it is customary to hold the temperature at about 55°C (131°F) for four hours. Then it is allowed to cool slowly.

The Hot Water Method is intended to begin with dry substrate. Water is placed in a container and the temperature is raised to 55-60°C (131-140°F). The dry substrate is added and the temperature is checked to be certain that it remains at 55-60°C (131-140°F). If the substrate is dry, and it is wetted by the hot water, it will **ALL** be at the temperature of the water. There will be little problem with wetting, because the heat melts the natural wax and helps penetration. If the substrate has gotten moist, 60°C (140°F) would be recommended and the substrate should be added very slowly while the water temperature is monitored closely, being certain that it is never less than 55°C (131°F). The substrate is held in the water for 30-60 minutes. Then the water is drained off. It is important that it not be held more than 60 minutes because it will become anaerobic and bad for the mushroom. Then it is allowed to cool slowly. Heating may be done with steam or direct fire. The problem with this method is that the resulting water is generally a disposal problem.

CLEAN WORKERS

Clean workers does not mean that they should be dressed for a fancy event, but rather that they should not be carrying any diseases or pests. If they have



Fig. 33. Personal hygene is very important. Hands must be washed. For critical operations, use gloves. Clothes can carry disease and insects.They should be cleaned every day.

been in a place where there is a problem it should be assumed that they are carrying it with them. Minimum cleaning should mean that they will dip their boots in a shallow bath of saturated salt or dilute hypochlorite when they enter a growing area. Hands should be washed with soap and water.

In the spawning area, special care should be taken. Those mixing the spawn with substrate and packing it, **must** wash their hands and anything that will touch the spawn or substrate. They should also wear latex gloves. Hair should be restrained and their outer clothing should be very clean; if possible it should be kept just for that work (**Fig. 33**).

Face masks are not of much value in protecting the crop, but during harvest, they are recommended in growing houses There is always a chance that some spores have been discharged into the air and may cause asthmatic or hay-fever in the workers.

Workers must enter through a door and can provide an entry for diseases and pests. The problem can be reduced by providing a air-lock room. The room can be built inside the growing or spawning room and very inexpensively with black plastic sheet. It should have an outside entry door and a second door into the growing or spawning room. It can provide a place for workers to clean-up and change clothes.

CLEAN SURROUNDINGS

The areas around growing houses and spawning areas can provide excellent

Fig. 34. Weeds, brush and rotting materials near growing facilities will harbor diseases and pests.

places for problems to hide. If wild mushrooms are growing just outside the door, the problems are at you door. Brush, weeds, stumps and old logs should be cleaned back to about 100 meters if possible. No rotting material, from animals or plants should be allowed in the area.

More important than all other things, the spent substrate must me taken as far away as possible, at least several kilometers. Before it is removed the growing area should be “cooked out.” Cook out is best done by using steam to heat the room to at least 60° for at least 6 hours. Unlike pasteurization, higher temperatures will not cause problems. We need to get rid of everything that might cause trouble. After cook out, the room should be thoroughly cleaned. Methyl bromide and formaldehyde are sometimes used instead of steam. However, both are very dangerous and should only be used by people

Fig. 35. *Trichoderma*, Green mold, is the most common disease of oyster mushrooms. It most generally comes in the air or from human handling. Generally, the substrate was over-heated at pasteurization time. **60°C Maximum!**

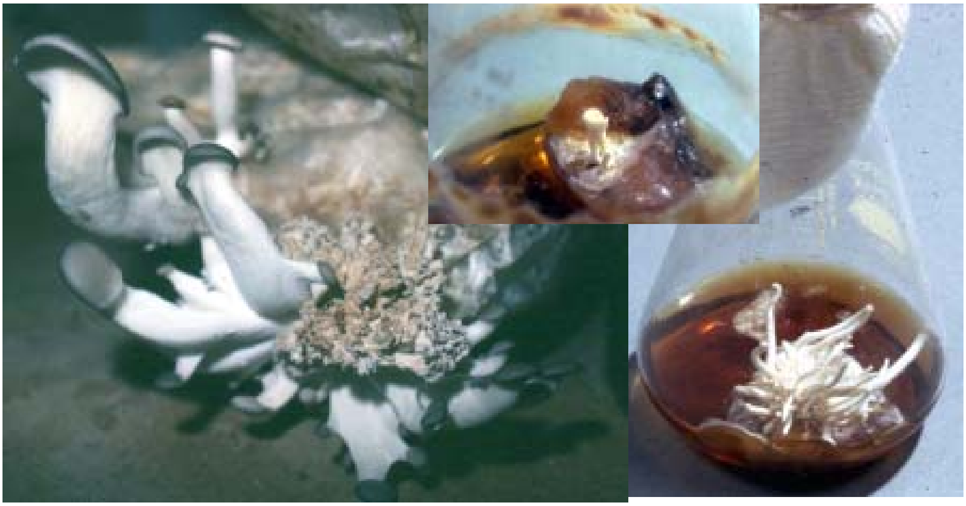


Fig. 36. Long stipes or stems is the most common physiological disease. It is usually caused by carbon dioxide, due to inadequate ventilation, but it may also be caused by inadequate blue light.

Fig. 37. Fat stems with almost no cap. The cause of this problem is not adequately studied, but it appears to be a natural poison in the substrate. Occurs on first flush, second flush is normal.

with training and experience.

WHAT TROUBLE LOOKS LIKE

I have said much about how to avoid problems and if you follow everything I said, you **MAY** never see disease or pests. Unfortunately, I can not guarantee that you will not. So I will to show you what such problems will look like so that you will notice them if they do appear.

Sanitation will help avoid problems, but things can still go wrong. You need to be constantly on the lookout for problems. If you do see diseased or infested materials, as soon a possible, they should be removed as far as possible from your growing area and destroyed.

Fig. 38. *Verticillium* = Dry bubble
Dry bubble causes distortion and spotting.
Above: *Pleurotus.* Right: *Agaricus.*

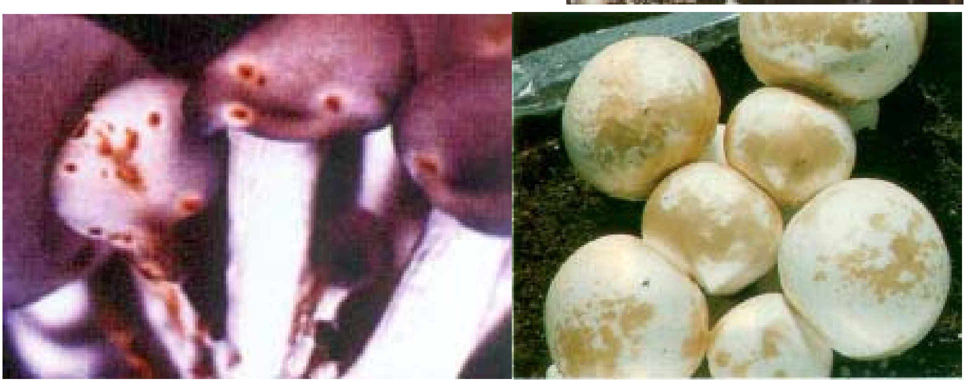


Fig. 39. *Pseudomonas tolaasii.* Left: *Pleurotus.* Right: *Agaricus*

Fig. 40. A Virus. The change in color is caused by a virus. Below: The small white arrow points to the virus DNA on an electrophoreogram.

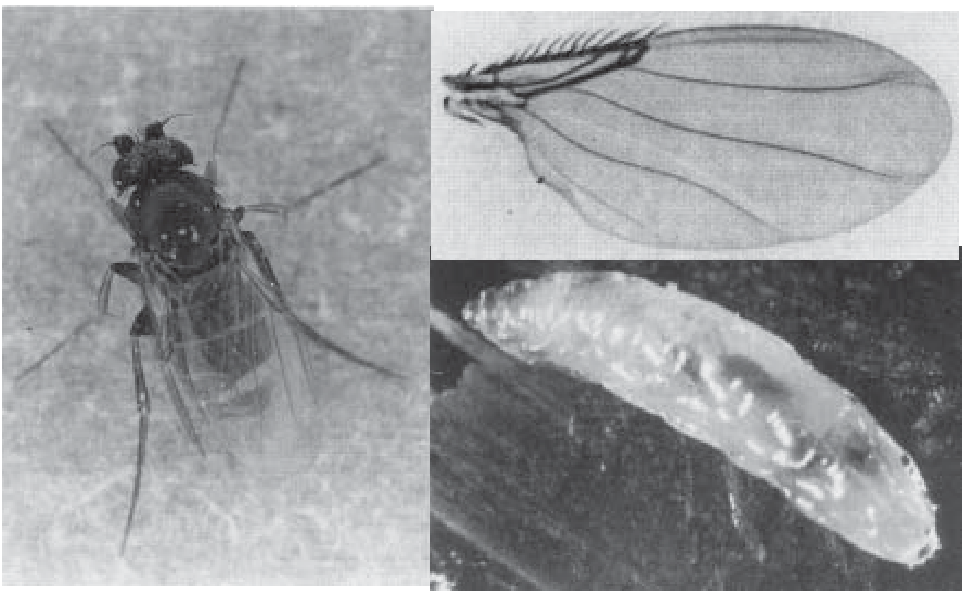


Fig. 41. Phorid fly = *Megaselia*. The larvae of the genus *Megaselia* like to. eat mushrooms and can cause great damage.

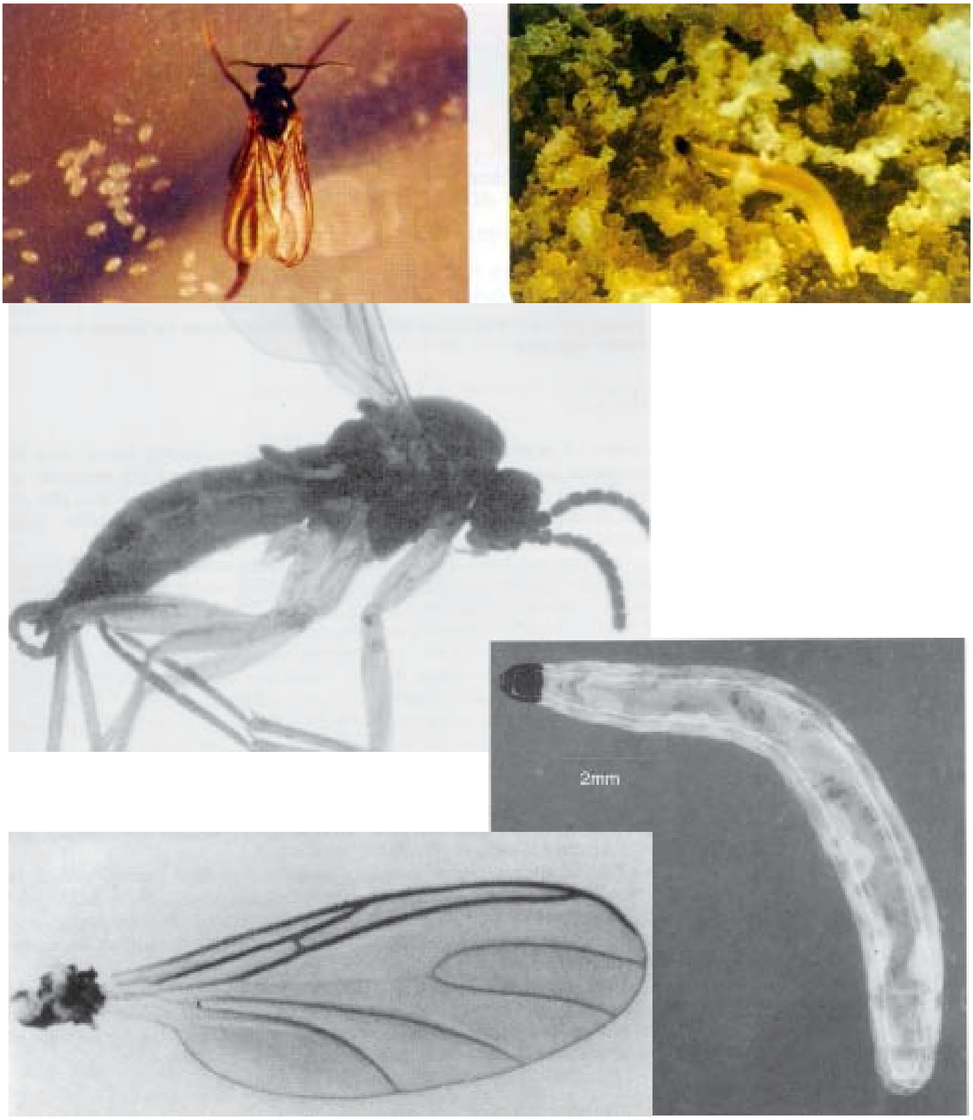


Fig. 42. Sciarid fly = *Lycoriella*. A major problem. The larvae (maggots) do the real damage. The genus *Lycoriella* is easily identified: black head of larva and wing pattern. Most will arrive in the air or are left from the previous crop. Wild mushrooms are their natural food.

Fig. 43. The genus *Heteropeza* has white larvae and the genus *Mycophila* (top) has orange larvae. The adults are very small. Larva size is variable.

Fig. 44. Slime molds make mushrooms unappealing. Left: *Physarum compressum*.Right: *Stemonitis herbatica*.

Fig. 45. Nematodes are microscopic to 1 mm round worms (above). *Pleurotus* may even eat (trap) them. Mites (right) do some direct damage, but the biggest problem is that they spread *Trichoderma* and other diseases.

Fig 46. *Mycogone pernicious,* Wet Bubble. Bubble causes distortion of the fruit body in *Agaricus.* Chlamydospores are characteristic of *Mycogone.*

Fig. 47. *Mortierella*, Shaggy stipe, a disease, caused by a. On *Agaricus*,

Fig. 48. Rosecome. A disease caused by petroleum products in the air or wather. May be fumes from a diesel or gasoline engine on equipment. On *Agaricus.*

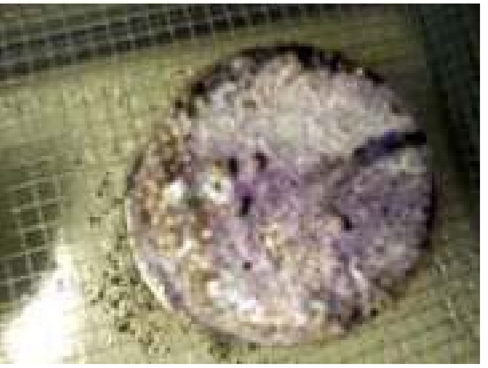
 

Fig. 49a. Lipstick. *Sporendonema.* **Fig. 49b.** Pink *Neurospora.*
These may appear on bad spawn or on substrate

OTHER POSSIBLE PROBELEMS

There are a number of other problems that can occur. For many the required management will be quite apparent.

Slugs and Snails can eat mushrooms and substrate.
Rats and Mice can eat mushrooms and spread disease quickly.
Excess water will keep air from reaching part of the substrate, the mycelium will not be able to reach the over wetted substrate.
Additional viruses
Coprinus It may leave mushrooms covered with its black "ink."

Several additional diseases known in *Agaricus*, but are not likey to cause problems with *Pleurotus.*

Cobweb, *Dactylium*
Diehlomyces, "Truffle"

Chapter 6

SPAWN MAKING: A JOB ONLY FOR WELL-TRAINED PERFECTIONISTS

Logically, this should be the first chapter, since we must have spawn before mushrooms can be grown. However, most mushroom growers buy their spawn. Spawn making is a business that does not mix well with mushroom growing. It should always be a completely separate facility at least several kilometers (miles) from ay mushroom growing facility.

Spawn making requires the utmost cleanliness and care. It must be cleaner than any area used for human surgery. All clothes must be cleaned every day. Shoes must be used only for the area where the spawn is produced, and **never** worn into any area that is not absolutely clean. All workers heads should be covered so that nothing can fall from hair into the spawn. Workers should wear surgical masks. Workers who smoke or are exposed to smoke must take a shower before they enter the spawn-making area. Workers must also take a shower and wash thoroughly after any exposure to any other fungi or mushroom material. All of the surfaces in the rooms should be hard. Ceiling, walls and floor must be washed regularly, preferably every day. All air must be filtered with High Efficiency Particulate Air (HEPA) filters.

There is some danger in making spawn, particularly if new cultures are started from mushrooms. It is reported that a number of amateurs have contracted serious mycoses (human diseases caused by fungi) as a result of attempting to make spawn. At first, such problems may sound unlikely. However, if in attempting to grow mushroom mycelium, the grain or agar becomes contaminated with a human pathogen, the amateur may propagate it and give himself or those around him a massive inoculation of disease causing organisms. We are naturally equipped to resist infections, but we are not able to resist any disease if we receive massive amount of the causal organism.

Some of the need for absolute cleanliness can be reduced if "laminar hoods" with certified High Efficiency Particulate Air (HEPA) filters are used for all of the work, **Fig. 50**. If a hood is used, it must be absolutely clean, workers must be clean, and everything that goes into the hood must also be absolutely clean. In the use of hoods, it is difficult to be certain that everything that goes in is absolutely clean. In the directions that follow, precautions for things placed in the hood will be discussed.

OBTAINING MUSHROOM CULTURES

The best and usually easiest way to get a culture is to obtain one from an established source such, as a culture collection, a research laboratory, or possibly another spawn producer. Some sources will charge for their cultures. However, the cost is not usually high from the most reliable sources, compared to the risk of other sources.

There are several reasons that one might want to make a totally new culture. One is that there may be great problems with getting a culture from an established source. Another is the desire to establish a new line because one observes some desirable characteristics in wild mushrooms or in only

Fig. 50. A laminar hood, suitable for preparing spawn. However, clutter is not permissible.

one or two mushrooms that they are being grown. There are two ways to approach making the new culture: from a spore print, or from mushroom tissue. With most mushrooms, the spore print method is very difficult, since one must start with a number of separate, single spore cultures and then breed them, by growing two together until they fuse. Some mushrooms behave

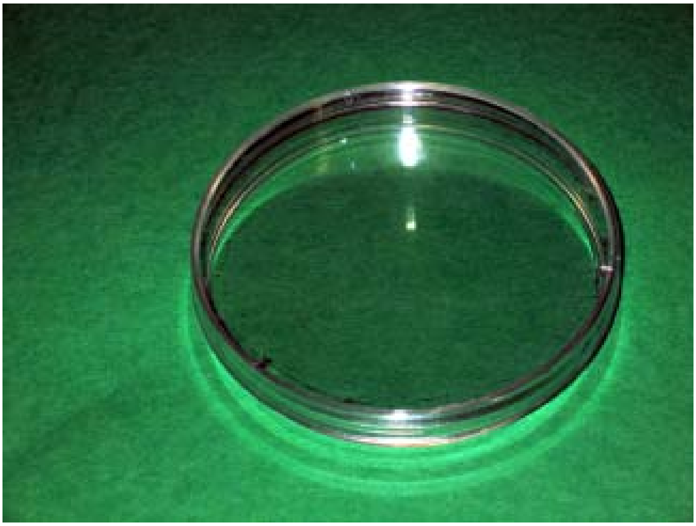


Fig. 51. A petri dish. Used for sterile cutting and for testing for contamination.

almost as if there were four sexes, and successful breeding will only occur with the correct two. We have not learned how to distinguish the "sexes" except by trial and error breeding. Thus, on average, breeding fails in three out of four attempts. *Agaricus bisporus* is an exception and single spores from it will normally produce a mycelium which can produce mushrooms, with no problems or benefit of breeding.

Spore Cultures: For culture purposes, spore prints are made by placing a piece of paper in the bottom of a jar and attaching a hook to the lid. The bottle is then sterilized. When the bottle has cooled, the mushroom is attached to the hook, with the gills down. The bottle is closed and allowed to stand for 8 to 24 hours, or less time if spores can be seen. A needle is used to scrape spores off the paper, one at a time. Each spore is placed on an agar "slant" in a test tube. In general, it will be wise to make at least ten tubes from the print of each mushroom. The tubes are then incubated at about 15 to 20°C (59 to 68°F) until substantial mycelium is seen.

Tissue Cultures: Tissue cultures are generally the best way to obtain a new culture. One can expect that the new culture will produce mushrooms with the same characteristics as the mushroom from which the tissue was

Fig. 52. A small laminar hood, suitable for work with small containers. For example starting new cultures and inoculating agar slants.

taken. While tissue cultures, done properly, are likely to succeed, some will be contaminated and some will fail to grow. For that reason, one will want to make several tubes from each mushroom.

To make a tissue culture, first take liquid chlorine bleach and dilute it with 10 parts of water to 1 part bleach in a small, clean container. Cut a piece of fresh mushroom about 1/2-1 cm (1/4-1/3 in) square. Drop the piece in the bleach and leave it for one minute. Open a sterilized petri dish, remove the mushroom piece from the bleach and put it in the plate, **Fig. 51**. A pre-sterilized plastic dish is preferred, glass works, but use care when cutting. Trim off the outside of the piece with a sterilized knife. Push the trimmings

Fig. 53. An autoclave. The steam-pressure vessel, used for sterilization.

aside and cut the remaining piece into cubes of about 2-3 mm. With a sterilized wire loop or with the knife, place the pieces on agar in tubes. Incubate at about 15 to 20°C (59 t0 68°F) until substantial mycelium is seen.

Both new culture procedures are best done in a small laminar hood or a glove box, **Fig. 52**. It will not be surprising if your agar shows round glistening spots after it is incubated, if that should happen, discard the tube. You may also see mycelium that is not associated with the tissue cube or the spore, those tubes should also be discarded.

WHAT IS STERILIZATION?

It is very important not to confuse sterilization and pasteurization. Pasteurization is never used in spawn making, but it is generally used for cultivating mushrooms. Sterilization requires a pressure vessel called a retort or autoclave, **Fig. 53**. Sterilization requires a minimum of 121°C (250°F) steam (2 atmospheres pressure) for 20 minutes. That short time is only adequate if nothing contains more than 20 ml of liquid and all glass vessels or other equipment is thin and easily heated. Longer times are necessary for greater volumes of liquid, heavier equipment, and especially for anything solid that occupies a substantial volume. Containers with 200 ml of liquid will require 30 minutes. Grain used as substrate for spawn will require many hours. The exact time will depend on the size and shape of the containers.

Another means of sterilizing is to heat things in a flame. Wires, needles and many other things are heated until they are cherry red. Usually that method is only practical with small metal items and then only to about 3 cm above the area that is actually used. Although they have been sterilized, the openings of tubes and bottles are normally put in a flame as soon as they are opened, kept open for only a few seconds and put in a flame again, just before they are closed. Knives and some other utensils, are generally first dipped in 70% alcohol and then put in a flame, just to ignite the alcohol, and used as soon as the alcohol flame goes out.

AGAR SUBSTRATES

Two formula are often used for agar substrates. One is called **Potato Dextrose Agar** or **PDA**. Cook 200g of pealed potatoes in 1 L of water. Drain and save the water. You are finished with the potatoes, but they are good, so eat them. Make the water back up to 1 L with fresh water add 20 gm dextrose (= glucose – not common sugar), and 18 gm agar. Heat until the agar dissolves. Put into containers, plug and sterilize. Many people will tell you to use only distilled water and laboratory grade agar. Water that is safe to drink after it is boiled and food grade agar are generally quite adequate for maintaining cultures. When the containers come out of the autoclave, they are generally laid down (“slanted”) in a manner that allows a maximum surface area for the mycelium.

I favor dilute **Malt Extract Agar.** Unfortunately, commercial dehydrated agar with that label may not even contain malt extract and will be very poor substrate for all fungi. Malt extract is available in places that supply amateur beer makers, as a syrup or occasionally a powder. Add 20 gm of the extract to 1 L of water and 18 gm of agar, heat until the agar is dissolved. Put into containers, plug and sterilize. As with PDA, the containers should be “slanted.”

KEEPING STERILIZED THINGS STERILE

If sterilization is done in a room that is washed daily, especially if chlorine bleach is used to wash it, it is only important to keep the items covered. However, if the room where sterilization is done is not very clean, things should be over-wrapped before they are sterilized and kept wrapped until they are in the laminar hood or other very clean place.

Although the table or bottom of the hood has been kept extremely clean, everything that touches it must be considered contaminated. Of course, that level of contamination is not a problem for the bottom of containers, workers hands or the handles of instruments. However, it is a problem for container covers, the working ends of needles, and other surfaces that will touch mycelium, agar, sterile grain, other substrate, or the inside of sterile vessels. Needles, knives and similar things will be re-sterilized with the flame every time they are used, so they may be laid down between uses, then flamed again.

Even with great care and careful cleaning, so that everything looks very clean, problems may remain. To be certain that everything has been done properly, and that filters are working properly, open agar plates should be placed in the laminar hood or other area, while culture and spawn containers

Fig. 54a. Glass ampules used to store mycelium in a liquid nitrogen refrigerator.

Fig. 54b. Plastic ampules also used to store mycelium in a liquid nitrogen refrigerator.

are open. When the work is completed, the plates should be closed and incubated with the cultures or spawn. Agar plates for this purpose will be petri dishes with a layer of the culture agar (PDA or malt). Any substantial number of colonies on the plates will indicate problems with cleanliness in the work area. Dishes must be labelled so that you will know what they are several days later.

KEEPING THE CULTURES

It will be necessary to have a stock of mycelium to keep a spawn making operation going. The usual method is to grow mycelium in tubes, then to take small samples and put them in a number of sterile ampules (small glass or plastic containers)(**Fig. 54**) with glycerol, seal them by melting the glass at the opening, then putting them into a liquid nitrogen refrigerator**, Figs. 55**. Liquid nitrogen must be added to the refrigerator at regular intervals so that the mycelium remains frozen in the liquid nitrogen. When it is time to prepare for a new batch of spawn, one ampule is removed, it is taken to the laminar hood or other sterile area, the top is broken off, and the contents put on the agar in a fresh, sterile tube. Then that tube is incubated at about 15 to 20°C

Fig. 55. A liquid nitrogen refrigerator.

(59 to 68°F) until the mycelium is well grown.

Liquid nitrogen refrigeration is now considered the only adequate method to preserve mushroom cultures. Continued re-culturing eventually results in reduced production and other losses in quality of mushrooms. More ordinary refrigeration of cultures at -10°C (+14°F) and preferably lower, will allow storage of mycelium for a year or two with little loss in quality.

SPAWN INOCULUM

The mycelium from one tube is used to inoculate several large tubes of sterile agar. The inoculation must be done under the most careful and clean conditions. A wire loop or hook that is flamed to a cherry red and cooled will be used to remove the mycelium from the one tube and put a piece in each of the others. The mouths of the tubes will be flamed just after they are opened and just before they are closed.

There are several possible things that may be done after the large tubes are grown and there are different dangers of contamination associated with each.

1. Mycelium from the large tubes may be placed directly into containers of sterilized grain that will become the final spawn. Since only a small amount of mycelium is used compared to the total grain, growth will be slow and contamination will have time to become established, or even to leak in through the area provided for air.
2. Mycelium from the large tubes can be placed into similar tubes filed with grain. When that grain is thoroughly grown, it will be used to inoculate the containers of grain that will become the final spawn. The final spawn will grow more quickly because of the greater, more similar inoculum and it is easier to be certain that the tubes are adequately sterilized than to be sure that a large container is adequately sterilized. However, it is more difficult to detect contamination on grain, compared to agar and it will go through two growth cycles on grain.
3. Some other material may be used for an intermediate step. One large spawn producer uses a stick coated with a substrate as the inoculum for the final spawn.

STERILIZATION OF GRAIN FOR SPAWN

Rye, milo (grain sorghum), and millet are all commonly used for making spawn. One preparation method: 10 Kg grain, in 15 L water, boil 15 minutes allowed to cool 15 minutes, drain well and stir. 120 gm of gypsum ($CaSO_4 \cdot 2 H_2O$) and 30 gm. ground limestone ($CaCO_3$) are mixed in, then the grain is place in containers and sterilized at 121°C (250°F). The length of time required for sterilization will vary with the size of the containers, and how tightly they are packed. To some degree, you will need to determine the time by trial. One liter bottles containing 350 to 400 gm of the prepared grain will require at least three hours at 121°C (250°F). That is, no time is counted until the vessel is up to pressure and its exhaust thermometer shows 121°C

Fig. 56. A v-blendor, used by a major spawn maker to sterilize the grain for spawn. The blendor rotates while high-pressure steam is put into the blendor. Since the grain is kept lose, heat penetrates quickly to sterilize.

Fig. 57. Filling bags with sterile grain from the v-blendor (**Fig. 56**).

(250°F). Cooling requires time as well, so one should expect that a minimum of five hours will be required from the time the autoclave is loaded until it is ready to be unloaded. If cooling is too rapid, the plugs or filters, that provide for air to enter the containers, will be blown out or damaged.

When the material has had a short time to cool, each container should be shaken to loosen the grain. They should be allowed to cool to 20 to 25°C (68 to 77°F) before they are inoculated.

Large spawn producers are able to use expensive and novel sterilizing system. One system is a high pressure steam V-blender, **Fig. 56** It is filled with the grain, then filled with steam. As it rotates every grain is in direct contact with steam, so sterilization is very rapid. The grain leaves the blender by sterile exit tube and goes directly into large, sterile, plastic bags with air fillers sealed in their sides. Inoculum of mushroom mycelium is added and the tops of the bags are heat-sealed.

INCUBATION

Once inoculated the containers should be placed on clean shelves at 15 to 20°C (59 to 68°F). After about one week, they should all be shaken to spread the mycelium evenly through the container. Shaking will speed growth and make the spawn a more even product. It may be wise to shake several times before the spawn is fully grown. If possible, the spawn should be used within a week after all of the grain has turned white with mycelium. If that is not possible, the spawn should be refrigerated at 4 to 5°C (39 to 41°F). Even in a refrigerator, the spawn will be old and weak after 30 days. If the spawn feels light in weight, it is old or it was not properly prepared.

SUMMARY

Spawn making facilities must be completely separate from mushroom growing facilities. Preferably the facilities should be separated by at least three kilometers (2 miles). Spawn making requires expensive equipment and a very high degree of careful work. Many operations required for production of quality spawn can be done at a lower cost per unit of spawn by large spawn producers. Spawn making requires full time work and management. The most important characteristic of an adequate spawn production facility is cleanliness.