Part III. Mushrooms Worldwide

Chapter 11

Mushrooms for the Tropics

GROWING SHIITAKE MUSHROOMS

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Why Choose Shiitake Mushroom?

Shiitake is, by far, the most popular and important edible medicinal mushroom in many countries (Chen, *et al*., 2000; Chen, 2001; Humble, 2001; Royse, 2001; Stamets, 2000). Shiitake, a name originated from Japan, is known in China as xiangu and in France as lentin. By using its scientific name, *Lentinula edodes*, you can be sure that you are talking about the same mushroom with people in other parts of the world. First discovered in China, this ancient Chinese mushroom, primarily in temperate climate, has a long-standing history as a culinary delicacy and an immunity booster, and produces lentinan, which is recognized in Japan as an anti-cancer drug. An anti HIV property has also been detected along with other health benefits.

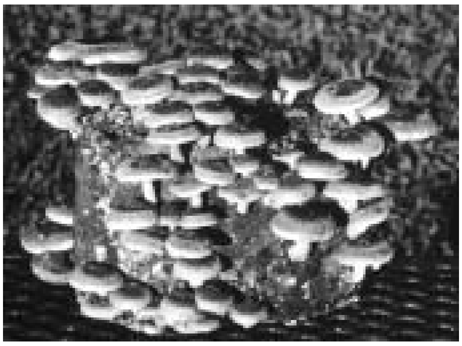

Figure 1. shiitake

It may come as a surprise that shiitake can only be found as a native species in Far Eastern countries such as China, Japan and Korea, but not in North America nor in Europe. Recent sightings of shiitake in the wild in U.S.A. are likely mushroom runaways escaped from cultivation, or cooking preparations. In China, where shiitake was first found, xiangu, the Chinese name, means fragrant mushroom (xian means fragrance, gu means mushroom). Two highly prized forms of xiangu are dongu, the winter shiitake (dong means winter), and huagu, the flower shiitake (hua means flower). Both forms with thick meaty mushroom caps are produced at winter-like temperature. Huagu, the most sought-after shiitake and the most expensive, is a form of dongu with a flower-like cracking pattern on the upper surface of the cap (Wu, 2000).

It is only natural that China was the first to discover how to grow shiitake almost a thousand years ago. Credit was given to Wu, Sang Kwuang in Zhejian Province as the ingenious observer who figured out how to enhance shiitake fruiting on logs found in the wild during Sung Dynasty in 1100 A. D. (Miles and Chang, 1989). During such early days, drifting shiitake spores implanted spontaneously on, perhaps, fallen tree trunks or branches. Scientific methodology evolved much later, when Dr. Shozaburo Minura in Japan developed the technique of inoculating natural logs with pure shiitake mycelial culture in 1914 (Stamets, 2000). During the early twentieth century, Prof. Chang-Chich Hu, of Jing-Ling University (now Nanjing University) in Nanjing, China, was one of the pioneers promoting shiitake cultivation in China, after he returned from Tokyo University in Japan. Only about two decades ago, in 1979, after a dozen years or so in research, China succeeded in large-scale shiitake synthetic-log cultivation on substrate blocks in bags, a much faster production compared to cultivation on natural logs (Huang, 1997). Today, China remains to be one of the largest in producing, consuming and exporting shiitake. In the new millennium year of 2000, imports of shiitake to Japan rose 33% to 42,057 tons, with a value of USD93.65 million. Almost all of the shiitake imported to Japan came from China.

In the U.S.A., shiitake cultivation began to take off between 1986 to 1996, following the lifting of a ban on importing life cultures of *L. edodes* by the USDA (United States Department of Agriculture) in 1972 (Royse, 2001). Now, shiitake in fresh produce, cultivated by American growers is the leading specialty mushroom in supermarkets across the country, while dry shiitake has a long-standing history as a mushroom treasure in Oriental grocery stores, particularly in China towns and other Oriental communities.

Shiitake growing is widely practiced not only in Southeast Asia (China, Taiwan, Japan, Korea, Singapore, the Philippines, Sri Lanka and Thailand) but also in North America (U.S.A. and Canada), Europe (with France leading, Germany, the Netherlands, Spain, Italy, England, Switzerland, Belgium, Finland and Sweden), Australia and New Zealand (Oei, 1996; Romanens, 2001). Shiitake cultivation is, indeed, a global-wide industry.

Growing shiitake in bags of synthetic logs is now the number one method used in China (Wu, 2000). It is also the most common way to grow shiitake in the U.S.A. Labor and material costs for using the traditional natural log for shiitake cultivation appear to be less profitable for American growers. Here we focus on shiitake bag cultivation, based on American and Chinese methodology. To encourage consistent success, the author provides a deeper understanding on crucial and basic stages in growing shiitake as a practical guide to the growers, including critical selection of strains, progress in mycelial growth and maturity in preparation of forming mushrooms, how to control the environment at each stage, how to trigger the mushroom formation, and how the mushroom grows. Special techniques for forcing huagu (the flower shiitake), the most expensive form on global markets are also described.

Shiitake Bag Cultivation (Synthetic Log Cultivation)

Strain Selection

To know the importance of shiitake strain selection is crucial. Shiitake strains vary widely, particular in fruiting temperature and mycelial maturation (early or late; shorter or longer production time). Also strain-related are substrate selectivity, growth rate (some fast strains may produce pre-mature fruiting), shiitake mushroom quality (shape, size, thickness, color, flavor and fragrance, etc.), yield and ecological adaptability to extreme temperature, usually cold tolerance. Based primarily on Chinese system, strains are classified into 4 categories according to their fruiting temperatures (Table 1).

Table 1. Shiitake strain classification largely based on Chinese system

Low temperature	Mid temperature	High temperature	Wide-range temperature
10℃	10-18℃	20℃ and above	5-35℃

In awake of intrusion of massive imports, Japanese developed a number of cultivation technique-dependent new shiitake strains with large and thick fruiting bodies known as basidiocarps (Watanabe, 2001). Both performance and stability of superior strains are important. Experienced growers are aware of the potential problems of strain attenuation. For example repeated subcultures and prolonged storage of the stock culture may result in smaller fruiting bodies and lower yield (Huub Habets).

Substrate selection

Aged broad-leaf sawdust is the preference for many for growing shiitake. Fresh sawdust without aging by fermentation can be used for shiitake only if it is from high quality tree species. Oak, chinkapin, hornbeam, sweetgum, poplar, alder, ironwood, beech, birch and willow are examples of commonly used non-aromatic broad-leaf hardwoods in the U.S. Sawdust from tree species of lower quality must be aged by fermentation (Oei, 1996). Select locally available and inexpensive resource, for example, fermented eucalyptus sawdust is used in Australia. There are growers who prefer to use aged sawdust regardless of tree species. Both substrate nutrients and physical textural property in aeration are important. Sawdust particles should not be smaller than 0.85mm.

Substrate formulation

For commonly used supplemented hardwood sawdust formulations, see Table 2. Many use a simple substrate with sawdust, bran and 1% $CaCO_3$ (Oei, 1996). 1% sucrose is also frequently added. In addition to hardwoods, the use of pine is a subject of great interest, since pine is a readily available forestry resource. Supplemented pine-hardwood substrate (Table 2-Formula C) was used as partial substitute for basal ingredient by the Forestry Research Institute of New Zealand for shiitake production with satisfactory results. Agricultural wastes, such as cottonseed hulls, corncobs, bagasse and straw can also be used as alternative basal ingredients.

Table 2. Formulation of sawdust-based substrates for shiitake cultivation

A.	Broad-leaf sawdust based (Wu, 2000)	
	sawdust	100kg
	wheat or rice bran	23.25kg
	gypsum	2.5kg
	calcium superphosphate	0.5kg
	sucrose	1-1.5kg
	water	100-140kg
B.	Broad-leaf sawdust based (Stamets, 2000)	
	sawdust	100 lb (or 64 gal)
	woodchips	50 lb (or 32 gal)
	rice or rye bran	40 lb (or 8 gal)
	gypsum (calcium sulfate)	5-7 lb (or 1 gal)
	water	60%
C.	The Forestry Research Institute of New Zealand	
	pine sawdust	6 parts (Monterey pine-*Pinus radiata*)
	hardwood sawdust	3 parts (beech or poplar)
	grain	1 part (barley)
D.	Straw-based substrate (Oei, 1996)	
	rice straw	50kg
	wheat straw	20kg
	sawdust	20kg
	sucrose	1.3kg

$CaCO_3$	1.5kg
citric acid	0.2kg
$CaSO_4$	0.5kg

Substrate sterilization

Sterilization depends on the nature of bags (polypropylene or polyethylene), bag size, nature and amount of the substrate per bag, and the total bulk. For sawdust-bran substrate, sterilize from 2-3 up to 4-5 hours at 121℃. Growers are advised to test their mixtures and adjust accordingly (Stamets, 2000).

Spawn and spawning

Fresh and vigorous spawn of appropriate age should be used. Select the best strain to match your interest. In general, through spawning (spawn thoroughly mixed with the entire substrate) in larger bags is used in the U.S., while top or localized spawning (spawn is left on the substrate surface or the inoculation hole) in smaller bags is used in China and Australia. Through spawning gives a much faster growth rate. Heat-sealed larger bags with microporous breathing filters, partly filled with the substrates, allow the manipulation of mixing the spawn with the substrate by shaking mechanically or manually. Smaller bags with ring necks and plugs that are fully loaded without leaving any air space in bags do not lend themselves to through spawning.

How to control the environmental factors?

Stamets (2000) summarized the growth parameters for shiitake cultivation in Table 3.

Table 3. How to provide the right environment for growing shiitake

	Spawn run	**Induction of primordial**	**Fruiting development**
Temperature	21-27℃ (70-80˚F) for all strains	10-16℃* 6-21℃** (50-60˚F) (60-70˚F) temperature fluctuation	16-18℃* 21-27℃** (50-70˚F) (60-80˚F)
Humidity	95-100% R.H.	95-100% R.H.	60-80% R.H.
Incubation	ca. 1-2 months strain-dependent	5-7 days	5-8 days
CO2	> 10,000 ppm, tolerant	< 1,000 ppm	< 1,000 ppm
Ventilation (oxygen)	0-1	4-7 /hour oxygen	4-8 /hour oxygen
Lighting	50-100 lux	500-2,000 lux at 370-420nm (green-uv)	500-2,000 lux < 500 lux (long stem)

*cold temperature (Source: Stamets, 2000)
**warm temperature

Be sure to remember that as a primarily temperate species, shiitake mushrooms are best produced at low temperature and little fluctuation of temperature and humidity, although high temperature strains are now available.

How shiitake mushrooms grow in cultivation

Production of shiitake involves both a vegetative phase of mycelial growth and maturation, and a reproductive phase of fruiting body formation. It is imperative for growers to observe closely the spawn run with many stages of intricate physiological changes and morphogenesis (change in physical features in growth), focusing on the transition from the vegetative phase to the reproductive phase. Growers should study the cultivation sections for details and check the sequence of shiitake photos.

Spawn run (mycelial growth and maturation)

For spawn run this intricate vegetative phase consists of 5 stages. All shiitake strains show optimal mycelial growth at 25℃. The duration of spawn run is usually 1-4 months, depending on the strains and methodology. No light is necessary during spawn run, however some light in the day/night cycle towards the end of the spawn run is conducive to induction of primordia. Different approaches can be used, such as providing light towards later stage in spawn run, short exposure to light of 4-hour/day-night cycle (Royse, 2001), or use a low level of light 50-100 lux, throughout spawn run (Stamets, 2000). The dramatic change from vegetative mycelial growth to the production of macroscopic fruiting bodies in the reproductive phase requires an enormous amount of energy reserves. A vigorous spawn run is of ultimate importance. It should be noted that strains vary greatly in duration for mycelial maturation. For one strain, 60 days is sufficient to mature, whereas this would be insufficient time for another strain which may produce deformed mushrooms (Miles and Chang, 1989).

Mycelial growth

Immediate following spawning (inoculation), whitish shiitake mycelia begin to grow on the supplemented substrate, until colonization is completed. This is an active assimilation phase with a high fungal metabolic rate. Enzymes are activated to break down complex substrate components (e.g. cellulose, hemicellulose and lignin) into simpler molecules which can be absorbed by the mycelium as nutrients for growth and propagation under favorite growth conditions.

Figure 2. Spawn run

In special cultivation practices, colonized mycelial blocks are subject to higher temperature toward the end of spawn run. In Japan, colonized blocks are often exposed to temperatures of 25-27℃ for a week before fruiting (Watanabe, 2001). In China, colonized mycelial blocks are sometimes exposed to temperatures at the upper limit of 27-30℃ for a period of time (Miles and Chang, 1989). The rationale of these methodologies is based on the conjuncture that while such higher sub-optimal temperature does not promote mycelial growth, it may facilitate the degradation of sawdust. It is not clear whether such claims have been supported by independent studies on decomposition of lignocellulose in sawdust. Also applied is the use of water spraying to colonized mycelial blocks without bags to promote mycelial maturation and browning (Watanabe, 2001). Growers should be aware that these effects may vary depending on the strain.

It helps to keep in mind that some fast-growing strains may produce unexpected pre-mature fruiting before mycelial maturation, which is not desirable. Care should be taken to move the blocks as little as possible during spawn run as moving or any physical shock may trigger pre-mature fruiting. Fast growth and shorter production times may not be the best choices. The resulting mushrooms may not have the meaty texture desired in Asian markets, but they could be acceptable in newer markets elsewhere. Usually, slow growth at winter-like temperature produces high quality dongu, the winter shiitake or huagu, the flower shiitake, the most expensive and sought-after shiitake, which are formed at cold and dry temperatures with diurnal fluctuations.

Mycelial coat formation

On the outer surface of the colonized substrate block, a layer of thick mycelial coat, initially white in color, is developed 2-4 weeks after spawning - the later stage of spawn run. At high CO_2 concentrations, a very thick mycelial coat could be formed.

Bump formation (blister stage, or popcorn stage)

Clumps of mycelia appear as blister or popcorn-like bumps of various sizes are formed on the surface of the mycelial coat in most strains, usually when the colonization of white mycelia covers the entire substrate in the bag, or sometimes earlier. Primordia are produced at the tips of some of these bumps. However, most bumps abort and never develop into fruiting bodies. The time of bump formation varies with strain, substrate and temperature. Bumps usually form 10 days faster at 25℃ than at 15℃ (Miles and Chang, 1989). Fluctuation of temperature and high CO_2 concentrations encourage bump formation. Growers should lower the CO_2 concentration in the bag by cutting slits on the bagin, when bumps become too numerous. In any case, some aeration should be provided during this time.

Browning and bark-formation (pigmentation and coat-hardening)

There are two different approaches, browning outside of the bag versus browning inside of the bag. Some growers remove the entire bag when browning covers 1/3 to 1/2 of the mycelial coat in the bag (Oei, 1996). Royse (2001) adopts browning outside of the bag. Bags are removed before pigmentation. Timing of bag removal is crucial. Yield can be affected if bag removal is too early or too late. Growers should maintain 60-70% R.H. to avoid contamination after bag removal. Air enhances browning by oxidation. When exposed to air, mycelia turn reddish brown at the surface and eventually form a dark brown protective, dry, and hardened surface which functions like a tree bark. The inner substrate becomes soft and moist as a consequence of fungal metabolism. The inner moisture content can be as high as 80% (Oei, 1996), ideal for fruiting body formation, except for strains that do not turn brown.

Fruiting induction to trigger primordia formation

Growers should remove the bag towards the end of the spawn run before or after browning. They should apply fruiting induction when the spawn reaches physiological maturity and after browning and bark formation. Water soaking is commonly used for fruiting induction after browning and bark forming. In general, the following factors promote fruiting.

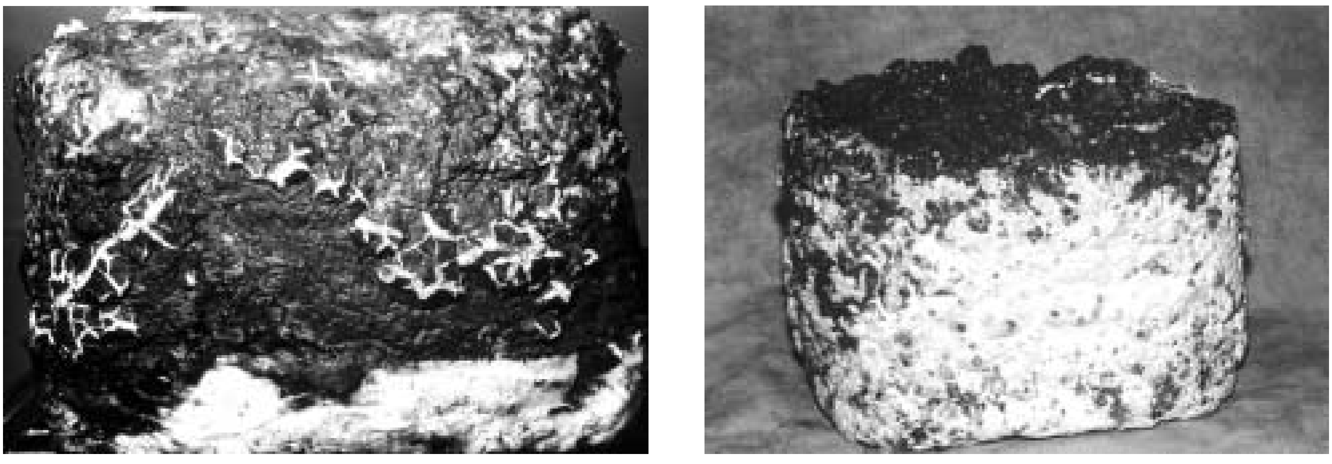

Figure 3. Plastic bag-removed substrate blocks

Table 4. Fruiting induction: factors promoting primordia initiation in *Lentinula edodes*

water soaking, most common (Royse, 2001 : 2-4 hours at 12℃; Stamets, 2000 : 24-48 hours)	
water spraying (Watanabe, 2001)	
temperature fluctuation	
high humidity; fluctuation of humidity	
removal of CO_2, or increase of oxygen supply	
physical shocks (agitation, disturbance)	stab (with a long metal needle) and inject (with water) turn the blocks upside-down (half-way during spawn run: Watanabe, 2001) beating (e.g. natural logs) electric stimulation

(Source: Oei, 1996; Watanabe, 2001)

Basidiocarp formation

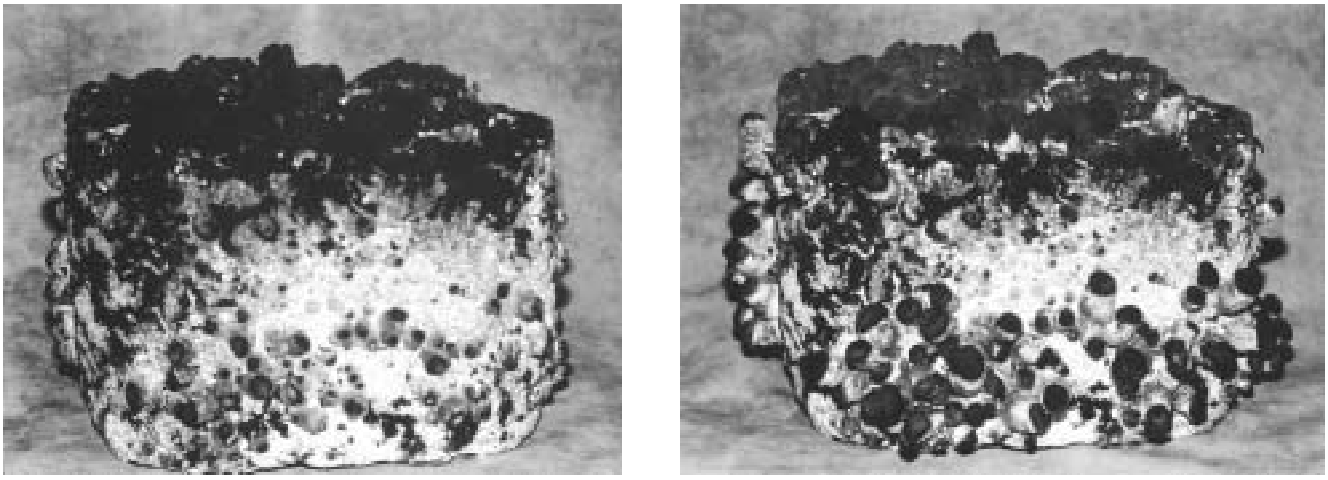

Figure 4. Basidiocarps on the synthetic logs

- primordia formation at the tip of the bump (blister)
- primordia develop into young mushroom button (dark brown)
- elongation of the stipe (stalk) as the button increases in size
- mushroom increases in size and thickness while color becomes lighter
- expanding (opening) of the mushroom cap from younger stage when the margin of the cap in-rolled downward

Harvest, post harvest and subsequent flushes

Growers should lower the humidity to 60% R.H. for 6-12 hours before harvesting for better shelf life. Harvest when the edge of the mushroom cap is still in-rolled, or when the mushroom cap is only partly extended (60-70%). This is the form desired by the Asian markets. Growers should hand-pick the mushrooms by holding the mushroom stalks and gently twisting them from the substrate block. They trim the end of the stalk of the harvest when necessary, and cut off residual stubs of stalks from the substrate. Remnants of residual stubs invite microbial contamination. After mushroom harvest, the humidity is lowered to 30-50% R.H. at 21℃, for 7-10 days of dormancy (Stamets, 2000), then soak the substrate block for up to 12 hours for the second flush, and up to 18 hours for the third flush (Royse, 2001). Larger bags with more substrate used by American growers produce more flushes, up to 5-6 flushes. Harvested mushrooms are dried at 60℃.

In China and Japan, shiitake quality is determined by shape (rounded with downward in-rolled edge before the cap is fully extended and central stalk), texture (thick and tight context, the meaty part), size, color, flavor (enhanced by cooking especially the fresh shiitake) and fragrance (enhanced by drying), in addition to freshness and being free from contamination, pests and impurities.

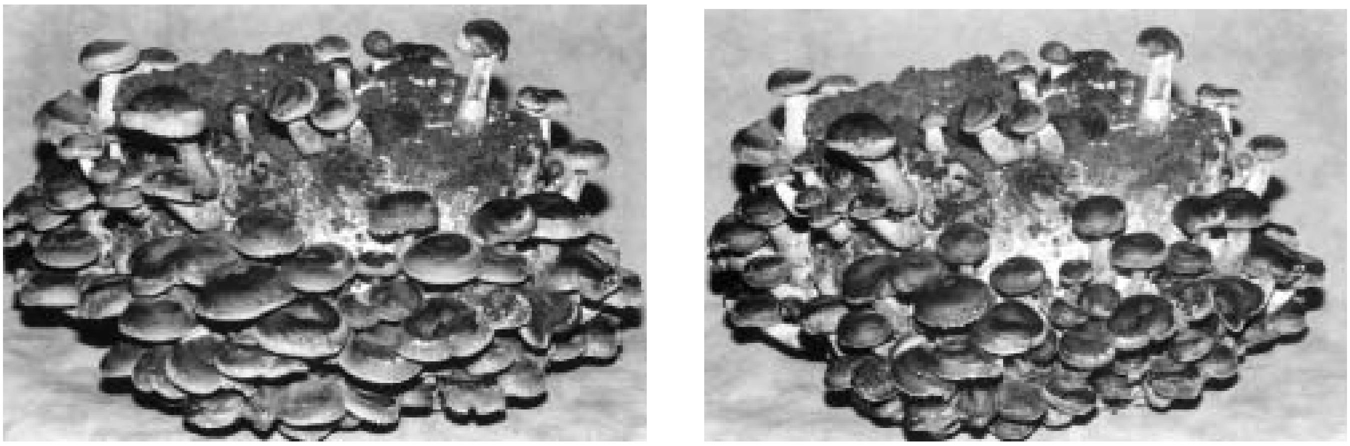

Figure 5. Fruitbodies

Growing shiitake in U.S.A.

Figure 6. Shiitake on log

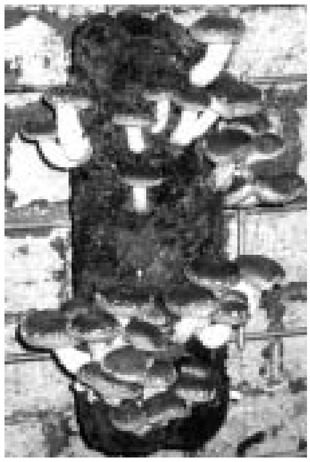

Figure 7. American style

In contrast to growers in Southeast Asia, such as China, larger heat-sealed bags with microfilter breathing windows are generally used by growers in North America for shiitake cultivation. These bags, each filled with 2-3kg, or more (5.5kg) of substrate in wet weight, produce more flushes of mushrooms in a shorter production time by using through spawning. These bags are in general less labor-intensive, less time-consuming, and experience less contamination. In methodology, through spawning, browning outside of the bag and inside of the bags, and water soaking for fruiting induction are all commonly practiced here. Mushrooms are produced under indoor controlled growth parameters. The more sophisticated growers use mechanization. There is a tendency for North American growers to use faster growing strains, especially the new growers, in order to gain confidence. The markets of fresh specialty gourmet mushrooms in North America are fairly new and include perhaps some less sophisticated consumers.

Shiitake Natural Log Cultivation

Let us examine the traditional natural log cultivation to see how shiitake has been grown for nearly a thousand years. Log cultivation today prefers indoor log cultivation under sheltered or controlled environments, instead of leaving it entirely to nature. Outdoor natural log cultivation is still in practice however, and may be best suited as the first step for growers who have limited resources.

Selection of tree species for logs to match specific strains

Non-aromatic hardwood logs for growing shiitake are strain-specific. Selecting the right tree species to match the chosen shiitake strain is indispensable. Favorite tree species to use in shiitake natural log cultivation in the United

States are oaks (*Quercus*), Chinkapin (*Castanopsis*), hornbeam (*Carpinus*) and tan oak (*Lithocarpus*). Softwoods such as alder and birch, although they have shorter shiitake production time available can also be used. Growers should check to see what kind of suitable trees are available locally.

Felling of trees and preparation of logs

Felling or chopping down the tree should be done during dormant season when log nutrient content is the highest and the bark tightly attached to the wood. Trees with intact bark are selected. Logs 7-15cm (2.5-7”) in diameter are cut into 1m length. Logs thicker than 25cm (10”) should be split lengthwise. Growers should drill inoculation holes 2.5cm apart, lengthwise every 15cm, and start the adjacent row midway at the top (placing holes in diamond shapes) as mycelium spreads faster along the wood grain than across. Lime water can be applied to the exposed surfaces at the end of the log to prevent uninvited weed molds.

Figure 8. Tree felling in dormant season

Figure 9. Drilling inoculation holes

Figure 10. Spawning

Spawn and spawning (inoculation)

Growers should select and prepare (or obtain) spawn of the best matching strain with the right temperature range and duration for maturity (see strain selection in bag cultivation). In China supplemented sawdust bran spawn is used for spawn, while wood plug spawn is preferred in the United States. Grain spawn is unsuitable because it could be eaten by rodents and infected by flies. Growers should use fresh spawn to inoculate the log 15-30 days after felling, when log moisture is reduced. Since *Lentinula edodes* is a saprophyte, it can only grow on dead wood, and not on newly felled trees still containing living cells. Spawn-filled inoculation holes should be sealed with hot wax or a mixture of hot wax and resin to prevent contamination and evaporation. In China, caps made of tree barks or plastic foams have been used to seal the inoculation holes.

Temporary laying for spawn run

In a laying yard indoor or outdoors, lined with pebbles on the bottom, inoculated logs should be stacked next to each other. The stack should be loosely covered to encourage spawn run. Growers should keep in mind that 25-28℃ is the optimum temperature for spawn run and avoid excessive moisture or drought. This stage is when the inoculation becomes established and begins to colonize and digest the woody substrate, as *Lentinula edodes* is a white rot fungus. Most mycelial colonization occurs during this period.

Figure 11. Temporary laying for spawn run

Permanent laying for spawn run

Logs are stacked indoors (in green-houses in the winter) in various arrangements, such as chris-cross vertically with one log space apart, to provide ventilation for continued spawn run. In China, during laying, logs are turned. If too dry, they should be sprayed with water. It takes 6-18 months for logs to be fully colonized by shiitake mycelium. The rate of the spawn run depends on such factors as shiitake strain, tree species, log size, log moisture content and temperature.

Figure 12. Permanent laying for spawn run

Raising for fruiting

Figure 13. Water-spraying on the logs for fruiting induction

When the logs are fully colonized, they are agitated by banging the logs with a hammer or dropping on end before they are moved to the raising yard for fruiting. Raising yards with shade cloth cover to avoid direct sunlight are usually cooler and provide more ambient moisture, which is conducive to fruiting. Small tree branches and straw can also be used for cover. For winter, green houses can be used. In such cases, soaking in water, a common practice, is used for fruiting. Water temperature should be 13-18℃. In the winter, logs are soaked for 16-48 hours, while in the summer, for 6-8 hours (Oei, 1996). A steel pipe on top of the logs prevents floating. During soaking CO_2 in the log is replaced by the water, giving the log enough moisture for the flush of mushrooms. The replaced CO_2 appears as bubbles. When the bubbles are no longer seen, it is an indication that the logs have soaked long enough. In China, logs are agitated within 36 hours before soaking, while in US vibration is applied prior to soaking. Soaking times should not be over 48 hours. In the raising yard, logs are stacked to allow air exchange for fruiting and ease for harvest.

Figure 14. Young fruiting body

Primordia and fruiting body formation

Primordia break through from under the bark usually within a week following soaking. Growers should maintain 80% R.H. for fruiting development (See control of environmental factors and how the mushroom (basidiocarp) grows).

Subsequent flushes

Following harvest of mushrooms, logs should go through a dormant stage, then an incubation period of 3 months to build up the nutrients and replenish with water in soaking for the next flush. This may be repeated 5 times under optimal conditions. The second and third years are the prime production periods when 75% of the total yields are produced.

Production of Huagu, the Flower Shiitake

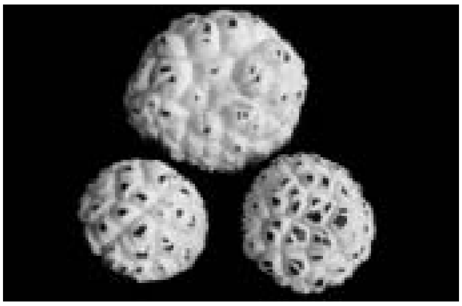

Figure 15. Huagu

Huagu, the flower shiitake, occurs spontaneously in nature during cold and dry winter months when mushroom spores are deposited by chance. Huagu is not a characteristic of a particular genotype, and it is not a genetically inherent trait. On the contrary, huagu, the shiitake mushroom with a unique morphological flower-like cracking pattern on the upper surface of the cap, is produced through manipulation of growth parameters. Success in cultivation of huagu can bring growers considerable extra income when they are growing for domestic and foreign consumption. Model huagu production systems can be found.

The principle of huagu formation

During the formation of shiitake basidiocarps (fruiting bodies), under winter winter-like conditions, or when the young mushroom buttons (not primordia) reach 2-3cm in diameter, dry air and cold temperature force the pilial (cap) surface into dormancy. Under such adverse environmental conditions, with drastic diurnal fluctuation of temperature and humidity, a protective dry surface is formed on the young mushroom cap. However, the inner context continues to grow at a slow pace with water available solely from the substrate. When favorable growth conditions return, the surface grows at a retarded rate, while the inner context develops at a normal pace. Under these conditions, shiitake mushroom buttons grow with the alternation of dormancy and growth, and a considerable differential growth rate between the surface and the inner context. In time, the rapid growth of the inner context ruptures the mushroom surface, producing a flower-like cracking pattern on the cap surface, thus the name, huagu.

Selection of strains

Low temperature, high quality and ecologically adaptable strains with cold tolerance are selected for huagu production. Strains towards the lower temperature margin in mid-temperature range can also be used. Examples of desirable Chinese huagu strains are: L-241-1, Jean-Yin #1, Yee-You #5, 7402, N-06. Strain characteristics should be thoroughly studied before cultivation. For fruiting outdoors, the time of spawning should be coordinated with the maturation characteristics in order to benefit from the winter stimulation. For example, strains 7402, N-06, late maturing strains, should be inoculated early during March and April, while 9018, Le 204, early to mid-maturing strains, should be inoculated in May-June in Bi-Yang, China (Yu, 1998). Growers should adjust for their local weather.

Timely application of forcing of huagu

Huagu forcing is initiated when the mushroom buttons reach 2-3cm diameter. If huagu forcing is applied too early when the buttons are smaller than 1.5cm diameter, these fragile young buttons may die of drought or freezing. If the technique is applied too late when the mushroom has already reached 3.5cm diameter or larger, the mushrooms do not respond readily.

Figure 16. Huagu, flower shiitake

Figure 17. Growing houses in Biyang, China

Conclusion

Shiitake cultivation on synthetic-log or natural log is a world-wide industry. Recent trends suggest that future shiitake production will be likely on synthetic logs that will shorten production time and provide year-round fresh shiitake for most markets.

In growing shiitake, the correct strains must be used for a given methodology. Close attention should be given to the intricate stages in the vegetative phase, the spawn run, and the transition to the reproductive phase. The importance of tree bark on natural logs and the artificial bark (the browned and hardened coat) on synthetic logs cannot be overemphasized. As shiitake logs age by going through the production of flushes, barks on logs become loose, detached or slough off. Production of shiitake mushrooms stops in areas where the bark is detached from the wood. In cultivation, growers should be keenly aware that *L. edodes* is primarily a temperate species. Quality shiitake mushrooms are produced at low temperature and fluctuations in temperature and in humidity between 70 and 90% R.H. (Stamets, 2000). Constant temperature is not conducive to fruiting.

With these detailed descriptions on crucial stages in growing shiitake and vivid photos, it is hoped that growers in countries with urgent economic needs will be inspired to use agricultural waste to cultivate this worthwhile mushroom which can be a delicious and nutritious supplement to daily food as well as providing medicinal benefits and possible income. Growing shiitake, if successful, may also lead to job creation. Japan alone employs more than 20,000 people in the shiitake industry.

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