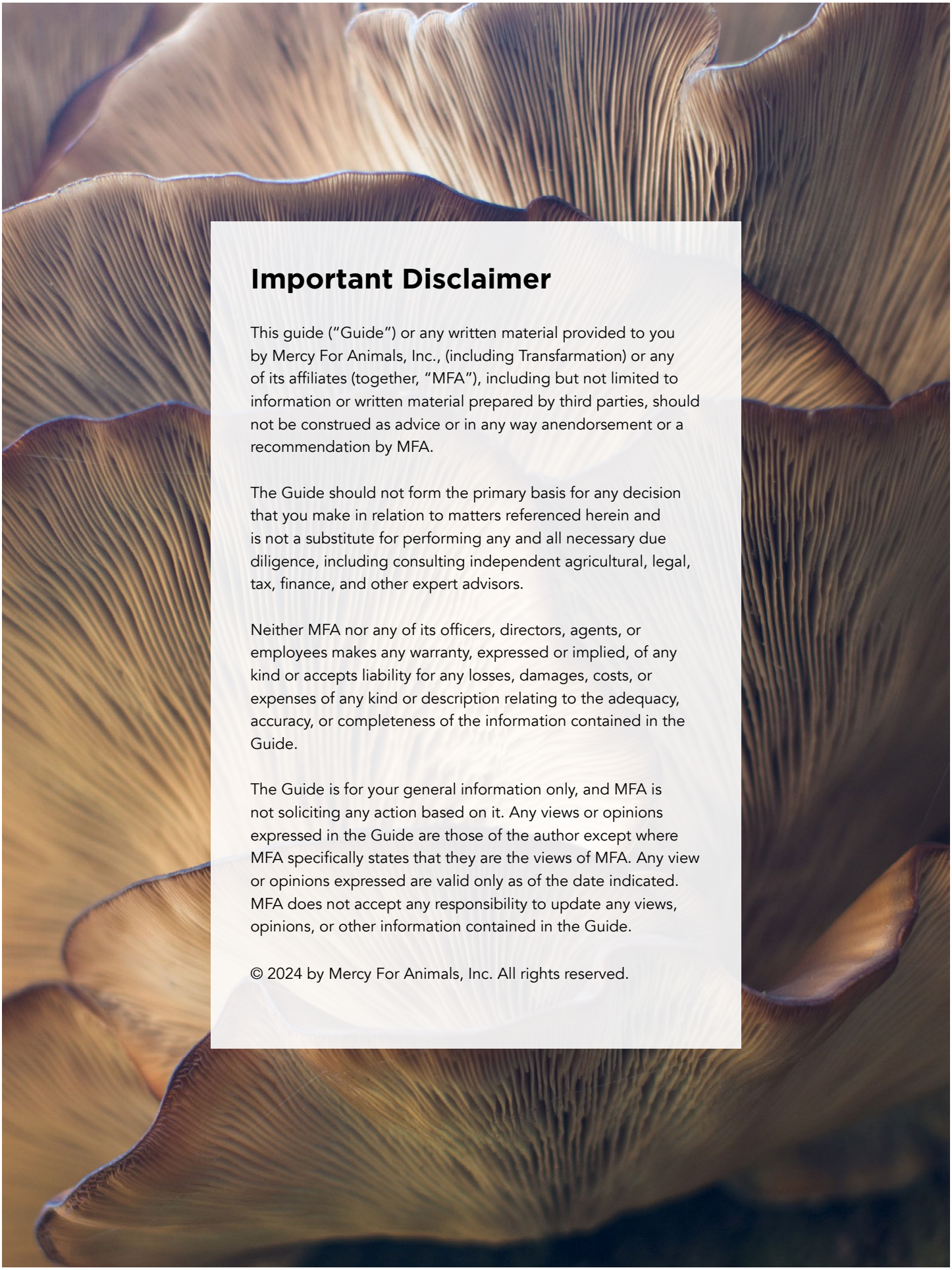
Guide to Commercial Hardwood Mushroom Production for Small & Midsize Farms

By Ches Stewart

Transfarmation



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Introduction

This guide provides beginning and prospective commercial mushroom producers with the foundational principles for setting up and operating their first commercial-scale mushroom operation. These principles can be applied to mushroom farms of vastly different scale, from supplying small farmers markets to serving wholesalers and national distributors. We will discuss input sourcing, substrate preparation and sterilization, basic lab skills, colonization monitoring, grow room management, postharvest handling, and finding a market.

Author and family in a Haw River Mushrooms grow room.

About the Author

I am the co-founder and owner of Haw River Mushrooms alongside my wife and business partner, Laura Stewart. I received a master of science degree in agricultural economics from Clemson University and a bachelor of science degree in animal science from Middle Tennessee State University. My professional agricultural experience includes managing six high tunnels at an Ohio produce farm and data gathering and reporting for the 2015–2016 poultry census.

I began cultivating mushrooms in 2012, initially anticipating it would be a one-off crop within a range of diversified produce. I quickly became enamored with the growing process and realized there was a high demand for mushrooms but few growers, especially at that time. After I started Haw River Mushrooms, I spent the first five years balancing the scaling of my business with off-farm work as a crop adjuster. I started growing on hardwood logs (a less labor-intensive growing methodology), transitioned to growing on straw bags in a high tunnel, and in my third year graduated to growing on amended sawdust. In 2017 I made the transition to full-time mushroom farming. As of this writing, I am in my 11th year of mushroom production and sixth year of full-time farming. Haw River Mushrooms produces over 37,000 pounds of mushrooms a year, which we sell at farmers markets and sell wholesale, as well as use in a line of shelf-stable and frozen prepared foods. We grow a variety of hardwood mushrooms, including blue oyster, grey oyster, golden oyster, pink oyster, snow oyster, Italian oyster, lion's mane, cinnamon cap, chestnut, reishi, and shiitake.

The Mushroom Market Today

There is considerable room—and need—for more U.S. mushroom growers. The North American mushroom market is expected to grow at a compound annual growth rate of 7.7% during 2019–2027. American consumers have an increasing interest in plant-based proteins, functional foods that provide health benefits as well as flavor, and crops that can be sustainably produced with regenerative agriculture practices. Mushrooms sit at the nexus of these thriving trends, leading to market opportunities for new growers in both small- and large-scale niches.

Building Out a Grow Space

Grow spaces can be as simple as an unheated greenhouse or a hobbyist tent, but to grow at a commercial scale, producers should invest in building out a climate-controlled structure. Grow rooms do not necessarily need to be brick-and-mortar spaces: Many growers, including me, build their infrastructure in modular structures, such as an insulated shipping container or a refrigerated trailer. More complex spaces may resemble a conditioned warehouse with multiple conditioned grow rooms.

Although mushrooms can be grown in a simple, unconditioned structure, this guide will focus on grow operations that start out in small modular buildings (like shipping containers and refrigerated trailers) with the goal of expanding into an existing structure on their own farm (like fowl and pig barns).

Designing Your Grow Space

Whether retrofitting a refrigerated trailer, shipping container, or chicken house or building a dedicated brick-and-mortar grow space, several variables must be managed to consistently cultivate mushrooms:

1. **Heating, cooling, and ventilation.** For an HVAC system in a grow room, a good ratio to follow is .75–1.00 ton per 100 square feet of actual grow space. Because spores and high moisture levels can shorten the life of your system dramatically, a portion of the entrance should be a dedicated preconditioning space and ducted directly into the grow room.
2. **Humidity.** The grow space should be kept at 90%–95% humidity. A quarter-inch waterline and misting nozzles on a high-pressure misting system will evenly distribute moisture, and properly spaced shelving will keep wet spots on fruit from becoming an issue.
3. **Fresh air exchange.** Mushrooms require fresh air to colonize, initiate pinning, and grow the fruit body. Because mushrooms require oxygen and emit carbon dioxide (CO2), you must always be bringing in fresh air and exhausting the CO2-heavy air. We use simple "can fans" (eight-, six-, or four-inch fans) that are easily installed and replaced. Because mushrooms create CO2, keeping the concentration levels below 700 parts per million (ppm) is vital. If a grow room has CO2 levels above 800 ppm, fruit bodies will be long-stemmed with undersize caps. And above 900 ppm, pinning mushrooms will cease development.
    - **Water escape and cleaning drains.** Often overlooked, drains are vital to a successful growing operation. Without drains, you cannot quickly clean your grow rooms—a constant chore—with pressure washers and commercial sanitizer. If you have fixed drains, installing a P-trap will help keep pests from entering your grow rooms through the drains. Otherwise, pests will easily get in and cause issues. In our grow rooms, we use a three-inch pipe. It rarely clogs and can handle a high volume of water.

If you are operating out of a room without a drain, a shop vacuum will work instead. A refrigerated trailer usually comes with a drain, and if you are using a shipping container, simply cut a drain hole in the metal. A fine mesh screen over the hole will help control the fungus gnat, fungus beetle, and slug populations in your grow room and allow all water to escape.

Stages of Cultivation

Commercial mushroom farms operate on a high-input, high-output schedule. By working with amended sawdust substrate (see "Substrate Sourcing and Preparation" below), growers achieve faster and larger yields with greater predictability. However, the trade-off for these benefits is that each stage of cultivation needs to be completed on a continuous schedule.

There are seven primary stages of colonization:

1. Substrate preparation.
2. Substrate sterilization.
3. Inoculation.
4. Colonization and spawn run.
5. Initiation and pinning.
6. Fruit body growth and harvest.
7. Postharvest handling.

At Haw River Mushrooms, we prepare our substrates on Monday, sterilize them overnight into Tuesday, inoculate them on Wednesday, and move most colonized bags into a grow room on Thursday. We harvest, monitor for contamination, and maintain a daily cleaning schedule. Commercial growers can simplify their operations by using colonized blocks on which mushrooms will fruit directly. Colonized blocks allow the commercial grower to circumvent substrate preparation, inoculation, and colonization, as well as spawn running, and advance directly to initiation and pinning. This method both reduces labor and eliminates the need for four infrastructure points (mixing area, lab, steam chamber, and colonization rooms) but increases up-front block purchase spending.

Each stage of the mushroom growing process will be described in greater detail below.

Substrate Sourcing and Preparation

Commercial growers of hardwood mushrooms typically use a substrate[1] of amended sawdust. Using sawdust instead of solid wood is like "pre-chewing" the food for the mushrooms, allowing the mycelia to colonize it more quickly. We supplement this sawdust with soybean hulls, which add nutritional amendments to further speed up the colonization process. Most hardwood varieties will be grown on a substrate of hardwood sawdust and soybean hulls known as "master's mix." Master's mix speeds up colonization greatly: A hardwood log inoculated with *Pluerotis ostreatus* mushrooms takes about six months to colonize and be ready to produce a fruit body, while a 10-pound bag of master's mix can accomplish this in only three weeks. Some mushroom varieties and strains, including shiitake and reishi, grow better with wheat bran instead of soybean hulls.

When my wife and I first started farming, we focused on growing mushrooms on straw (farmers can also use many similar agriculture byproducts, such as corn stover or soybean stalks). Straw was extremely labor-intensive and used the space inefficiently. But growing on straw does provide more flexibility in the cultivation cycle (allowing growers to inoculate once every four to six weeks instead of weekly) and reduces disease pressure. Straw bags are often used by high-tunnel farmers, who tie hanging bags to overhead structures to add to crop density without sacrificing precious high-tunnel soil space. In addition, the mushrooms naturally create CO2, a beneficial resource in the high-tunnel environment for plant photosynthesis. Straw substrate may also be desirable for farmers or homesteaders using mushrooms as an add-on crop because they allow for a less intensive production schedule.

While straw substrate may be the best choice for certain growers' capacity and conditions, our own production and consistency dramatically increased when we switched to sawdust supplemented with soybean hulls.

Sourcing and Testing Substrate

Hardwood can be sourced from local sawmills, which produce it by the ton and need outlets to help them clear it. While some growers use hardwood pellets available at farm supply and home improvement stores, we have found that this hardwood is more expensive, reduces production yields, may contain unpredictable foreign source materials, and may be difficult to source in the summer months. Instead, try calling your local sawmills to see whether they can deliver sawdust by the ton (or load it for you if you have an appropriate transport vehicle).

Before agreeing to source from the sawmill, confirm two important conditions:

1. Make sure that the mill does not process pine or cedar in the same space that they process the sawdust. Pine and cedar contain resins that will negatively affect your spawn runs. The sawdust should be sourced from hardwoods only. However, you have flexibility as to which hardwoods you use. For example, a mix of hickory, maple, and oak is perfectly acceptable. You can send your substrate to the Vilgalys Mycology Lab at Duke University for testing if you are concerned pine may be in your mix.
2. Do not accept sawdust that has been sitting for months, as it is more likely to have become a host to contaminants that are difficult to sterilize and can consume the nutrition intended for your mushroom cultures. The ideal sawdust should be slightly aged; several weeks is a good length of time. Freshly cut sawdust may still contain enzymes that defend living trees from consumption by spores in nature. However, freshly cut sawdust can still be used in a pinch because the enzymes will eventually succumb to your commercial culture.

Sourcing Soybean Hulls

Soybean hulls can be acquired in bags from many local feed stores (you may need to request a special order) or delivered on farm to be stored in a grain silo or supersack.

Mixing Substrate

The most common substrate mix is half hardwood sawdust and half soybean hull at a 60% moisture level. We add water using a water flow meter and hand test the substrate (which should hold together loosely in your hand but not produce water when squeezed). We use a moisture sensor to confirm the moisture level. The mix is then added to a "unicorn bag," a specialized bag with a ventilation patch.

Block Sterilization and Colonization

Steam Pasteurization

We use steam to "super-pasteurize" our blocks. This is also called atmospheric steaming because we don't pressurize the container. We use a steam generator to pump steam directly into a 20-foot shipping container until it reaches 195 degrees and maintains this temperature for two hours (all

[1]Substrate refers to the materials a mushroom is grown on. Button and agaricus mushrooms grow on a soil-based substrate, such as composted manure mixed with carbohydrate bulk amendments. This guide focuses on hardwood mushrooms, which are grown on substrates including freshly cut logs, amended sawdust, or sterilized straw.

temperatures noted in this guide are Fahrenheit). The doors are then opened for the bags to cool. There are many viable alternatives to this method, including livestock tanks heated with propane burners or sauna steamers.

Inoculation Lab

Our pasteurized bags are then put into the lab to cool. Our lab is a 12- by 20-foot building with heating and cooling. We use an eight-foot laminar flow hood to inoculate our substrates in sterile air. A commercial flow hood is necessary for reliable production.

Colonization and Spawn Run

Our current operations center on two 53-inch refrigerated trailers for colonization. We maintain the temperature at 70 degrees and do not humidify the space. We have found that we can maximize colonization times (and therefore production) at this temperature. During this stage, each block produces about one British thermal unit of heat daily. Exceeding 70 degrees in your space can cause heat stress and slow colonization. Bags are positioned four inches apart due to the heat generated as the mushroom colonizes the substrate. Mind the difference between the inner and outer temperatures of the bags: If the outside of the bag is consistently 70 degrees, the interior could be 80 degrees, depending on species, substrate, etc.

Grow Room Management

Grow rooms are kept between 60 and 63 degrees and use a high-pressure misting system to maintain 90% humidity. Most blocks (such as those with oyster varieties, lion's mane, and cinnamon caps) are brought into grow rooms when 90% colonized. Generally, it is better to allow the blocks to colonize completely before they are brought into the grow room, but we have had success with our method. Slower-growing mushroom varieties, like shiitake and maitake, are brought into the grow room after a longer colonization period and are completely colonized.

Bag Opening

Because we grow on 10- to 12-inch blocks, we make a single cut on the side of the block with a sharp knife. We recommend 70% isopropyl alcohol to disinfect your knife. Preparing each block should take about 20 seconds. Follow these steps:

1. Put on gloves and spray your knife with disinfectant.
2. Choose the side of the block to cut open.
3. Cut a straight four-inch slit along the plastic without digging or gouging the substrate.
4. Flip the block upside down and squeeze the remaining air out of the block.
5. Place the block on shelving (ideally, a rolling rack).
6. When the rack is full, drape plastic sheeting over the blocks to create a microclimate for pin development.
7. Move the whole rack into the grow space.

Daily Chore Checklist

A grower must attend to certain maintenance tasks every day:

- ☐ Check grow rooms' CO_2 level twice daily.
- ☐ Harvest mushrooms twice daily.
- ☐ Make boxes for the next day.
- ☐ Check grow rooms for contamination and colonization.
- ☐ Sweep and clean floors of grow rooms.
- ☐ Make any needed repairs.
- ☐ Check in with yourself about ongoing operations: Are the humidity levels and airflow both correct? Are the rooms the right temperature? Do you have any bills that need settling?

Weekly Chore Checklist

Don't let a week pass without checking off all these items:

- ☐ Clean and sanitize grow rooms.
- ☐ Pressure-wash walls and floors.
- ☐ Sanitize walls, floors, and drains.
- ☐ Clean out HVAC system and change filters.
- ☐ Order inputs (soy hulls, sawdust, grow bags, etc.).
- ☐ Coordinate and communicate with wholesale buyers.
- ☐ Clean and sweep.
- ☐ Dispose of old blocks.
- ☐ Move new blocks into grow rooms.

Disease Management

Master's mix is an ideal food for quick and consistent mushroom culture growth. However, contaminants also thrive on growing mediums. A strong disease-management program is critical to staying ahead of potential contaminants.

Common Fungal Disease

Bacterial Blotch usually develops on the outer surface of mushroom fruit bodies and manifests as brown spots or streaks. It's often caused by mushroom saturation that goes on for hours. Bacterial blotch can be avoided by cleaning grow rooms (pressure-washing floors, ceilings, and shelves), protecting the mushrooms from pests (with PyGanic 5.0 insecticide, for example), and inspecting misting nozzles.

Trichoderma (or "trich") is a type of fungus that is found in all soils and can form mutualistic relationships with plants. Trich is so common (especially in the Southeast) that you will almost certainly encounter it at some point, but with good substrate and lab management, its impact can be minimized. Fortunately, trich is relatively easy to control through proper monitoring.

Neurospora crassa is a contaminant that needs to be taken very seriously. If it is not handled swiftly and properly, neurospora can derail an established mushroom farm. In its early stages it has a very noticeable pink-orange color and a chalky texture. In its later stages, it grows small hairlike pins and takes on a slightly darker orange color. If an employee suspects a block is contaminated with neurospora, they should bring a station manager to the block to examine it and determine the next steps. Do **not** pick up the block or bring it to anyone. If you do have a block with neurospora, immediately spray it with 70% isopropyl alcohol and then cover the whole block with a single-use grocery bag. This lowers the chance of it spreading its spores to any mycelial blocks nearby. Once the block is fully covered, tie the bag ends together and dispose of it in a dumpster. Do not put it in the compost, where it can continue to grow and find its way back into the grow rooms.

Neurospora Stages

1. **Early.** If you catch neurospora contamination on a block early enough (before it has developed fruit bodies or spored), then you may be able to save the blocks near it. These blocks must be heavily monitored for the next two weeks to determine whether they are contaminated. If an employee notices that neurospora has developed on the blocks, they should tell management immediately.
2. **In progress**. If an employee finds a block with neurospora beyond the early stage, they should tell a manager. The safest approach is to spray all the blocks on the rack with 70% isopropyl alcohol and then seal each of the blocks in trash bags. Do not simply move the rack's seemingly uncontaminated blocks elsewhere, as there is a strong

chance of spreading the neurospora. Once all the blocks have been bagged and removed from the grow room, move the contaminated rack out of the grow room and clean and disinfect it thoroughly. Wait 24 hours before moving the rack back into the grow room.

3. **Advanced.** If neurospora ever makes it to the advanced stage, then drastic measures need to be taken. This means taking everything out of the grow room and giving it a deep clean. This must be taken very seriously; be even more thorough in your cleaning than you normally would be. Everything in the grow room, from the rack to each surface, should be bleached, cleaned with Simple Green disinfectant, and then bleached again. Do not rush. Missing even one spot could put you back in the same situation. Be sure to clean the HVAC system and replace the polyducting. If you are in a grow room that has advanced neurospora, do not enter any other grow room, as the neurospora could stick to your clothes and migrate into the new area. Before moving any materials back into the grow room, you will need to fog the room with a mixture of oxine and citric acid to ensure that the room is as clean as possible.

Harvest and Postharvest Handling

When to Harvest

Harvesting mushrooms at the right time and in the right order maximizes their quality and shelf life for your customers. For oysters, the time to harvest is when the caps have begun to flatten out but the edges are still curled underneath. This is long before spores are dropped, and shelf life can be extended. It is better to harvest a little early than to try to maximize cap weight and size.

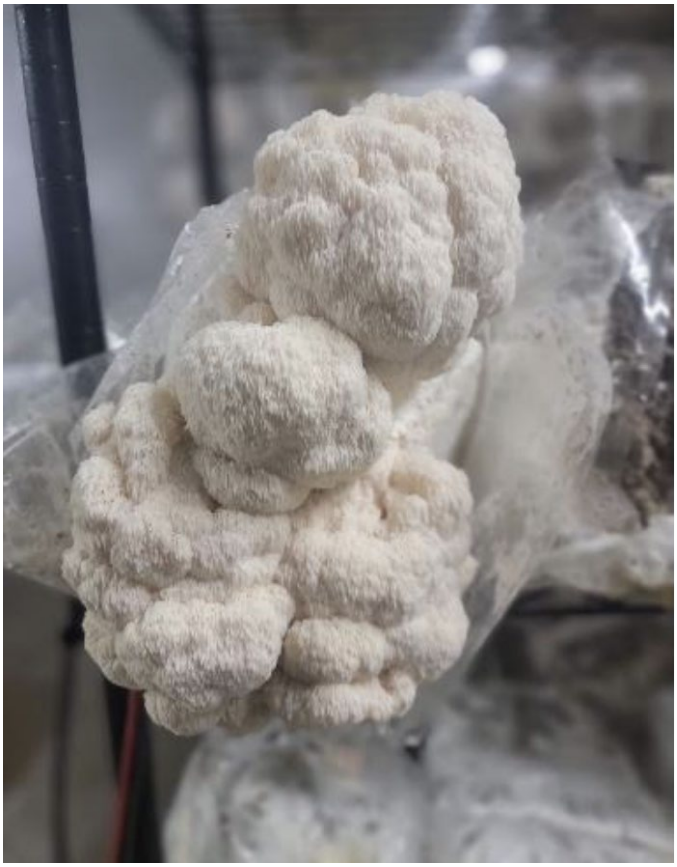
Oyster mushrooms pinning.

A cluster of blue oyster pins.

Blue oyster mushrooms ready to harvest.

Unlike oysters, lion's mane should be harvested when fruit bodies are firm and the hairs haven't extended or grown out. Mushrooms are typically harvested twice daily (morning and night) to catch them at their optimal maturity.

Lion's mane mushrooms pinning.



Lion's mane mushrooms ready to harvest.

Lion's mane grown past optimum harvest time to a length that increases risk of bruising and shortens shelf life.

Harvested mushrooms should be placed in cardboard boxes or crates lined with butcher paper and stored at 38 degrees. Airflow in cold storage spaces should be monitored, as too much air can dry mushrooms out and cause lion's mane to yellow.

Sales Channels

I believe that there is still ample room for growth in the U.S. fresh mushroom market. However, the market environment has already changed considerably since we entered it in 2012. New growers should be aware that mushrooms have a limited shelf life, and market strategy should include plans for fast turnaround from harvest to sale (ideally, no more than a seven-day gap). While retail sales offer tempting margins, growers should be keenly aware of what their losses are for any product unsold at the farmers market: Unsold mushrooms then have a 48-hour window before being sold as B-grade or converted to a shelf-stable form. There are many ways to establish a customer base, from opening an on-farm store to participating in farmers markets, forming a subscription service for regular customers (such as community supported agriculture), wholesaling to chefs at farm-to-table restaurants, and wholesaling to distributors. For more information on this, please see Transfarmation's buyer engagement document.

Conclusion

Mushrooms are in high demand and growable with a relatively small footprint. Their indoor growing conditions help insulate them from the impacts of extreme weather or temperature swings. And they can produce a quick and abundant yield. The trade-off for these benefits is that they are labor-intensive and vulnerable to contamination, and they have a short shelf life that requires a strong marketing and distribution plan. The grower willing to navigate these challenges enters a market climate of strong demand, healthy margins, and positive business growth for established mushroom cultivation operations.