Part I Shiitake

Chapter 4

Shiitake Bag Cultivation

Further Reading

Shiitake Bag Cultivation in the U.S.

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The major advantages of producing shiitake on sawdust bags compared with producing shiitake on natural logs are: consistent market supply through year-round production, increased yields, and decreased time required completing a crop cycle. The cycle for supplemented sawdust block cultivation lasts approximately 3 months from time of inoculation to cleanout. Biological efficiencies for nutrient supplement substrate average from 75% to 125%. In contrast, the natural log cultivation cycle usually lasts about 6 years with maximum efficiencies around 33%. The time required on sawdust substrate is about 6% of the natural system with about 3 times the yield efficiency. These advantages far outweigh the major disadvantages of a relatively high initial investment cost to start a sawdust block manufacturing and production facility. As a result of these developments, shiitake production in the United States has increased dramatically in the last 10 years.

Substrate preparation

Sawdust is the most popular basal ingredient for shiitake bag cultivation in the U.S.. Starch-based supplements (10-60% dry weight) such as wheat bran, rice bran, millet, rye, and maize are added to the mix. These supplements serve as nutrients to provide an optimum-growing medium. Other supplements, added in lesser quantities include $CaCO_3$, gypsum, and table sugar. The ingredients are combined in a mixer and water is added to raise the moisture content of the mix to around 60%. Bags are made of heat resistant polypropylene and contain a breather patch made of microporus plastic. The filled bags are stacked on racks (Fig. 1A), loaded into an industrial-sized autoclave (Fig. 1B), sterilized for 2 hours at 121℃, cooled in a clean room and inoculated with shiitake spawn. The bags then are heat-sealed and the spawn is through-mixed (evenly distributed) into the substrate by mechanical or hand shaking. An alternative method of substrate processing and spawning is to heat-treat, cool, inoculate and aseptically bag the substrate in the same machine.

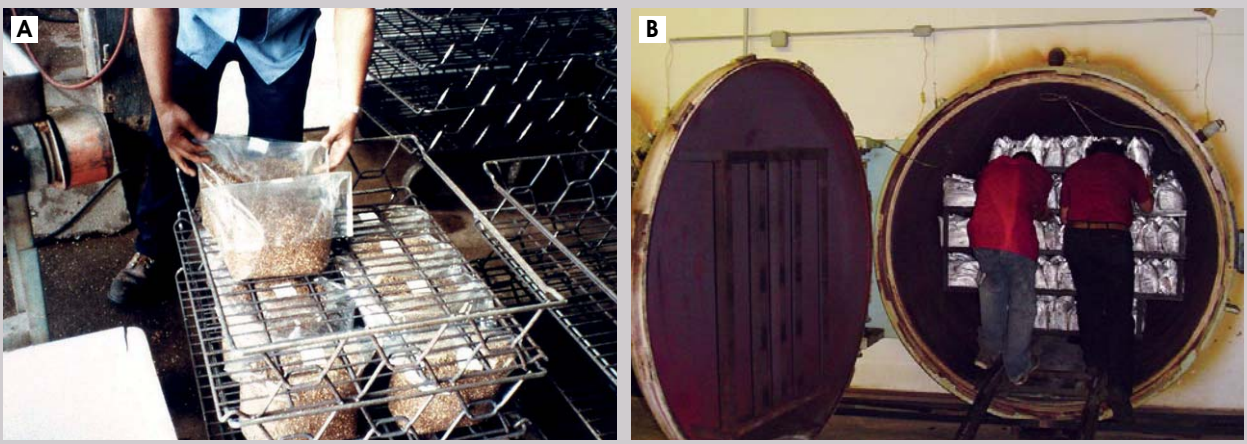

Figure 1. Sterilization **A**: Stacking of supplemented substrate contained in microporus filter bags onto autoclave carts. Tops of bags are folded over so that adjacent bags do not cover patches that allow for gas exchange. **B**: Workers moving carts containing shiitake medium in bags into large autoclaves.

Spawn run and browning

If through mixing of the spawn (2-3% of wet substrate weight) into the sterilized substrate is used, a 20-25 day spawn run at 21℃ (4 hours light per day) is all that is required (Fig. 2A). With this method, the bags are removed from the substrate after completion of spawn run and the substrate blocks are exposed to an environment conducive for browning (oxidation of surface mycelium, also called skin formation by growers) of the exterior block surfaces. The browning process allows the mycelium on the log surface to aggregate and toughen thereby forming a layer of hyphae that is resistant to desiccation. During the browning period (4 weeks) shiitake blocks are maintained at a temperature of 19℃ while CO_2 levels are maintained at 2,200-3,000ppm (Fig. 2B). Maintaining CO_2 at these levels requires less energy use (less heating or cooling of fresh air) and promotes faster browning of the block surfaces. Sawdust blocks may be watered lightly 1-3 times per day to maintain continuous surface moisture which helps to facilitate the browning process. Excessive watering, however, will cause the surface mycelium to turn black, an undesirable consequence that may reduce yield at a later stage. Blackening of the surface mycelium may be the result of bacterial growth with subsequent loss of the protective nature of the hardened mycelium. Many growers have learned to properly brown the exterior surfaces of the blocks using only humidification control. As the browning process nears completion, primordia begin to form about 1-2mm under the surface of the log and as the primordial enlarge, cracks (called "staring" by growers) may form in the protective hyphal layer. Staring (forming star like cracks) is a good indication that the block is ready to be soaked and to produce mushrooms. If through mixing of the spawn is not used, a spawn run of 45-90 days in the bag is necessary to achieve proper spawn run and browning.

Figure 2. Spawn run and browning **A**: Spawn run in substrate contained in microporus filter bags stacked on shelves in a standard Pennsylvania double (800m²). Bags are spaced approximately 1cm apart to facilitate air movement and cooling. **B**: Colonized substrate blocks on shelves 8 days after removal of bags. To enhance browning (oxidation) of substrate surfaces, water (mist) is applied 1-3 times daily.

Browning outside of the bag has some advantages and disadvantages over browning inside the bag. Browning outside of the bag produces a firmer, more resilient sawdust blocks that will resist breakage during soaking, harvesting and handling. In addition, browning outside the bag allows use of more productive strains that may cause blistering of the substrate if browning is completed inside the bag. Blistering is a condition wherein the outer surface of the log may buckle and develop air pockets that tend to flake off when removed from the bag. Browning outside the bag reduces the tendency for blocks to blister. Yields and mushroom quality tend to be higher when sawdust blocks are browned outside the bag. The disadvantage of browning outside the bag is the additional management required (watering 2-3 times per day and maintenance of higher relative humidity) so that block surfaces do not dry out. If log surfaces dry out, Trichoderma spp. may begin to colonize the desiccated hyphae and bits of exposed substrate.

Fruiting and harvest

To stimulate maturation of primordial when browning is completed, blocks may be soaked in water (12℃) for 3-4 hours. For blocks that are browned inside the bag, soaking on the first flush is not required because sufficient water is available to support the first flush of mushrooms. However, soaking of sawdust blocks is required for the second and

Figure 3. First-flush shiitake maturing on synthetic logs made from nutrient supplemented sawdust. After spawn run and browning, blocks are soaked and placed on shelves.

subsequent flushes. Soaking allows water to rapidly displace carbon dioxide contained in substrate air spaces, and provides enough moisture for one flush of mushrooms. After soaking, blocks are placed on shelves and mushrooms begin to enlarge. Approximately 7-11 days after soaking, mushrooms are ready to harvest (Fig. 3). Mushrooms are twisted from the surface and the residual substrate is sometimes removed with a knife or scissors to provide for a cleaner product. After all mushrooms have been harvested from the substrate, the blocks again are soaked in water. The second soaking may require up to 12 hours and the third soaking may require up to 18 hours to replace the water lost through production of mushroom tissue and through evaporation. The average time from the peak harvest of one flush to the peak of the next flush is about 18 days.

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