# 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.

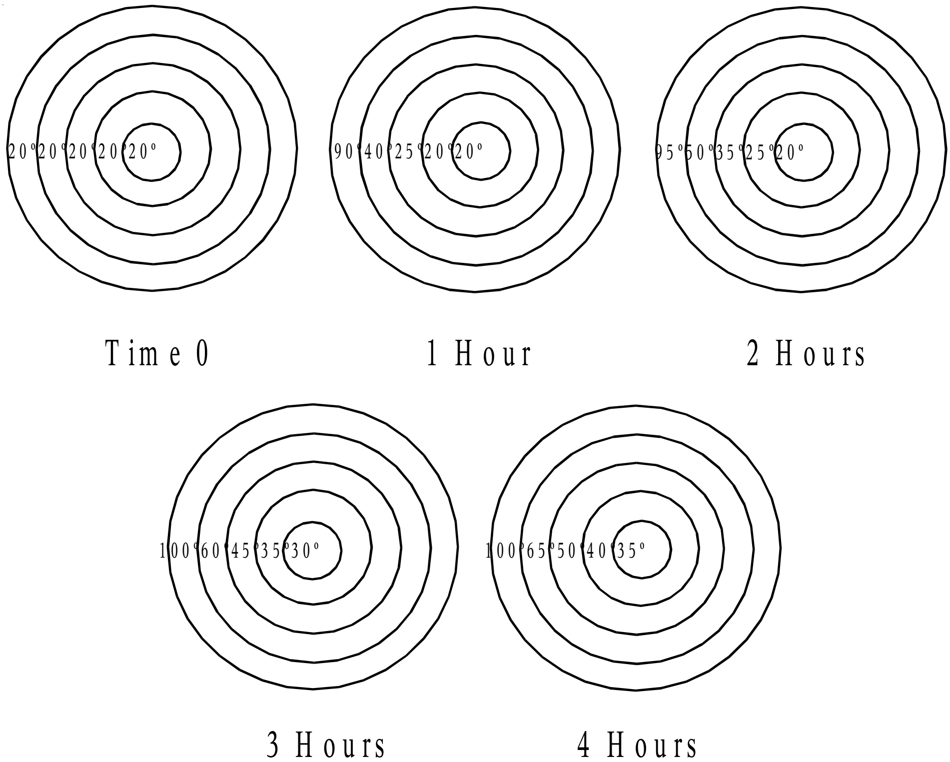


**Fig. 7**. The diagrams represent the problem of using steam to pasteurize substrates.

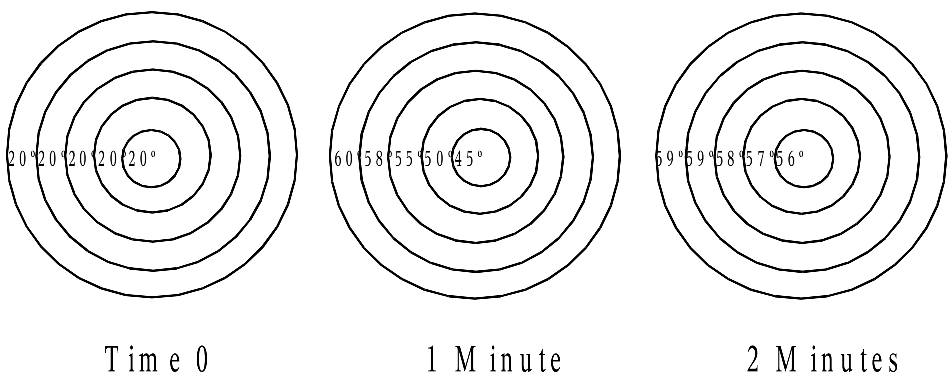


**Fig. 8**. The diagrams represent heat flowing with the water to pasteurize substrates.

## 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

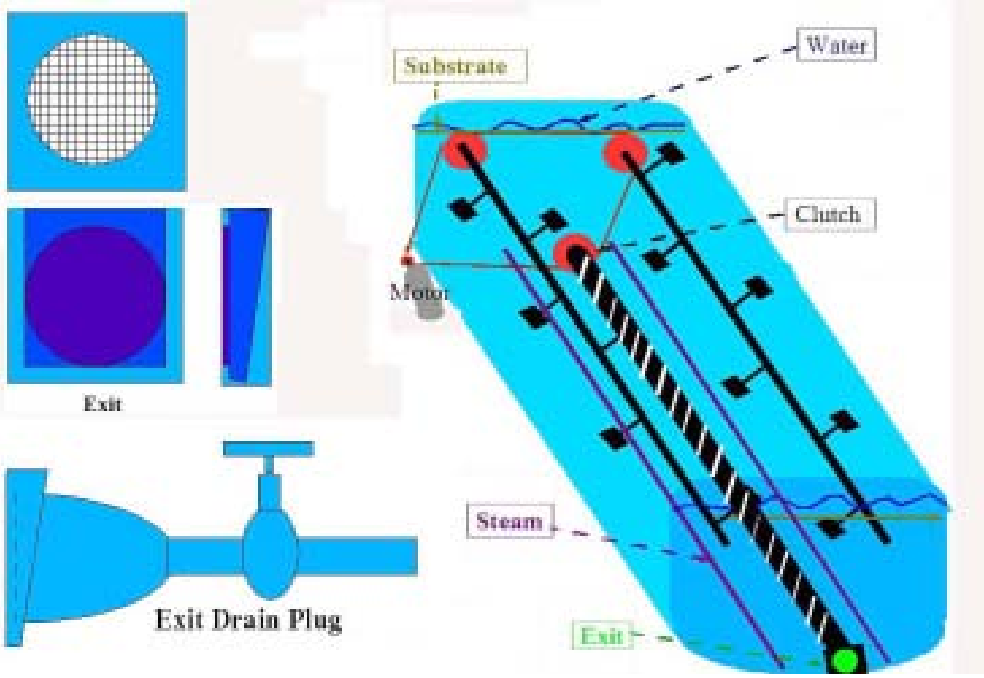


**Fig. 12**. A diagram showing the parts of the double shafted mixer and the drain plug needed to use the device with excess water.

(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.